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Potash rate and source effects on tuber yield and quality (hollow heart, size, and processing quality), and nutrient (K, Ca, Mg, and Cl) concentrations in petioles and tubers were evaluated in three experiments, two in the Columbia Basin in Oregon (McDevitt and Levy) and one in Central Oregon (Powell Butte). The Powell Butte experiment included additional variables of rate and time of N application. The effects of KCl and K_2SO_4 were compared at 83 and 249 lb K/A rates. Rates of K ranged from 0 to 581 lb/A with some treatments applied at planting only, while in other treatments the applications were split.

Potash fertilizers increased total yield, yield of 6+ oz tubers, and decreased the incidence (%) of hollow heart (HH) and brown center (BC) in the Powell Butte and McDevitt experiments. Yields were increased with all rates of K in the Powell Butte experiment; from 18.3 T/A total yield and 6.0 T/A 6+ oz tubers in the K check treatments up to 25.6 T/A total yield and 12.6 T/A 6+ oz tubers for high K rates. In the McDevitt experiment, yields were increased only at high K rates (35.8 T/A total yield and 26.4 T/A 6+ oz tubers for the 581 lb K/A vs 33.4 T/A total and 20.8 T/A 6+ oz tubers for the check treatment).

Hollow heart and brown center were reduced with potash fertilizers at the Powell Butte and McDevitt experiments with greater reductions when KCl was used as compared to K_2SO_4. Time and rate of N variables established in the Powell Butte experiment also showed an effect on hollow heart; N applications at

planting reduced HH and BC as compared to mid-season (July 7) applications when N rates were 120 lb N/A or more.

In the Levy experiment, with higher initial soil K and Cl levels, K and Cl did not increase yields or reduce HH and BC.

Potassium levels in petioles from check plots in the McDevitt experiment were above suggested critical levels and remained high throughout the season. In the McDevitt and Powell Butte experiments, potash fertilization increased petiole K with KCl treatments being more effective in increasing K concentrations than comparable rates of K_2SO_4. Petiole Ca levels also were lower in the K_2SO_4 treatments. Levels of total cations (meq/100g dw) were higher in petioles from KCl treatments than from comparable K_2SO_4 treatments.

Potash increased K levels in tubers with Ca and Mg also being increased with high K rates. Competitive interactions between K and Ca or Mg were not found. Potassium source did not significantly affect Ca and Mg levels in tubers and there was no relationship between these nutrients and the incidence of hollow heart and brown center. Low K levels in tuber centers and stem ends were found in K check and K_2SO_4 treatments, however, suggesting some relationship to the disorder.

Petiole Cl levels correlated well (r=0.9) with Cl applied. Low concentrations of NO_3-N were associated (r=-0.9) with high Cl concentrations in petioles without reductions in yield. Concentrations of Cl in petioles correlated well (r=0.9) with Cl found in tubers throughout the season. Tubers from high KCl treatments had lower specific gravities than tubers from check and low K treatments without affecting processing quality.

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Potash Fertilizer Effects on Yield, Hollow Heart, and Nutrient Levels in Potato Tubers and Petioles

INTRODUCTION

Hollow heart is a physiological disease or disturbance in potato that is widespread in its occurrance in the U.S. and abroad and is of economic importance. Since study of the disorder began in the early 1900's, several factors which influence hollow heart have been identified. Conflicting results are often reported. Hollow heart has been found to be affected by plant spacing (Moore,1925, 1927; Werner,1926), stress caused by drought and/or high temperatures (Dinkel,1960; Krantz,1947), low temperatures at tuber set (Van Denburgh et al.,1979,1980), conditions favoring rapid vine growth during rapid tuber enlargement phase (Crumbley et al.,1973), and by fertility levels, especially of nitrogen and potassium (Nelson,1970). Some varieties have been found to be less susceptible than others.

In some years, potato crops grown in Eastern and Central Oregon are greatly and widely affected by physiological disorders. In other years, the occurrance of the disturbance is minimal. This seasonal variation and widespread occurance points to the importance of stress due to climatic effects--drought, heat, cold.

One approach to ameliorating the climatic effects is to better understand and manage the fertility influences on hollow heart (or other internal disorders). Both nitrogen and potassium are known to affect the occurrance of hollow heart. In 1982 Oregon potato experiments, internal disorders seemed to be lower with high levels of KCl fertilizer. In 1983, three experiments were established to compare the effects of K-sources (sulfate vs chloride), rate, and time of application. Two experiments were in the Columbia Basin of Oregon and one in Central Oregon. The Central Oregon experiment included additional variables of rate and time of nitrogen application. This thesis reports the results of these 1983 experiments.

LITERATURE REVIEW

Potassium

Potassium was one of the first elements to be recognized as essential for the growth of plants (Birner and Lucanus,1866). Later it was shown that K is the only monovalent cation indispensable to the nutrition of higher plants, within which it is also the most abundant mineral element.

Even though K is present in all plant cells in relatively large amounts, it has been no simple matter to discern the functions of K in plants. Potassium, unlike N and P, two other major nutrients, does not enter into the structure of the main biochemical constituents of plant material (proteins, carbohydrates, lipids). It has been possible to attribute numerous plant physiological functions to K but information about mechanisms of its action remain obscure (Mengel and Kirkby,1982). Potassium has influences in the following areas: water economy, photosynthesis and translocation of photosynthates, phosphorylation, respiration, metabolism of carbohydrates and of organic acids, protein synthesis and metabolism of N compounds, and enzyme activation.

Potassium is very important in the water status of plants. Active K uptake is often responsible for the uptake of water in cells and tissues. Turgor of young leaf cells of Phaseolus vulgaris was dependent on their K content (Arneke,1980). The low K treatment resulted in lower turgor than the high K treatment and growth rate, cell size, and water content of tissue were reduced. It was concluded from these results that in young tissues K is indispensible to obtain optimum cell turgor which in turn is required for cell expansion. Turgor in young tissues appears to be the most sensitive parameter indicating K nutritional status. (Mengel and Kirkby,1982).

Water loss is lower in plants well supplied with K due to a reduction in transpiration rate (Brag,1972). This is due not only to the K effects on the osmotic potential of the mesophyll cells but also to the transpiration rate being controlled to a large extent by the opening and closing of stomata. Stomatal opening is due to the osmotic effect of mainly K ions in guard cells. As higher levels of K keep guard cells turgid, the stomata remains open allowing entry of CO_2 and increased photosynthesis. The K ion in the guard cell is generally balanced by malate (a photosynthetic product) as the accompanying anion (Humble and Raschke,1971) but Cl has been found in plants with non-photosynthesizing guard cells (von Uexkull,1984). Raschke and Schnable (1978) found that when KCl was applied a proportion of the guard cell K was balanced by Cl and the rest by malate.

Potassium has a clear effect on the rate of CO_2 assimilation and, hence, photosynthesis. The effect of K on turgor and stomatal opening has already been mentioned. Peoples and Koch (1979) reported that K promoted the synthesis of the enzyme ribulose biphosphate carboxylase. Potassium also decreased the diffusive resistance for CO_2 in the mesophyll. Potassium has been shown to enhance the translocation of photosynthates (Mengel and Kirkby,1982) although the mechanism for this has not been shown. Rapid migration of photosynthetic products is necessary to maintain a high level of photosynthetic activity. Transport of these products is impaired at levels of K deficiency that have no direct effect on photosynthesis.

Potassium not only promotes the translocation of newly synthesized photosynthates but also promotes the conversion and mobilization of assimilates. Koch and Mengel (1977) as well as Secer (1978) found that in spring wheat, K increased the mobilization of proteins stored in leaves and stems and also promoted the translocation of the nitrogenous degradation compounds toward the grains. In potato (Haeder et al.,1973), K promoted protein synthesis in the above ground parts and sugar and especially starch synthesis in the tubers.

Potassium has a beneficial effect on ATP synthesis (Watanabe and Yoshida (1970), Hartt (1972), Pfluger and Mengel (1972)). The specific function of K in the energy conversion process is not yet completely understood. Since ATP is required for many synthetic reactions, K may indirectly promote the synthesis of various organic compounds, such as proteins, sugars, and polysaccharides (Mengel and Kirkby,1982).

One of the fundamental functions of K is its activation of various enzyme systems. In most cases K is the most efficient cation in effecting this activation. More than forty enzymes are known to be activated by K, more or less specifically (Evans and Sorger,1966). These include enzymes involved in glycolysis, starch synthesis, and protein synthesis, as well as phosphorylation and respiration. In many plant tissues it appears that K may be present in relatively high concentrations in relation to enzyme activation requirements. Impairment of enzyme activation by lack of K is unlikely to limit the crop production process.

Ion interactions:

Of all cation species, K is known to traverse biological membranes most rapidly. Potassium uptake (and transport) is thought to be due to both active and passive processes and K uptake is selective in relation to other cations (Mengel and Kirkby,1980).

Numerous experiments on growing plants in complete nutrient solutions have shown that increasing the concentration of K in the outer solution depresses the uptake of other cation species. The reverse effect of other cation species on K uptake has also been observed. Since there is little evidence that the uptake of Ca, Mg, and Na is carrier mediated (active uptake), it is unlikely that the depression of uptake of these cation species results from a competition for a common carrier site. This uptake depression is most likely due to nonspecific cation competition (Mengel,1973) because all cation species are involved and the extent of uptake depression depends mainly on the concentration of the cation species in the outer solution and the permeability of the membrane to the individual cations.

At low concentrations ($<10^{-3}$ to 10^{-4}M) the absorption of K is the same whether the counter ion is a slowly absorbed anion (SO_4) or a rapidly absorbed anion (Cl) (Epstein et al.,1963; Hiatt,1968). Likewise, the absorption of Cl is almost the same when the counter ion is Ca, a slowly absorbed cation, or K, a rapidly absorbed cation. To keep electroneutrality, excess cation absorption results in exchange of hydrogen ions from the root (Jackson and Adams,1963; Hiatt,1967a) and excess anions are absorbed in exchange for HCO_3.

At higher ion concentrations where uptake is by diffusion, cations and anions must be absorbed in equivalent quantities (Hiatt, 1968). Potassium absorption is much slower from K_2SO_4 than from KCl because SO_4 is absorbed much slower than Cl . Cation absorption is greater when the cation is supplied as a NO_3-salt. The reduction of NO_3 (in the root) leads to organic acid synthesis in response to shifts in pH or bicarbonate levels in the tissue. The organic ions created serve as a source of nondiffusible negative charges for the accumulation of cations (Hiatt and Leggett,1974). Ammonium competes directly with K for absorption sites and the assimilation of NH_4 leads to the production of H ions (anion accumulation stimulated but not cation).

Potato Yields and Nutrient Levels

Potato yields at time of harvest or at maturity depend on date of planting, environmental conditions, and variety (Burton,1966). Generally, the longer the growing season the greater the yield of tubers. Environmental factors such as day length, light intensity, temperature, water availability, soil aeration, and nutrient supply all contribute to final tuber yield (Smith,1968).

A summary of yields of Russet Burbank potatoes from 47 fields in the Columbia Basin of Oregon (Rizzio et al.,1983) shows mean total yields from 26.7 T/A, for fields in the first year of potato production, to 23.9 T/A, for fields in the fourth year of potato production. The mean yields of #1 and 2 grade were from 23.7 T/A (1st year) down to 15.3 T/A (4th year). In the Columbia Basin of Washington, yields in excess of 80 t/ha (32 T/A) have been reported (Kunkel,1969).

The response of potatoes to potassium fertilization varies widely with soil type. Lorenz (1947) found that in soils with a high K level, K applications did not affect K content of plants or tubers at any stage of growth. Washington and Idaho researchers (James et al.,1968; Middleton et al.,1975; Roberts,Dow,& Cline,1983; McDole,1978) report that K check plots had potato yields of 90-97% of maximum for K-treated plots when soil K values were 200 to 250 ppm $NaHCO_3$ extractable K. Other researchers, however, have reported responses to K. Terman et al. (1953) and Eaves and Leefe (1953) report that both yield and K content increased with higher K applications. Kunkel and Holstad (1972) found that K significantly (.005 level) increased yield in five years of experiments (1963-1967) in Washington's Columbia Basin. Increased yields due to K were also reported by Jackson et al. (1974).

Henderson (1965) found that K_2SO_4 applications resulted in higher total yield of tubers than KCl but KCl produced more marketable size (6+ oz) and less seed size (<4 oz). Rizzio et al. (1983b) report that K_2SO_4 and KCl did not produce significantly different yields although there was some indication that KCl gave higher yields on older fields. Dickens (1962) found that total yields from KCl and K_2SO_4 were the same but KCl gave on average a greater yield of large tubers and smaller yield of medium tubers than K_2SO_4.

Potatoes take up K in greater quantities than most other plants. Whether K is supplied by soil or fertilizer (at planting), K concentration in the upper plant is higher early in the season and declines during the season (Geraldson et al.,1973). Nitrate-N levels also decline (Geraldson et al.,1973) while Ca and Mg levels rise. Chloride concentration increases and maintains an approximately constant level throughout the season. Petiole tissue analysis is a useful indicator of the K status of potatoes. Critical nutrient ranges (CNR) (Dow and Roberts,1982) have been suggested for particular time or growth stages. At the 2-cm tuber growth stage, a CNR of 9.5-11.0% K has been suggested by several researchers (Jackson et al.,1974; Roberts et al.,1983; Middleton et al.,1975). At 30 days after 2-cm tuber the CNR is 9.0-10.0% K and at 60 days after 2-cm tuber the CNR is 8.0-9.0% K (Dow et al.,1978; Middleton et al., 1975). A summary of petiole nutrient levels sampled at early tuber stage (.75 inch diameter) from 47 fields in the Columbia Basin showed 10.0-10.2% K, 0.93-1.26% Ca, 0.42-0.72% Mg, and 2.07-2.88% NO_3-N (Rizzio et al.,1983).

Tuber tissue levels of K, Mg, Ca, and Cl have been reported as follows: 1.4-2.8% K, 0.01-0.12% Ca, 0.04-0.22% Mg, and 0.04-0.8%Cl

(Lampitt and Goldenberg,1940). Poovaiah et al. (1983) found 4.5% K, 0.05% Ca, and 0.14% Mg in their experiments. Arteca et al. (1980) report stem end K at 2.1%, bud end K at 2.5%, stem end Ca at 0.07%, bud end Ca at 0.05%, stem end Cl at 0.16%, and bud end Cl at 0.14%. The K contents are strongly influenced by soil composition and the fertilizer used (Chaminade,1942).

Chloride

It is well established that chloride is essential for higher plants. However, there is not much concern with possible deficiency since the occurance of this element is extremely widespread in the biosphere and plants require it in only very low amounts. There is concern about damage associated with high levels of chloride for some crops.

Not much is clearly known about the function of chloride in plants. A possible role in photosynthesis has been postulated (Bove et al.,1963; Kelley and Izaua,1978) but this idea has been questioned (Terry,1977). Functions that Cl probably fulfill relate mainly to the high mobility of the Cl and the fact that the ion is tolerated over a wide concentration range. Chloride may act as a counter-ion in rapid K-fluxes and contribute to turgor. Clarkson and Hanson (1980) have drawn attention to the biochemical inertness of Cl which allows it to fill osmotic and cation neutralization roles which may have biochemical or biophysical consequences of importance. In coconut and oil palms, Cl is found in nonphotosynthesizing guard cells as the anion to balance with K (von Uexkull,1984). Plants which take up large amounts of Cl usually have a high water content since the Cl is an important osmoticum (Mengel and Kirkby,1982).

Competitive effects in uptake between Cl and NO_3, and Cl and SO_4, are well known (De Wit et al.,1963; Hiatt and Leggitt,1974). Nitrate is taken up more rapidly than Cl, and Cl more rapidly than SO_4 (Hiatt and Leggitt,1974). Lundegardh (1959) showed that in wheat plants (Triticum aestivum L.) NO_3 and Cl ions in solution depress the uptake of one another. De Wit et al. (1963) suggested the existence of a competitive interaction between NO_3 and Cl uptake by perennial ryegrass (Lolium). In a greenhouse study with potatoes, Murarka et al. (1973) observed this NO_3-Cl competition during the uptake process and also found that the two ions may be competing when they accumulate in the plants. They found that Cl significantly decreased amounts of total N and nitrate N in the top but did not affect the total amount or concentration of the protein N. There was no reduction in dry matter yield. The authors concluded that Cl at moderate levels does not interfere with conversion of N to protein. They cautioned that high Cl may lead to plant tissues that are low in nitrate even though the plant is adequately supplied with N. Errors may be made when NO_3-N concentrations are used to predict N fertilizer needs. A low NO_3-N level might be interpreted as a need for additional N fertilizer when the plant has not had a reduction in growth or in protein produced. One possible result of unneeded N fertilizer application is increased incidence of hollow heart.

The competitive antagonism of NO_3 and Cl was observed in a field study with Russet Burbank potatoes (Saffigna and Keeney, 1977). Chloride reduced the NO_3-N concentration in tops and petioles, and total N in tops and tubers. Saffigna and Keeney (1977) suggested that the Cl status of the plant must be considered if petiole NO_3-N is to be used as a guide to N fertilization.

James et al. (1970) may have misinterpreted the implications of reduced potato petiole NO_3-N caused by increased levels of Cl. They recommended that soil and tissue levels of Cl need to be monitored to obtain a complete interpretation of soil and tissue tests for NO_3-N (just as Saffigna and Keeney did). However, they concluded that increased Cl availability could increase the optimum N fertilizer rate required for potatoes.

Specific Gravity

Tuber dry matter content or specific gravity has a direct relationship to processing quality. Low solids or low specific gravity gives poor quality dehydrated products, french fries, potato chips and other processed products (Smith,1968). Potatoes with high solids also display a desirable, dry or mealy consistency after boiling or baking.

There is considerable evidence that K fertilizer results in a decrease in specific gravity (McDole et al.,1978; McDole,1978; Terman et al.,1953; Timm and Murkel,1963). Further reduction in specific gravity has been shown with the use of KCl as compared to K_2SO_4 (McDole,1978; Terman et al.,1953; Timm and Murkel,1963; Lucas et al.,1954; Dickens et al.,1962). Chloride has been considered responsible for this reduction but $CaCl_2$ did not show the same results as did KCl (Laughlin,1962). Haeder et al. (1975) reported that their experiments suggested that the negative effect of chloride on tuber filling results from impaired translocation of photosynthate from the leaves toward the tuber. It can, however, be indirectly concluded from a later publication by this author and others (Beringer et al.,1983) that this is not the case. The later paper showed that low starch contents due to high K rates were not caused by impaired translocation of photosynthate from the leaves toward the tuber as was postulated. They instead concluded that the starch content of the high K rate was primarily a dilution effect of more water per unit tuber dry weight. There were lower osmotic potentials due to increased K supply. Since the experiment used a 1:1 mixture of KCl and K_2SO_4 to produce the potatoes and impaired translocation was not found, the "impaired translocation" hypothesis should be rejected in regard to Cl as well. The lowered tuber osmotic potentials found in the experiment were probably due to both K and Cl.

Terman et al. (1953) state that it is the K rather than the Cl content of the plant that is chiefly responsible for the differences in specific gravity and dry matter of the tubers. They found K in tubers fertilized with KCl was slightly higher than that in tubers grown with K_2SO_4. Apical (bud end) halves of tubers grown with KCl were lower in dry matter and higher in K than the stem end halves. Stem end halves of tubers were higher in both Cl and dry matter which is evidence, according to Terman, that K content rather than Cl is the chief factor causing differences in dry matter. Johnston et al. (1968) also reported that K contents increased from stem end to bud end and that dry matter decreased from the stem end to the bud end. Arteca et al. (1980) found the same distribution of K and Cl in tubers. It seems that the Cl effect on specific gravity may be indirect and due to its influence on K movement and accumulation.

Hollow Heart

Hollow heart of potatoes is a physiological disease or disorder in which a cavity is formed in the central region of the tuber. This cavity is usually, but not always, bordered with brown necrotic cells. Browning may occur without a cavity and is referred to as brown center. Brown center is generally considered to be a precursor to hollow heart.

Several factors affect the incidence of hollow heart: stress caused by drought and/or high temperatures, low temperatures at tuber set, conditions favoring rapid vine growth during rapid tuber enlargement phase, plant spacing, tuber size, and fertility levels, especially nitrogen and potassium.

Stress caused by drought and/or high temperatures has been given as a cause of hollow heart by many (Dinkel,1960; Krantz,1947; Wolcott and Ellis,1959). A common condition observed to cause hollow heart has been increased moisture supply after a period of more or less deficiency (Kallio,1960; Wolcott and Ellis,1959). Crumbley suggests that hollow heart may be initiated in small tubers as follows:

> "1.) Tubers under moisture stress convert stored starch to soluble sugars, resulting in a greatly reduced water potential in the tuber. The result is a rapid though perhaps short period of cell enlargement, occurring primarily in the perimedullary region where water potential would be lowest. The growth differentials between cells in the pith and the perimedullary regions causes a rupture which develops into a cavity or hollow heart as growth resumes. And/or 2.) following injury to some cells in the tuber due to reabsorption of minerals and carbohydrates or depletion of food reserves followed by tuber enlargement."

Water stress in small tubers can occur under field conditions even though there may be adequate soil moisture. If temperatures are relatively high and atmospheric demand for water is high at the time of early tuber formation, roots may deplete much of the nearby soil water. It may take several hours for additional water to move in the soil to the roots, depending on the hydraulic conductivity and moisture content of the soil (Crumbley et al.,1973). If stress is prolonged the sugars converted from starch may also be reabsorbed by the tops.

According to Krantz (1947) hollow heart in commercial fields has been associated with conditions favoring heavy vine growth during periods of rapid tuber enlargement. Krantz and Lana (1942) were able to increase the incidence of hollow heart by removing foliage early in the season. The foliage injury itself was not the immediate cause of hollow heart as its increase seemed to occur only when the injury was rapidly replaced by new growth. They suggested that the active renewal of vegetative growth following defoliation may have led to a temporary nutritional deficiency which initiated the development of the disorder.

Hollow heart has been found to be most prevalent in large tubers (Moore,1927; Krantz,1947; Krantz and Lana,1942; Levitt,1942). Closer spacing reduces hollow heart (Moore,1927; Nelson,1970). With closer spacing, tubers are restricted in size and the plants are not as susceptible to rapid growth spurts. Seed tuber and seed piece size also can affect hollow heart. Hollow heart was lowest in tubers from plants grown from 57g whole seed pieces and highest in tubers from plants grown from 28g seed pieces cut from 228g seed tubers (Nelson and McThorenson,1982). The whole seed pieces had a higher number of mainstems per hill, greater total number of tubers, and lower average tuber size.

Cool temperatures at the time of tuber iniation contribute to hollow heart. Van Denburgh et al. (1979,1980) were able to induce brown center by subjecting plants to cool environments (10°C) at tuber initiation.

Field research has shown that increasing N applications increase the incidence of hollow heart while increasing K applications reduce the incidence of hollow heart (Kallio,1960; Nelson,1970). Highest rates of N tend to reduce yields while increasing K results in increasing yields (Kallio,1960). The high N fertilizer rate causes excessive vine growth during tuber development and growth. The influence of K on water uptake and retention and on carbohydrate mobilization and phloem transport may directly or indirectly affect the incidence of hollow heart.

Many of the physiological disorders afflicting potato tubers are related to the calcium content of the tuber tissue or to an imbalance between K + Mg and Ca (Poovaiah et al.,1983). In results from four years previous to 1982, Poovaiah et al. (1983) note that reduced Ca in the tuber or an imbalance between K, Mg , and Ca (high concentrations of K and Mg in comparison to Ca) predisposes the tuber to physiological disorders. Their earlier report showed a positive correlation between this cation imbalance and hollow heart symptoms. It is believed that Ca-related physiological disorders are due to an inefficient distribution of Ca rather than poor Ca uptake (Bangerth,1979).

Osmotic Adjustment--Plant Response to Water Stress

Water deficits have been shown to induce a lowering of the osmotic potential in some species and cultivars, thereby contributing to maintenance of turgor as water potential decreases (Turner and Jones, 1980). The maintenance of turgor during changes in plant water status should maintain the metabolic processes of the plant and aid in its growth and survival. Osmotic adjustment in this situation is the lowering of osmotic potential following the net accumulation of solutes in response to water deficits or salinity.

The contributions of solutes to osmotic adjustment were assessed by Jones et al. (1980) when they measured the influence of water deficits on concentrations of major solutes in fully expanded sorghum leaves and partly expanded sunflower leaves. The decreased osmotic potential at full turgor in fully expanded sorghum leaves at a moderate level of stress was fully accounted for by increases in sugars, K, and Cl with the contributions of total inorganic ions and sugars (glucose and sucrose) being approximately equal. In fully expanded sunflower leaves, the response to stress was an increase in the concentrations of the inorganic ions K, Mg, Ca, nitrate, and amino acids. The partly expanded sunflower leaves showed increases in the concentrations of K, Ca, and Mg ions. The increases in inorganic cations were balanced by increases in the concentration of NO_3, carboxylic acids, and Cl, with NO_3 making the major contribution. This information points out the relative importance of inorganic ions as components of osmotic potential.

Levy (1983a,b) compared the effects of water stress on six potato cultivars (cv.). In the cv. Alpha, the accumulation of dry matter was the greatest, one indication that it was least affected by water stress. Alpha showed the highest degree of turgor maintenance in the leaves, in agreement with the highest degree of osmotic regulation (in leaves). In general, an increase in total soluble solids (sucrose equivalent) was found in tubers harvested from the water-stressed plants, with the highest increase in Alpha. The values of osmotic potential in tubers of cv. Alpha decreased more than in the other water-stressed cultivars. This was probably related to the increased total soluble solids. Inorganic ions were not measured in this study.

Tubers and above-ground portions of the plant responded similarly to changes in soil water potential in a field study on water stress relations of potato by Epstein and Grant (1973). Changes in the tuber water potential corresponded to changes in relative water content of potato leaves. The authors hypothesized that tuber water potential was a function of plant water potential with little direct effect of the soil environment. This is possible because the tuber, in the modifying soil environment, is less subject than the leaf to rapid environmental changes.

MATERIALS AND METHODS

Three field experiments were conducted in Oregon in 1983 to evaluate the effect of potash fertilizers on potato yield, quality, and hollow heart and brown center. One experiment was established in Powell Butte while the other two were located in the Columbia Basin at the McDevitt and Levy farms. The potato variety was Russet Burbank (Solanum tuberosum L.) at all three sites. Initial soil test values for the sites are shown in Table 1. (Soil test methods--Berg and Gardner,1978).

Table 1: Analyses of soil samples at experiment sites

	Soil nutrients measured				
	pH	P	K	Ca	Mg
		---ppm---		--meq/100g--	
Powell Butte	5.9	28	130	7.0	3.0
McDevitt	7.1	15	211	5.5	1.2
Levy	8.5	11	325	6.0	1.8

Powell Butte Experiment

The Powell Butte experiment was located on the Central Oregon Experiment Station in Powell Butte, Deschutes County, Oregon. The climate is semiarid with cool winters and warm dry summers. The average annual air temperature is 45° to 50° F. The average frost-free (32° F) growing season is 50 to 90 days and the 28° F-free growing period is 110 to 140 days. The mean annual precipitation is 8 to 12 inches.

The soil at this location is a Deschutes sandy loam. This series is a member of the coarse-loamy, mixed, mesic family of Xerollic Camborthids. The Deschutes soils are used for irrigated crops, range, and wildlife. The experimental site had been in potatoes in 1981 followed by winter wheat in 1982. In the years 1977-1980 the site had been in grass hay and alfalfa.

In the Powell Butte experiment, 18 fertilizer treatments (Table 2) were established with four replications in a randomized block design. The first group of treatments (1-10) involved K source, rate, and timing. The second group of treatments (11-18) had N rate and timing variables.

The base treatment for the experiment was 40 lb N, 66 lb P, and 32 lb S/A which was provided with monoammonium phosphate-sulfate (16-20-0-14) and concentrated super phosphate (0-45-0). The base treatment was banded with the planter. The first 83 lb K/A was banded with the base treatment. The balance of higher K rates was hand broadcast as were all supplemental N treatments. All mid-season fertilizer applications were hand broadcast.

In treatments 1-10 the K sources used were KCl and K_2SO_4. The K rates were 0, 83, 249, 415, and 581 lb K/A. Some of these treatments were applied at planting only (trts. 2-5) while in the others the applications were split between planting and two later applications (July 7 and July 27). These treatments all received an added 120 lb N/A for a total of 160 lb N/A applied.

In the second treatment group (trts. 11-18), N rates of 60, 120, and 240 lb N/A were made in addition to the base N treatment for totals of 100, 160, and 280 lb N/A. These treatments were applied with 40 lb N as ammonium sulfate, in order to assure adequate S nutrition, and the remainder as ammonium nitrate. However, treatments which received the N application at planting (trts. 11, 12, 13, and 18) received 20 rather than 40 lb N/A as ammonium sulfate. These treatments received a July 7 application of gypsum in order to provide the difference of approximately 24 lbs. of S/A. Treatments 11-17 each received KCl at the 249 lb K/A rate at planting.

Plots were four rows wide (3 ft/row) and 40 ft long. Yields were taken from a 20 ft length of the center two rows (6 ft). Plots were irrigated with solid set sprinkler. Irrigation totaled 15.25 inches for the entire season. The experiment station staff irrigated and provided weed, fungal, and insect pest control. One herbicide application of Eptam 7-E was made prior to planting. To control Colorado potato beetles, an application of Parathion was made in mid-July followed two weeks later with Guthion.

Table 2: Treatments applied to potatoes at Powell Butte, 1983

	Date of application							Total	
	18May		7July		27July		K		
BT*	N	K	N	K	N	K	Source	N	K
	------------		lb/A		------------			- lb/A -	
BT	0	0	120	0	0	0	None	160	0
BT	0	83	120	0	0	0	KCl	160	83
BT	0	83	120	0	0	0	K_2SO_4	160	83
BT	0	249	120	0	0	0	KCl	160	249
BT	0	249	120	0	0	0	K_2SO_4	160	249
BT	0	83	120	83	0	83	KCl	160	249
BT	0	83	120	83	0	83	K_2SO_4, KCl, KCl*	160	249
BT	0	83	120	166	0	166	KCl	160	415
BT	0	83	120	332	0	0	KCl	160	415
BT	0	249	120	166	0	166	KCl	160	581
BT	0	249	60	0	0	0	KCl	100	249
BT	60	249	0	0	0	0	KCl	100	249
BT	120	249	0	0	0	0	KCl	160	249
BT	0	249	60	0	60	0	KCl	160	249
BT	0	249	120	0	120	0	KCl	280	249
BT	0	249	240	0	0	0	KCl	280	249
BT	240	249	0	0	0	0	KCl	280	249
BT	120	0	0	0	0	0	None	160	0

*BT (base treatment) 40 lb N/A, 66 lb P/A, 32 lb S/A banded at planting
40 lb N/A as ammonium sulfate = 46 lb S/A
remaining N as ammonium nitrate

*K source--K_2SO_4 18May, KCl on 7July and 27July appl. dates

McDevitt Experiment

This experiment was located on the McDevitt farm (Royal Columbia Farms) near Hermiston, Oregon. The climate is arid with cool winters and hot, dry summers. The average annual air temperature is 53°F. The frost-free period (32°F) is 160 to 190 days. The average annual precipitation is 7 to 10 inches.

The soil at this site is a Quincy fine sand. This series is a member of the mixed, mesic family of Xeric Torripsamments. The Quincy soils are used for irrigated crops, range, and wildlife habitat. The experimental site had been in alfalfa for four preceding years and in an alternating wheat-potato sequence for the seven years before alfalfa.

The experimental plots were located within a 120 A circle of Russet Burbank potatoes. Nine fertilizer treatments (Table 3) were established with five replications in a randomized block design. The base treatment for the experiment was 32 lb N, 57 lb P, and 32 lb S/A which was provided by monoammonium phosphate-sulfate (MAP) (16-20-0-14) and concentrated super phosphate (0-45-0). The base treatment was banded at planting (April 20) as well as the first 83 lb of K/A. The balance of the higher K rates was hand broadcast at planting.

Potash sources used were KCl and K_2SO_4. The K rates were 0, 83, 249, and 581 lb K/A. Treatments 2-4 were applied at planting only while treatments 5-9 received split applications: at planting and one or two later applications (June 28 and July 19). These applications were broadcast by hand.

Treatment 8 received 40 lb N/A at plant. Nitrogen for the season was provided by the grower, in the form of urea ammonium nitrate (UAN), through the center pivot sprinkler irrigation system. The plots all received N application at the same rate of 225 lb N/A. Herbicides, fungicides, and insecticides were also applied by the grower, some through the irrigation system.

The plots were four rows wide (2.91 ft/row) and 40 ft long. Yields were taken from a 25 ft length of the center two rows.

Table 3: Treatments applied to potatoes at McDevitt and Levy experiments, 1983.

Date of application: planting[†] BT[‡]	planting[†] K	28June K	19July K	K Source	Total K
	lb/A	lb/A	lb/A		lb/A
BT	0	0	0	None	0
BT	83	0	0	KCl	83
BT	249	0	0	KCl	249
BT	249	0	0	K_2SO_4	249
BT	83	498	0	KCl	581
BT	83	249	249	KCl	581
BT	83	83	83	KCl	249
BT	83 [a]	83	83	KCl	249
BT	83	83	83	K_2SO_4, KCl, KCl[s]	249

[†] Planting dates: McDevitt, 20April; Levy, 6April

[‡] BT (base treatment) 32 lb N/A, 57 lb P/A, 28 lb S/A banded at planting

[a] Treatment received additional 40 lb N/A as ammonium sulfate, broadcast at planting

[s] Treatment K source: K_2SO_4 at planting, KCl on 28June and 19July application dates

Levy Experiment

The Levy experiment was located in the Columbia Basin area, southwest of Hermiston and west of Echo. The climate is arid with cool winters and hot, dry summers. The average annual air temperature is 49-53° F and the frost-free period is 150-210 days.

The soil at this location has been classified as an Ephrata loamy sand. (Recently, it has been reclassified as an Adkins soil). This series is a member of the mixed, mesic Xerollic Camborthids. However, the presence of a calcareous layer or pan in the C horizon (at 24 in depth) would more likely require the soil to be reclassified. Some growth problems of potato plants were observed when this calcareous layer was found close to the surface as a result of leveling or exposure occuring on slopes.

Ephrata soils are used for irrigated small grains, some dryland grain, and range. The recent cropping history of the experimental site was corn followed by wheat.

The experimental plots were located within a 105 A circle of Russet Burbank potatoes. Nine fertilizer treatments were established with five replications in a randomized block design. These treatments were identical to the McDevitt experiment (Table 3) as were the methods and timing of application (see McDevitt experiment-- materials and methods).

Nitrogen was provided by the grower in the form of UAN through the center pivot sprinkler irrigation system. The plots all received N applications at the same rate for a total of 288 lb N/A. Herbicides, fungicides, and insecticides were applied by the grower, some through the irrigation system.

The plots were four rows wide (2.91 ft/row) and 40 ft long. Yields were taken from a 25 ft length of the center two rows.

Plant Sampling

Petioles were sampled from the third or fourth leaf of the yield rows (center two out of four rows in the plots). Petiole sampling dates on June 28 in the McDevitt and Levy experiments and July 7 in the Powell Butte experiment represent the 2 cm tuber stage (for comparison to a CNR). Mid-season tuber samples were taken from a 5 ft length of row from one of the two center rows, 3 ft into the plot from the end. Tubers sampled in mid-season were cut open and a lengthwise wedge (approximately 2 cm wide), that included the peel, was taken as a subsample for nutrient analysis.

In the Columbia Basin experiments, a minimum of two burlap sacks were filled with potatoes from each plot at harvest. These were weighed in the field. One sack per plot was brought back to Corvallis to evaluate size and grade distribution. (The other sack was left for the grower.) Tubers from this sack were selected to be evaluated for hollow heart and brown center and for nutrient analysis. In the Powell Butte experiment all of the tubers harvested from each plot were used in the grading of size and quality. For the Powell Butte and McDevitt experiments, subsamples of harvest tubers were partitioned into peels, centers, bud ends, and stem ends for nutrient analysis. In the Levy experiment peels were not analysed separately.

Plant Analysis

Petiole samples collected during the summer were dried for at least 48 hours at 70° C. Tuber samples were dried at the same temperature for at least 72 hours. All dried samples were ground in a stainless steel Wiley Mill to pass a 20 mesh screen and were stored in manila envelopes.

The dried, ground plant material was digested in $HNO_3:HClO_4$ (perchloric acid digest). Potassium, Ca, Mg, Zn, and Mn were analysed by flame atomic absorption spectrophotometry using procedures specified by the manufacturer (1976 Perkin Elmer manual, Analytical Methods for Atomic Absorption Spectrophotometry). An aliquot of this digest was analysed for P by formation of the phosphomolybdenum complex (Technicon industrial method 334-74 A/A) using a Scientific Products CFA 200 auto-analyzer.

Nitrate-N was determined colorimetrically on water extracts from petiole samples using the auto-analyzer. The analysis utilized the copperized cadmium reduction method (Keeney and Nelson,1982).

Petiole and tuber Cl were determined by potentiometric titration with $AgNO_3$ using a Cl specific ion electrode (Cantliffe et al,1970).

Evaluation of Hollow Heart and Brown Center

In each experiment, 20 tubers from each plot, 10 greater than 10 oz and 10 6-10 oz, were evaluated soon after harvest. A second group of 20 tubers from these two size groups were evaluated at HR Simplot Inc. (a potato processor in Hermiston) after 75 days of storage. Excessively large tubers (giant hill- >600g) were not included in this evaluation.

Tubers were cut lengthwise into quarters and the occurance of hollow heart and brown center was observed. Hollow heart was either present or not present. Brown center was major, minor, or not present. The brown center classification was similar to Simplot guidelines which are based on the size and darkness of discoloration.

Statistical Analysis

Statistical analysis of data was done by utilizing the Statistical Interactive Programming System (SIPS) of the OSU Computer Center. Treatment effects were tested using the F statistic (P values are given). Treatment means were compared using an appropriate LSD at the 1, 5, or 10% level.

RESULTS

Powell Butte Experiment

Yield and Hollow Heart

Potash fertilizers increased total yield, yield and % of 6+ oz tubers, and decreased the incidence (%) of hollow heart (HH) and brown center (BC) (Tables 4 and 5). Total yields were increased from 18.3 to 25.6 T/A. Yields were increased by the K_2SO_4 treatments at both the 83 and 249 lb K/A rates (21.2 and 23.2 T/A) but the increases were slightly higher for the KCl treatments at the same rates (22.6 and 25.2 T/A). Splitting the K applications at the 249 lb rate showed no improvement over the single applications. The KCl treatments at the 415 and 581 lb K/A rates yielded the highest (25.6 T/A) but were not significantly higher (.10 level) than the 249 lb KCl treatment.

The yield of 6+ oz tubers was increased from 6.0 to 12.6 T/A. The 12.1 T/A yield from the 249 lb rate of KCl at planting was higher (.05 level of significance) than the yields from the lower K rates as well as the yield from the K_2SO_4 treatment (8.8 T/A) at the same rate. The 249 lb K/A rate of KCl at planting also yielded higher (.05) than the split applications at the same rate. The higher KCl rates (415 and 581 lb K/A) also produced high yields of 6+ oz tubers (11.9-12.6 T/A).

Hollow heart and brown center were highest in the ten largest tubers sampled from each treatment. There was a large decrease in hollow heart when K was added, from 27.5% in the K check treatment down to 0.0 and 2.5 for the 415 lb K/A, KCl treatments. For all tuber samples (ten, twenty, and forty largest tubers) the decrease in hollow heart plus brown center was greater when KCl was applied than when K_2SO_4 was applied. The decrease in hollow heart in the forty largest tubers was greater (.05 level) for KCl than for K_2SO_4 at the 249 lb rate.

Time and rate of N application (Table 6) did not significantly affect yield if 249 lb K/A (KCl) was provided; yields were slightly reduced at the 100 lb N/A rate. Maximum yields were obtained when

Table 4: Potash rate and source effects on potato yield and grade (size). Powell Butte, 1983.

K Treatment				Yield		
Date of Appl						
18/5	7/7	27/7	Source	Total	6+oz	<4oz
---- lb/A ----				---------T/A-------		
0	0	0	None	18.3	6.0	4.3
83	0	0	KCl	22.6	9.1	4.3
83	0	0	K_2SO_4	21.2	7.4	4.3
249	0	0	KCl	25.2	12.1	4.4
249	0	0	K_2SO_4	23.2	8.8	5.4
83	83	83	KCl	24.2	9.8	4.5
83	83	83	K_2SO_4 KCl,KCl	24.3	9.8	4.7
83	166	166	KCl	25.6	11.9	4.7
83	332		KCl	25.6	12.5	4.0
249	166	166	KCl	24.4	12.6	3.8
			P value	.0000	.0000	.0408
			LSD .05	2.5	2.3	2.2
			LSD .10	2.1	1.9	1.8

Table 5: Potash rate and source effects on hollow heart and brown center. Powell Butte, 1983.

K Treatment				In ten largest		In twenty largest		In forty largest	
Date of appl									
18/5	7/7	27/7	Source	HH	HH+BC	HH	HH+BC	HH	HH+BC
---- lb/A ----				---------------- % ---------------					
0	0	0	None	27.5	37.5	15.0	20.0	10.0	12.5
83	0	0	KCl	2.5	10.0	1.2	6.2	1.9	4.4
83	0	0	K_2SO_4	10.0	12.5	5.0	10.0	4.4	6.9
249	0	0	KCl	5.0	10.0	2.5	6.2	1.9	3.8
249	0	0	K_2SO_4	5.0	17.5	2.5	12.5	7.5	12.5
83	83	83	KCl	5.0	5.0	2.5	5.0	3.8	5.0
83	83	83	K_2SO_4 KCl,KCl	10.0	22.5	5.0	12.5	5.0	9.4
83	166	166	KCl	2.5	5.0	3.8	5.0	3.8	5.0
83	332		KCl	0.0	10.0	0.0	10.0	2.5	7.5
249	166	166	KCl	5.0	5.0	2.5	3.8	1.2	1.9
			P value	.0001	.0000	.0004	.0018	.0159	.0615
			LSD .05	9.2	12.0	5.3	8.1	4.7	7.2
			LSD .10	7.7	10.1	4.4	6.8	4.0	6.0

Table 6: Nitrogen time and rate effects on potato yield and grade (size). Powell Butte, 1983.

N applied			K	Yield		
Date of Appl						
18/5	7/7	27/7	Applied	Total	6+oz	<4oz
lb/A				T/A		
0	60	0	249	23.7	10.7	4.3
60	0	0	249	24.1	11.3	4.1
0	120	0	249	25.2	12.1	4.4
120	0	0	249	25.5	12.9	3.6
0	60	60	249	25.4	11.3	4.6
0	120	120	249	24.8	10.8	4.6
0	240	0	249	24.9	11.9	4.6
240	0	0	249	24.6	13.0	3.7
0	120	0	0	18.3	6.0	4.3
120	0	0	0	21.5	8.7	4.3
			P value	.0000	.0000	.0408
			LSD .05	2.5	2.3	2.2
			LSD .10	2.1	1.9	1.8

Table 7: Nitrogen time and rate effects on hollow heart and brown center. Powell Butte, 1983.

N applied			K	In ten largest		In twenty largest		In forty largest	
Date of appl									
18/5	7/7	27/7	Applied+	HH	HH+BC	HH	HH+BC	HH	HH+BC
lb/A				%					
0	60	0	249	0.0	2.5	0.0	2.5	0.6	3.1
60	0	0	249	2.5	2.5	1.2	2.5	1.2	1.9
0	120	0	249	5.0	10.0	2.5	6.2	1.9	3.8
120	0	0	249	0.0	2.5	0.0	2.5	0.6	1.9
0	60	60	249	0.0	0.0	0.0	0.0	1.9	2.5
0	120	120	249	2.5	5.0	1.2	3.8	1.2	2.5
0	240	0	249	5.0	10.0	3.8	7.5	3.1	5.0
240	0	0	249	2.5	5.0	1.2	3.8	1.9	3.8
0	120		0	27.5	37.5	15.0	20.0	10.0	12.5
120	0	0	0	5.0	12.5	2.5	8.8	4.4	7.5
			P value	.0001	.0000	.0004	.0018	.0159	.0615
			LSD .05	9.2	12.0	5.3	8.1	4.7	7.2
			LSD .10	7.7	10.1	4.4	6.8	4.0	6.0

+K applied as KCl.

treatments received 160 lbs of N/A, 40 with the base treatment at planting plus 120 lb N/A. Yields were lower (.05 level), however, when K was not provided. Comparison of the two K check treatments shows that when the 120 lb of N/A was applied at planting, total yield and yield of 6+ oz tubers were higher (.05 level) than when the same amount of N was applied later (July 7). Hollow heart and brown center (Table 7) were greatly reduced (.05 level) when 120 lb N/A was applied at planting (27.5% vs 5.0% in the 10 largest tubers sample group). This same trend was found in the other N rate and time treatments which showed that more than 60 lb N/A on July 7 increased hollow heart and brown center. The treatments which had received only 40 lbs N at planting may have been low in N by July 7. High rates of N applied on July 7 may have caused an accelerated increase in growth resulting in growth stress that increased hollow heart and brown center.

The K rates and sources did not affect processing quality of french fries. The fry test conducted at Simplot's quality control laboratory did not show discoloration of the fries with the high rate of K or KCl (Appendix Table 1A). Discoloration in fries is caused by an improper starch:sugar balance.

Petiole Nutrient Level--Yield Relationships

Nutrient levels of K, Ca, and Mg in petiole samples taken on July 7 are given in Table 8 for treatments with different K and N rates at planting. The two check treatments (K zero and N + K zero) had 6.5 and 7.2 %K, falling well below the critical nutrient range of 9.5-11.0 %K suggested by several researchers (Jackson et al.,1974; Roberts et al.,1983; Middleton et al.,1975). Potash increased K concentrations and decreased Ca and Mg concentrations with the KCl treatments being more effective than comparable rates of K_2SO_4 in increasing K concentration. The petiole K concentrations for the 83 and 249 lb rates were higher (.05 level) with KCl treatments (9.6 and 10.8 %K) than with K_2SO_4 treatments (8.4 and 9.6 %K). At the 249 lb K/A rate the K_2SO_4 treatment also had a lower (.05 level) Ca concentration than the KCl treatment.

Table 8: Potash rate and source effects on petiole K, Ca, and Mg concentrations. Powell Butte, July 7, 1983.

Treatment			Nutrient Concentrations			
N	K	Source	K	Ca	Mg	K+Ca+Mg
-- lb/A --			%			meq/100g dw
0	0	None	6.5	1.94	1.65	399.0
0	83	KCl	9.6	1.73	1.25	435.9
0	83	K_2SO_4	8.4	1.76	1.39	418.2
0	249	KCl	10.8	1.82	1.31	475.0
0	249	K_2SO_4	9.6	1.54	1.28	428.3
60	249	KCl	9.8	1.66	1.46	453.2
120	249	KCl	11.1	1.66	1.37	479.6
240	249	KCl	10.1	1.66	1.53	467.2
120	0	None	7.2	1.94	1.73	423.5
		P value	.0000	.0313	.0011	.0000
		LSD .01	1.49	0.33	0.30	31.5
		LSD .05	1.10	0.24	0.22	23.2
		LSD .10	0.91	0.20	0.18	19.3

Table 9: Potash rate and source effects on petiole K, Ca, and Mg concentrations. Powell Butte, July and August, 1983.

K Treatment				Nutrient concentrations					
				Sampling date					
Date of appl				27July			18Aug		
18/5	7/7	27/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----				%					
0	0	0	None	4.1	2.07	2.33	2.7	1.80	2.77
83	0	0	KCl	6.4	1.78	1.86	4.7	1.95	2.45
83	0	0	K_2SO_4	5.4	1.66	2.00	4.0	1.80	2.60
249	0	0	KCl	8.7	1.70	1.62	7.7	1.74	2.01
249	0	0	K_2SO_4	8.3	1.39	1.58	7.6	1.38	2.02
83	83	83	KCl	6.2	1.76	1.95	6.8	1.65	2.23
83	83	83	K_2SO_4 KCl,KCl	5.6	1.86	2.12	6.3	2.01	2.34
83	166	166	KCl	8.2	1.77	1.80	9.2	1.96	2.12
83	332		KCl	7.2	1.88	2.14	9.1	1.54	1.88
249	166	166	KCl	9.4	1.76	1.67	10.1	1.81	1.78
			P value	.000	.067	.000	.000	.36	.000
			LSD .05	1.4	0.30	0.30	1.6	0.44	0.32
			LSD .10	1.2	0.25	0.25	1.4	0.37	0.27

The effects of potash on petiole K, Ca, and Mg for July 27 and August 18 sampling dates are shown in Table 9. All treatments receiving less than 249 lb K/A by July 7 fell well below the critical nutrient range for K (9.0-10.0 %K) on the July 27 sampling date. The K check treatment had the highest petiole Ca and Mg levels on this date with some treatments being significantly (.05) lower in these nutrients. The K_2SO_4 treatment at the 249 lb K/A rate continued to have lower (.05 level) Ca concentrations than the KCl treatment for both the July 27 and August 18 sampling dates. On the August 18 sampling date, treatments receiving less than 249 lb K/A by July 7 had petiole K concentrations that fell below the K levels found in 249 lb K/A and higher rates. The 249 lb K/A split treatments had only 6.8 and 6.3 %K but still produced yields 94% of the maximum yield for the experiment; yields of 6+ oz tubers, however, were reduced. The 415 and 581 lb K/A treatments maintained high levels of K (9.2 and 10.1 %K) through August 18 and produced the maximum total yields and yields of 6+ oz tubers. The 249 lb K/A rate of KCl with lower K (7.7%) on August 18 produced similar yields.

The effects of rate and form of potash on petiole Cl and NO_3-N are shown in Table 10; changes in Cl and NO_3-N during the season are shown in Figure 1. All treatments shown received identical N applications. Reduced levels of NO_3-N were associated with higher levels of Cl. On July 27 the KCl treatment (249 lb K/A rate) with 5.6 %Cl, had 1.3 %NO_3-N while the K check and K_2SO_4 (249 lb K/A) treatments, with 0.4 and 0.3 %Cl, had 2.6 and 2.0 %NO_3-N. Even though levels of NO_3-N in the KCl treatments at 83 and 249 lb K/A rates were reduced, total yield and yield of 6+ oz tubers were higher for these treatments than for the comparable K_2SO_4 treatments. The plants took up more Cl as higher amounts were applied. Since very little Cl is metabolised, Cl levels are maintained in the plant through the season. (Appendix table 4 includes the effects of higher rates and time of application). The effect of Cl applied on petiole Cl in August (Figure 2) showed a positive correlation (r=0.91).

Levels of Cl in petioles correlate well with Cl found in tubers throughout the season (Figures 3-6). The r values were .95 for July

Table 10: Potash and chloride effects on petiole NO_3-N and Cl and tuber yield. Powell Butte, 1983.

Date of appl 18/5 N	18/5 K	7/7 N	K Source	7/7 Cl	7/7 NO_3-N	27/7 Cl	27/7 NO_3-N	18/8 Cl	18/8 NO_3-N	Yld 6+oz
lb/A				%						T/A
0	0	120	None	0.4	3.6	0.3	2.7	0.5	2.6	8.7
120	0	0	None	0.6	2.8	0.4	2.6	0.9	2.7	6.0
0	83	120	KCl	4.2	2.3	3.0	1.7	4.0	1.6	9.1
0	83	120	K_2SO_4	0.6	2.9	0.3	2.1	0.6	2.3	7.4
0	249	120	KCl	6.7	2.3	5.6	1.3	7.2	1.0	12.1
0	249	120	K_2SO_4	0.6	3.0	0.4	2.0	0.6	1.5	8.8

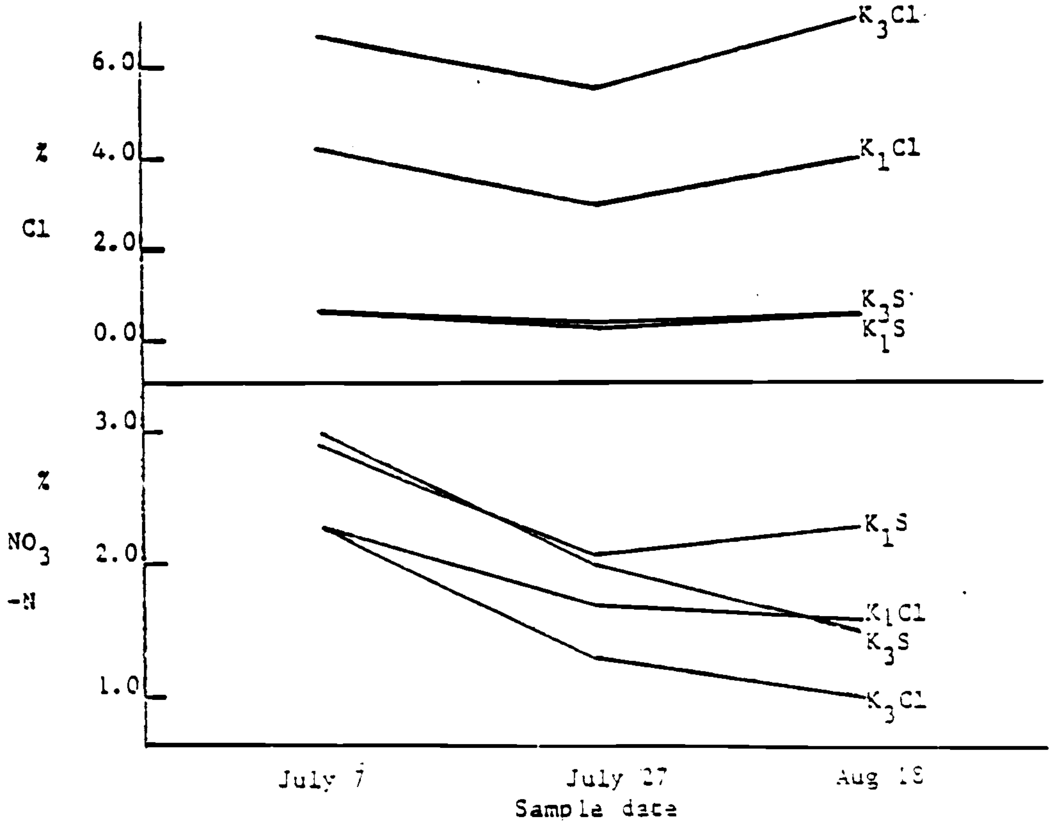

Figure 1: Potash and chloride effects on seasonal distribution of Cl and NO_3-N in potato petioles. Powell Butte, 1983.

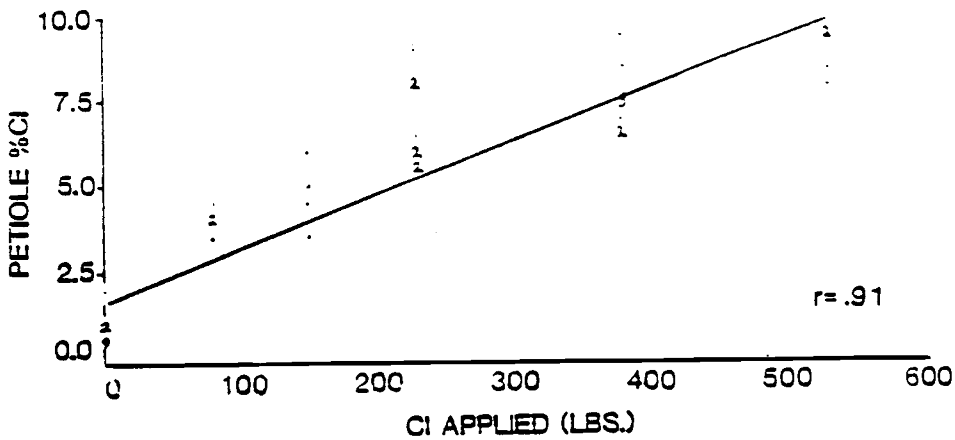

Figure 2: Relationship between Cl applied to Cl in petioles on August 18, 1983. Powell Butte.

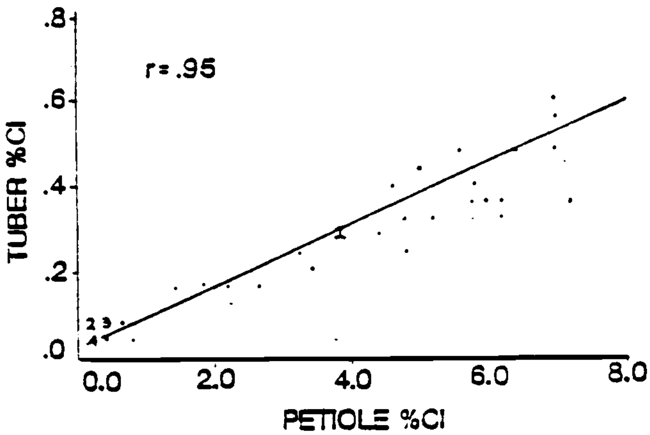

Figure 3: Relationship between petiole Cl and tuber Cl. July 27, 1983. Powell Butte.

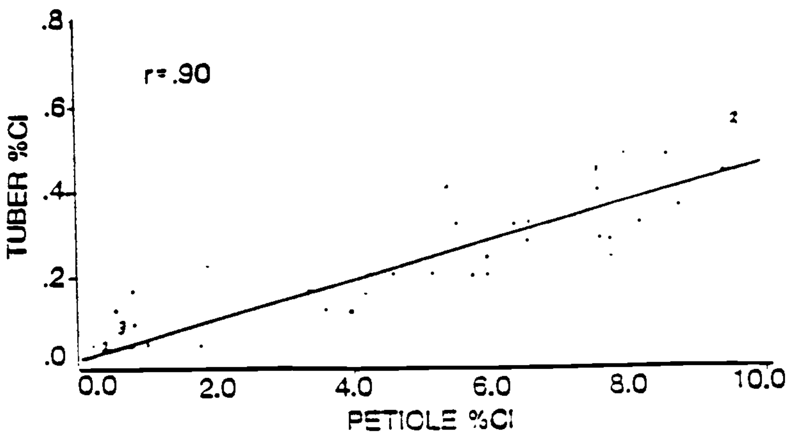

Figure 4: Relationship between petiole Cl and tuber Cl. August 18, 1983. Powell Butte.

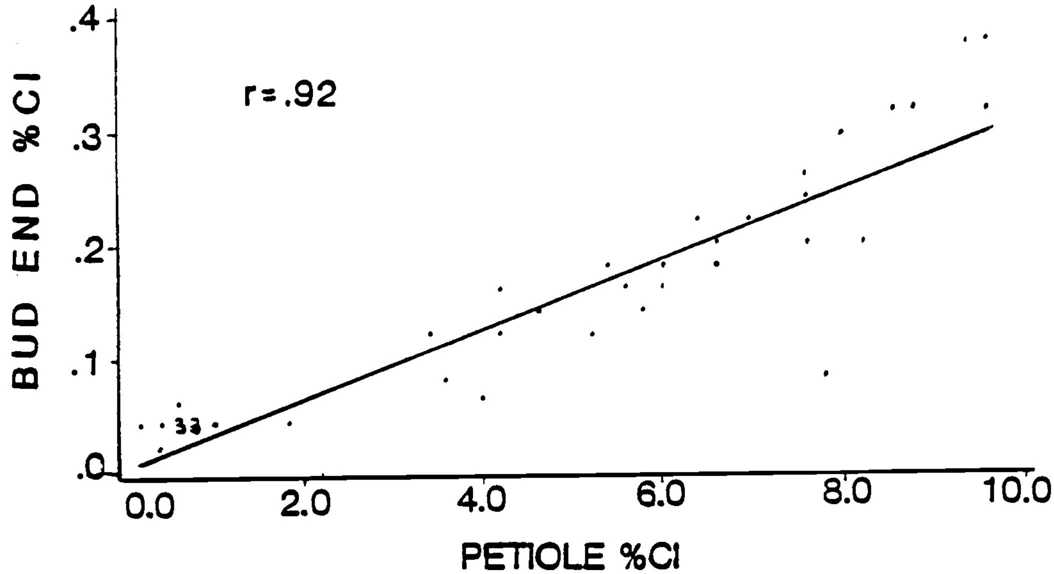

Figure 5: Relationship between petiole Cl on August 18 and tuber bud end Cl at harvest. Powell Butte, 1983.

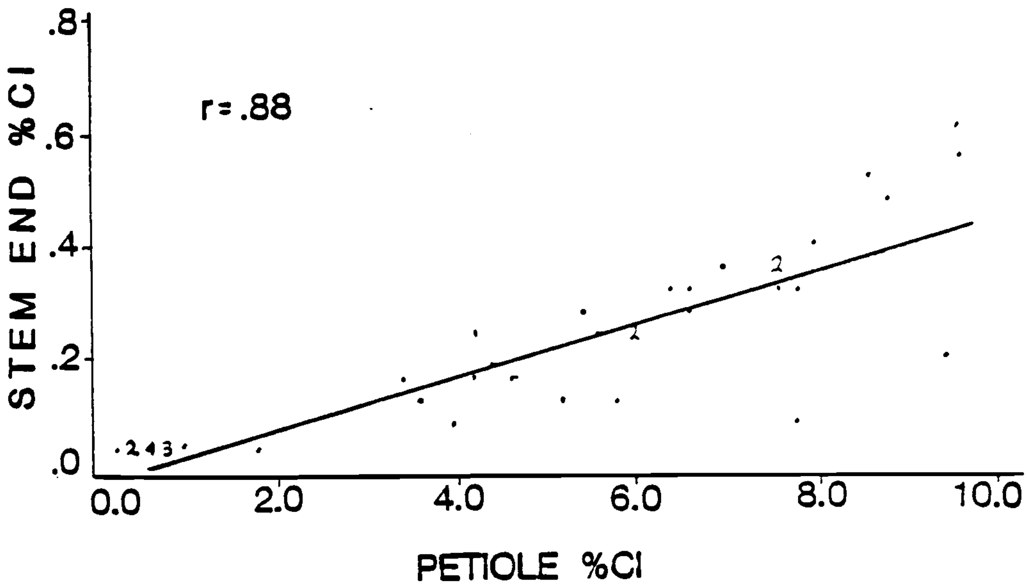

Figure 6: Relationship between petiole Cl on August 18 and tuber stem end Cl at harvest. Powell Butte, 1983.

27 tubers and petioles, .90 for August 18 tubers and petioles, .92 for harvest bud end (tuber part) and August petioles, and .88 for harvest stem end (tuber part) and August petioles.

Nutrient Levels in Tubers

Tuber Cl levels are shown in Table 11. Chloride values for the K check, and K_2SO_4 treatments were low (.03-.08 %Cl). As levels of Cl applied increased, Cl in tubers increased. Tuber Cl concentrations were higher when Cl was applied earlier in the season. The trend was the opposite for specific gravity (Table 11). The K check treatment had the highest specific gravity (1.0927) while the 581 lb K/A treatment had the lowest (1.0788). Treatments with split applications later in the season had higher specific gravity. Despite lowered specific gravities, processing quality of the tubers, as measured by Simplot's quality control lab, was not reduced (Appendix Table 1).

Tuber K, Ca, Mg, and Cl levels for the July 27 and August 18 sampling dates are shown in Tables 12 and 13. The K treated plots showed increases in K concentration as compared to the check with higher K concentrations found in tubers from treatments with higher K rates. Tubers from KCl treatments tended to have slightly higher K than tubers from comparable K_2SO_4 treatments. Tuber Ca and Mg were not significantly affected by treatment. Levels of both tended to be higher in treatments that received high K applications early (415 and 581 lb K/A). Total meq of cations and of cations plus Cl were higher for the higher K rates. They were also higher for KCl than for K_2SO_4 treatments.

The harvest tubers (Table 14) showed significant differences in K between treatments and between tuber parts. Potassium was lowest in the K check treatment while higher K rates had higher K concentrations in the tuber parts. When comparing KCl and K_2SO_4 treatments at the 249 lb K/A rate, differences in K in the center, stem end, and peel are found. The KCl treatment had higher K than the K_2SO_4 treatment: 2.44 vs 1.99 in the center, 1.66 vs 1.29 in the stem end, and 3.40 vs 3.09 in the peel. Potassium was highest in the peel, followed by the center, the bud end, and the stem end.

Table 11: Potash and Cl effects on specific gravity and Cl levels in whole tubers on July and August sampling dates and in bud and stem ends of tubers at harvest. Powell Butte, 1983

K Treatment					Cl concentration			
Date of appl				Specific	Whole tuber		Bud end	Stem end
18/5	7/7	27/7	Source	Gravity	27/7	18/8	harvest	harvest
---- lb/A ----					------------ % ------------			
0	0	0	None	1.0927	.06	.07	.04	.03
83	0	0	KCl	1.0888	.21	.17	.10	.12
83	0	0	K_2SO_4	1.0927	.05	.06	.04	.03
249	0	0	KCl	1.0838	.41	.32	.23	.35
249	0	0	K_2SO_4	1.0886	.06	.08	.04	.04
83	83	83	KCl	1.0875	.31	.27	.15	.20
83	83	83	K_2SO_4 KCl,KCl	1.0892	.14	.18	.14	.16
83	166	166	KCl	1.0849	.33	.37	.25	.29
83	332		KCl	1.0833	.38	.33	.22	.34
249	166	166	KCl	1.0788	.55	.32	.32	.52
			P value	.0000	.0000	.0000	.0000	.0000
			LSD .01		.09	.10	.07	.09
			LSD .05	.0044	.07	.07	.05	.07
			LSD .10	.0037	.06	.06	.04	.06

Table 12: Potash rate and source effects on tuber K, Ca, Mg, and Cl concentrations. Powell Butte, July 27, 1983.

K Treatment: Date of appl 18/5	7/7	27/7	Source	K	Ca	Mg	Cl	K+Ca+Mg	K+Ca+Mg+Cl
---- lb/A ----				---------- % ----------				--meq/100g dw--	
0	0	0	None	1.68	.046	.084	.06	52.2	54.0
83	0	0	KCl	1.87	.054	.089	.21	57.9	63.8
83	0	0	K_2SO_4	2.19	.054	.089	.05	53.5	55.0
249	0	0	KCl	2.19	.051	.089	.41	65.9	77.4
249	0	0	K_2SO_4	1.85	.048	.096	.06	57.6	59.3
83	83	83	KCl	2.03	.052	.089	.31	61.9	70.5
83	83	83	K_2SO_4 KCl,KCl	1.85	.047	.084	.14	56.6	60.6
83	166	166	KCl	2.01	.054	.087	.33	61.3	70.5
83	332		KCl	2.31	.060	.090	.38	69.5	80.1
249	166	166	KCl	2.45	.073	.098	.55	74.0	89.5
			P value	.000	.20	.13	.000		
			LSD .05	.26	—	—	.07		
			LSD .10	.22	—	—	.06		

Table 13: Potash rate and source effects on tuber K, Ca, Mg, and Cl concentrations. Powell Butte, August 18, 1983.

K Treatment: Date of appl 18/5	7/7	27/7	Source	K	Ca	Mg	Cl	K+Ca+Mg	K+Ca+Mg+Cl
---- lb/A ----				---------- % ----------				--meq/100g dw--	
0	0	0	None	1.30	.042	.085	.07	49.9	51.0
83	0	0	KCl	1.42	.038	.090	.17	56.8	59.6
83	0	0	K_2SO_4	1.36	.038	.100	.06	58.8	59.8
249	0	0	KCl	1.70	.040	.095	.32	63.8	70.2
249	0	0	K_2SO_4	1.61	.042	.105	.08	62.4	63.5
83	83	83	KCl	1.62	.038	.095	.27	61.4	65.6
83	83	83	K_2SO_4 KCl,KCl	1.65	.038	.095	.18	63.1	66.9
83	166	166	KCl	1.86	.035	.100	.37	68.2	75.3
83	332		KCl	1.90	.058	.100	.33	68.8	75.0
249	166	166	KCl	2.10	.048	.100	.62	73.3	82.5
			P value	.000	.45	.21	.000		
			LSD .05	.21	--	--	.07		
			LSD .10	.17	--	--	.06		

Table 14: Potash rate and source effects on tuber K, Ca, and Mg concentrations in tuber parts at harvest. Powell Butte, 1983.

K Treatment				Nutrient concentrations					
Date of appl				Bud End			Center		
18/5	7/7	27/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----				----------	----------	---------- %	----------	----------	----------
0	0	0	None	1.58	.034	.095	1.40	.022	.098
83	0	0	KCl	1.84	.033	.098	1.95	.022	.112
83	0	0	K_2SO_4	1.76	.031	.150	1.68	.020	.128
249	0	0	KCl	2.12	.030	.098	2.44	.028	.115
249	0	0	K_2SO_4	2.00	.036	.115	1.99	.022	.128
83	83	83	KCl	2.02	.032	.098	2.16	.022	.112
83	83	83	K_2SO_4 KCl,KCl	2.04	.040	.108	2.25	.030	.122
83	166	166	KCl	2.25	.033	.110	2.61	.022	.112
83	332		KCl	2.29	.031	.105	2.54	.027	.120
249	166	166	KCl	2.45	.034	.110	2.89	.020	.125
			x	2.03	.033	1.09	2.19	.023	.118
			P value	.000	.91	.16	.000	.49	.005
			LSD .05	.24	--	--	.28	--	.016
			LSD .10	.20	--	--	.23	--	.013

K Treatment				Nutrient concentrations					
Date of appl				Stem end			Peel		
18/5	7/7	27/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----				----------	----------	---------- %	----------	----------	----------
0	0	0	None	0.90	.028	.082	2.39	.087	.140
83	0	0	KCl	1.16	.030	.092	2.78	.090	.168
83	0	0	K_2SO_4	1.05	.026	.102	2.75	.097	.168
249	0	0	KCl	1.66	.030	.098	3.40	.097	.158
249	0	0	K_2SO_4	1.29	.034	.105	3.09	.100	.175
83	83	83	KCl	1.40	.029	.092	3.10	.092	.152
83	83	83	K_2SO_4 KCl,KCl	1.49	.036	.095	3.25	.113	.158
83	166	166	KCl	1.69	.032	.112	3.42	.098	.182
83	332		KCl	1.65	.037	.107	3.49	.099	.168
249	166	166	KCl	1.95	.034	.102	3.84	.113	.178
			x	1.42	.031	.099	3.15	.099	.165
			P value	.000	.62	.22	.000	.45	.018
			LSD .05	.20	--	--	.34	--	.023
			LSD .10	.16	--	--	.28	--	.019

There were no significant differences in tuber Ca due to treatment. The F test P values were high for all tuber parts. Calcium was highest in the peel, followed by the bud and stem ends, and was lowest in the center.

The harvest tubers had differences in tuber Mg between treatments and tuber parts. Magnesium levels were higher in K_2SO_4 treatments (than in comparable KCl treatments) and in the 415 and 581 lb K/A treatments. The peel was highest in Mg, followed by the center, the bud end, and the stem end.

McDevitt Experiment

Yield and Hollow Heart

Potash fertilizers increased total yield, yield of (%) 6+ oz tubers, and decreased the incidence (%) of hollow heart (HH) and brown center (BC) (in the 20 largest tubers) (Tables 15 and 16). The 83 and 249 lb K/A rates did not significantly (.05 level) affect yield but KCl treatments at these rates did decrease the amount of hollow heart and hollow heart plus BC. At the 249 lb K/A rate the KCl treatment had a lower (.05 level) amount of hollow heart plus BC than the K_2SO_4 treatment. The higher K rates (581 lb K/A) resulted in an increase in total yield, a significant increase in (%) 6+ oz tubers (20.8 T/A for the check vs 26.4 and 24.1 T/A for the high K rates) and lower levels of hollow heart. The highest rate of K (581 lb K/A) showed a significant increase in (%) 6+ oz tubers over the intermediate K rate (249 lb K/A as KCl).

The % hollow heart and BC results from the twenty tubers stored for approximately 75 days and evaluated at Simplot showed more variability than the twenty tubers evaluated immediately after harvest. They were generally lower in HH and BC than the first twenty tubers. When both groups are pooled together into a group of forty the results (Table 16) showed lower hollow heart and hollow heart plus BC in KCl treatments at the 83, 249, and the 83+249+249 lb K/A levels.

Nutrient Levels in Petioles

Nutrient levels of K, Ca, and Mg in petiole samples for June 15 and 28 are given in Table 17 for treatments differing at that point in the experiment (different K treatments at planting). The K concentrations of petiole samples from the K check plot were 12.2 and 11.0 %K for the two dates, respectively. This is higher than the critical nutrient range of 9.5-11.0 %K suggested by several researchers (Jackson et al.,1974; Roberts et al.,1983; Middleton et al.,1975).

The KCl treatments increased petiole K more than comparable K_2SO_4 treatments. On the June 15 sampling date in the K_2SO_4 treatment at the 249 lb K/A rate, the petioles had significantly (.05)

Table 15: Potash rate and source effects on potato yield and grade (size). McDevitt, 1983.

K Treatment				Yield		
Date of Appl						
20/4	28/6	19/7	Source	Total	6+oz	<4oz
---- lb/A ----				---------T/A-------		
0	0	0	None	33.4	20.8	4.9
83	0	0	KCl	33.5	20.8	4.9
249	0	0	KCl	33.9	21.4	4.4
249	0	0	K_2SO_4	34.1	23.5	4.1
83	498		KCl	35.8	26.4	3.4
83	249	249	KCl	35.4	24.1	4.7
83	83	83	KCl	34.3	23.9	3.9
83	83	83	KCl	33.3	22.1	4.3
83	83	83	K_2SO_4 KCl,KCl	34.0	23.3	4.2
			P value	.77	.08	
			LSD .05	3.3	3.8	
			LSD .10	2.2	3.2	

Table 16: Potash rate and source effects on hollow heart and brown center. McDevitt, 1983.

K Treatment				In ten largest		In twenty largest		In forty largest	
Date of appl									
20/4	28/6	19/7	Source	HH	HH+BC	HH	HH+BC	HH	HH+BC
---- lb/A ----				----------------- % ----------------					
0	0	0	None	14	24	8	16	6.5	11.0
83	0	0	KCl	4	6	3	4	3.0	4.5
249	0	0	KCl	6	8	3	5	2.5	3.0
249	0	0	K_2SO_4	16	24	9	15	7.5	11.0
83	498		KCl	4	10	3	7	6.0	8.0
83	249	249	KCl	0	10	2	7	4.0	6.0
83	83	83	KCl	2	8	9	13	7.5	9.0
83†	83	83	KCl	12	14	6	9		
83	83	83	K_2SO_4 KCl,KCl	18	22	11	14	8.0	9.0
			P value	.06	.02	.16	.04		
			LSD .05	13	13	8	9		
			LSD .10	11	11	6	7		

†Treatment received 40 lb N/A as ammonium sulfate.

Table 17: Potash effects on June petiole K, Ca, and Mg concentrations. McDevitt, 1983.

Treatment		Nutrient concentrations					
		Sampling date					
		15June			28June		
K	Source	K	Ca	Mg	K	Ca	Mg
lb/A		%					
0	None	12.2	1.26	0.62	11.0	1.35	0.71
83	KCl	13.4	1.30	0.62	12.0	1.18	0.58
249	KCl	14.5	1.45	0.65	13.4	1.27	0.50
249	K_2SO_4	13.8	1.11	0.51	12.3	1.22	0.54
83	K_2SO_4	12.4	1.34	0.58	11.6	1.34	0.58
	P value	.001	.083	.001	.000	.703	.011
	LSD .05	1.0	0.25	0.07	0.8	---	.11
	LSD .10	0.8	0.21	0.06	0.6	---	.09

Table 18: Potash rate and source effects on petiole K, Ca, and Mg concentrations. McDevitt, July and August, 1983.

K Treatment				Nutrient concentrations					
Date of appl				Sampling date					
				19July			16Aug		
20/4	28/6	19/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----				%					
0	0	0	None	9.0	1.09	1.18	8.9	1.50	1.35
83	0	0	KCl	10.5	1.08	1.10	9.0	1.48	1.28
249	0	0	KCl	13.0	0.99	0.78	11.0	1.39	0.92
249	0	0	K_2SO_4	12.3	0.87	0.69	11.4	1.15	0.85
83	498		KCl	13.8	1.08	0.78	12.6	1.28	0.75
83	249	249	KCl	13.9	1.04	0.73	12.8	1.56	0.77
			P value	.000	.167	.000	.000	.054	.000
			LSD .05	1.2	---	0.11	1.1	0.29	0.20
			LSD .10	1.0	---	0.09	0.9	0.24	0.17

lower Ca and Mg levels than the KCl treatment. The K concentration difference between KCl and K_2SO_4 at the 249 lb K/A rate on June 28 was significant at the .05 level.

On both sampling dates the K check treatment K concentration is significantly lower than all other treatments except for the 83 lb K/A, K_2SO_4 treatment. On June 28 the check treatment had a higher (.05 level) Mg concentration than all other treatments and Ca was higher, though not significantly.

Petiole sample nutrient levels for July 19 and August 16 are given in Table 18. The K concentration of petiole samples from the K check plot were 9.0 and 8.9% for the two dates, respectively. These levels are above recommended critical nutrient ranges of 9.0-10.0 %K and 8.0-9.0 %K for these dates. All treatments receiving 249 lb K/A or more maintained K levels at or above 11.0% through mid-August. The treatments which yielded higher total and 6+ oz, 581 lb K/A as KCl treatments, also had significantly higher K concentrations on both these dates. At mid-August they still had 12.6 and 12.8 %K.

Calcium and Mg levels (Table 18) continued to be lowest in the K_2SO_4 treatment through July and August. Calcium and Mg were significantly (.05) lower in the K_2SO_4 treatment than the K check treatment for both dates. The check treatment had a significantly (.05) higher level of Mg than all treatments except for the 83 lb K/A, KCl treatment.

The relationship between petiole Cl and NO_3-N is shown graphically in Figures 7 and 8. As was expected there was a negative correlation between Cl and NO_3-N with r values of -.85 and -.93 for July and August sampling dates, respectively.

Petiole Cl and NO_3-N concentrations for all sampling dates are shown in Table 19. In most cases, differences are highly significant (.01 level). All treatments received identical N applications. Reduced levels of NO_3-N were associated with higher levels of Cl. On June 28 the 249 lb K/A, KCl treatment, with 6.0% Cl, had 1.4% NO_3-N while K check and K_2SO_4 (249 lb K/A) treatments, both with 0.6% Cl, had 2.1 and 1.9% NO_3-N, respectively. Changes in Cl and

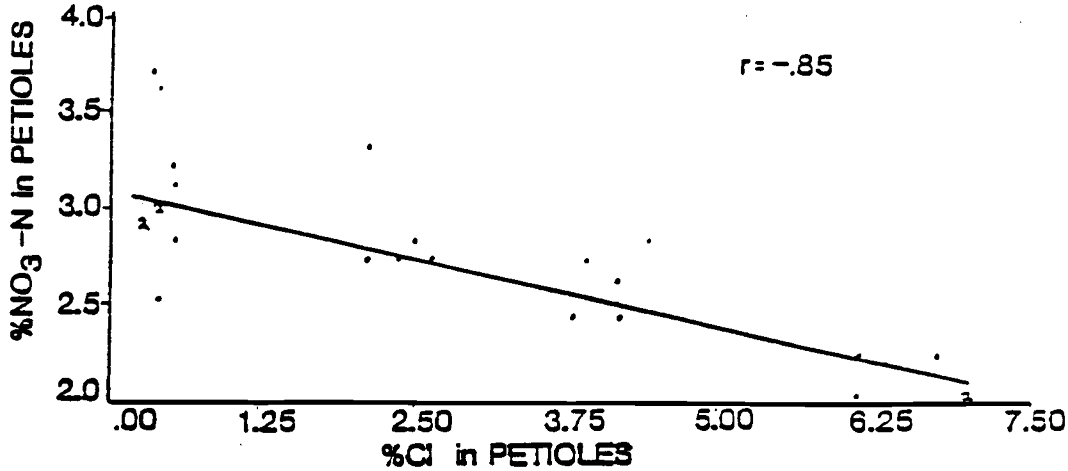

Figure 7: Relationship between Cl and NO_3-N in potato petioles. July 19, 1983. McDevitt.

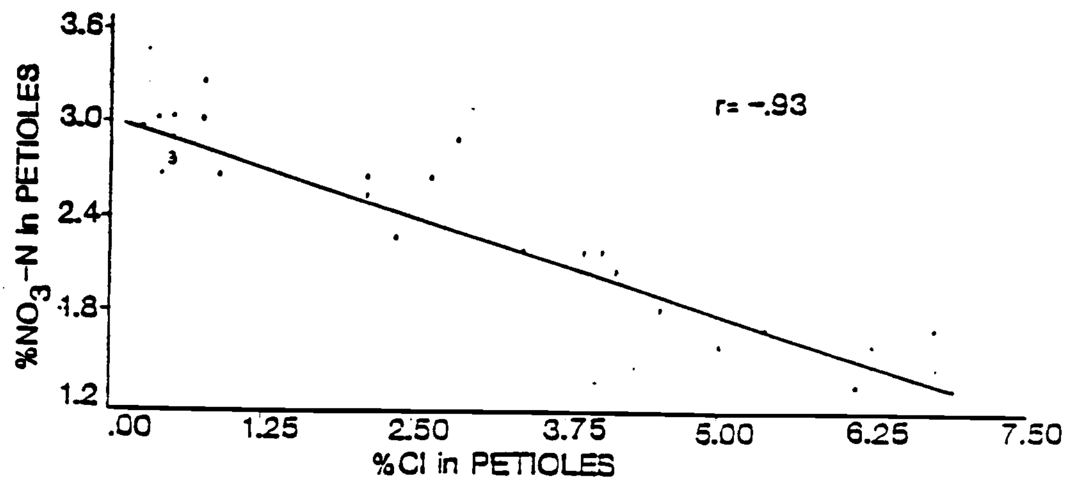

Figure 8: Relationship between Cl and NO_3-N in potato petioles. August 16, 1983. McDevitt.

Table 19: Potash and chloride effects on petiole NO_3-N and Cl, and yield. McDevitt, 1983.

K Treatment		Nutrient concentrations								
		Sampling date								
Date		15June		28June		19July		16Aug		Yld
20/4	Source	Cl	NO_3-N	Cl	NO_3-N	Cl	NO_3-N	Cl	NO_3-N	6+oz
lb/A		%								T/A
0	None	0.6	2.4	0.5	2.1	0.4	3.1	0.6	2.9	20.8
83	KCl	3.2	2.2	3.2	1.6	2.3	2.8	2.4	2.6	20.8
249	KCl	6.5	2.1	6.0	1.4	4.0	2.6	4.0	2.1	21.4
249	K_2SO_4	0.6	2.5	0.6	1.9	0.4	3.0	0.6	2.8	23.5
	P value	.0000		.0000		.0000		.0000		.08
	LSD .01	.60	.30	.58	.40	.51	.31	.86	.29	
	LSD .05	.44	.22	.42	.29	.38	.23	.64	.22	3.8
	LSD .10	.36	.18	.35	.24	.31	.19	.53	.18	3.2

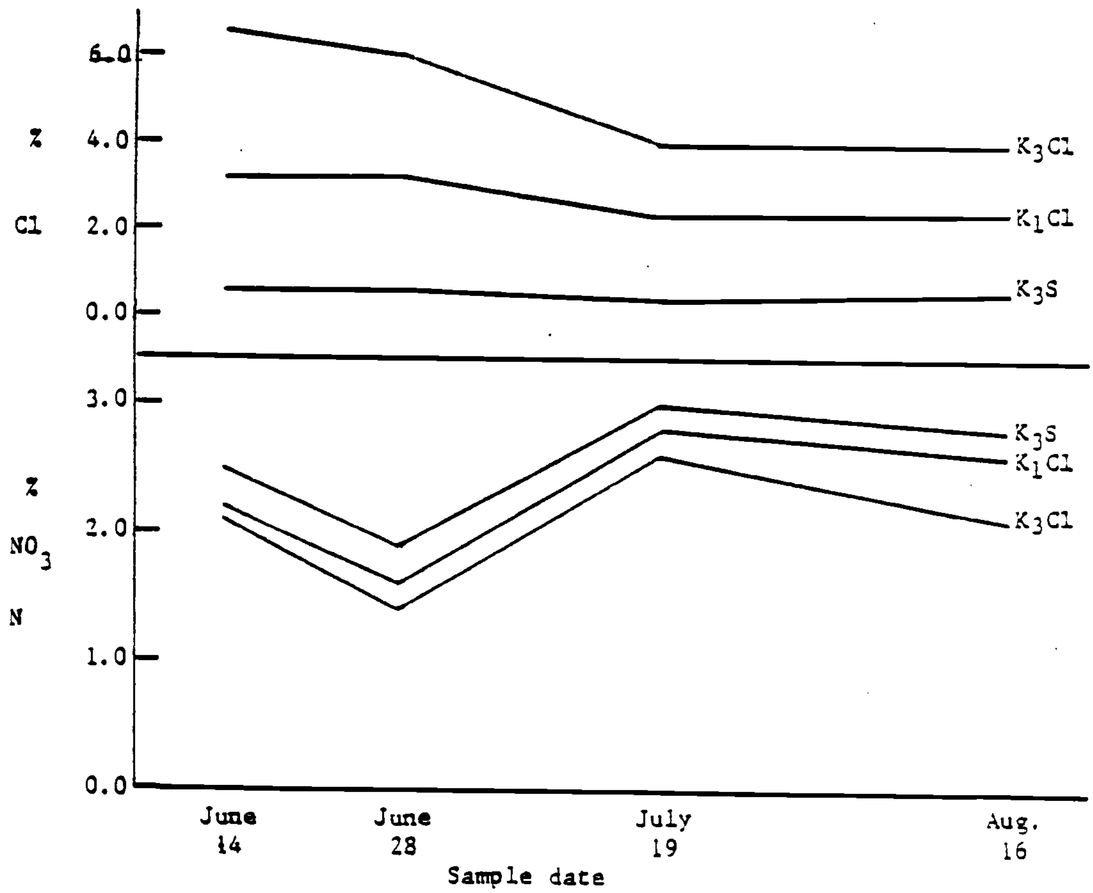

Figure 9: Potash and chloride effects on seasonal distribution of Cl and NO_3-N in potato petioles. McDevitt, 1983.

NO_3-N during the season are shown in Figure 9. Even with reduced levels of NO_3-N (Table 19), total yields were very similar and 6+ oz yields were not significantly different at same rates of K/A. Regression of total yield with NO_3-N levels in August showed a poor negative correlation (r= -.4). This negative slope was due to high KCl treatments (with low NO_3-N) yielding high and the K check treatments (with high NO_3-N) yielding slightly lower.

Petiole Cl levels (Table 19) show that the potato plants took up increasingly large quantities of Cl as higher amounts were applied. A regression of the effect of Cl applied on petiole Cl in August (Figure 10) showed a positive correlation (r= .87).

Levels of Cl in petioles correlate well with Cl found in tubers throughout the season (Figures 11-14). The r-squared values were .82 for June tubers and petioles, .73 for July tubers and petioles, .88 for harvest peels and August petioles, and .83 for harvest centers and August petioles.

Nutrient Levels in Tubers

Tuber Cl levels are shown in Table 20. Chloride values for the K check and K_2SO_4 treatments were the same. The 83 lb K/A, KCl treatment had significantly higher Cl than the check and K_2SO_4 (83 lb K/A) treatments yet lower (.01 level) than the 249 and 581 lb K/A, KCl treatments. Tuber Cl levels were higher in the 581 lb K/A, KCl treatments but differences were not as wide as in the petioles.

Tuber K, Ca, and Mg levels for the June 28 and July 19 sampling dates are shown in Table 21. The K treated plots showed slight increases in K concentration compared to the check . There was little difference in the levels of Ca or Mg.

The harvest tubers showed differences in K between treatments and between tuber parts (Tables 22 and 23). The peel, stem end, bud end, center with internal disorder (hollow heart and brown center), and center with no disorder were all significantly different from each other. The most interesting differences in K are the difference between the bud and stem end (1.65 vs 1.20) and that between centers with internal disorder (ID) and centers from tubers without any disorder (1.54 vs 1.80).

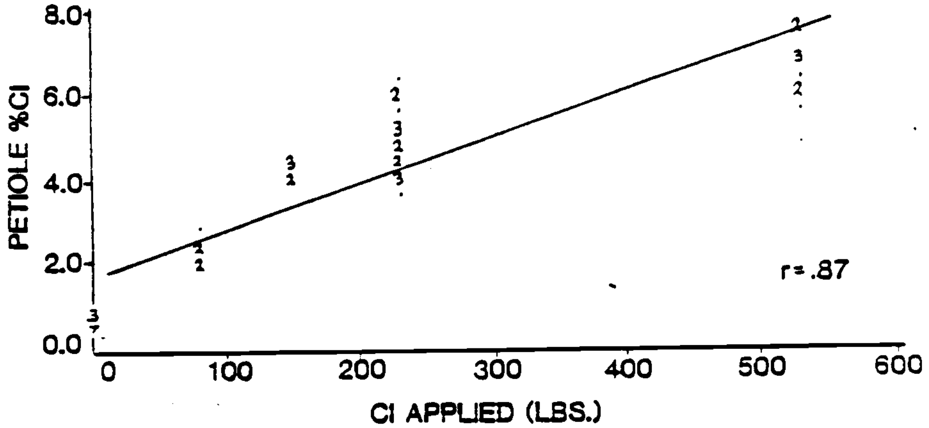

Figure 10: Relationship between Cl applied to Cl in petioles on August 16, 1983. McDevitt.

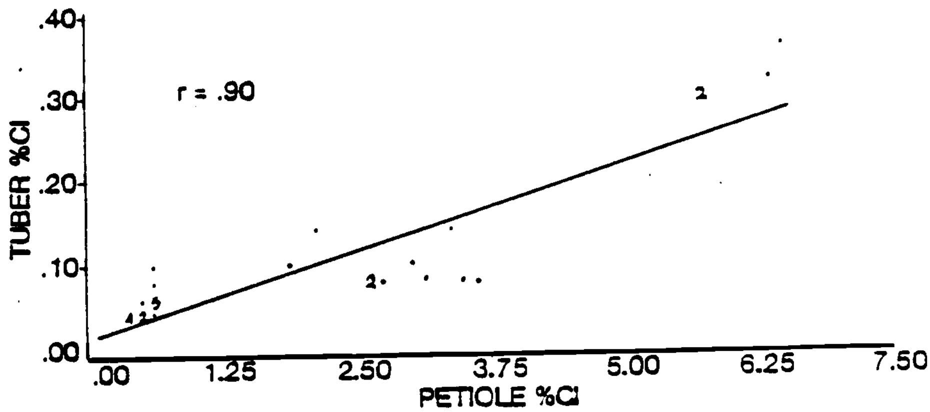

Figure 11: Relationship between petiole Cl and tuber Cl. June 28, 1983. McDevitt

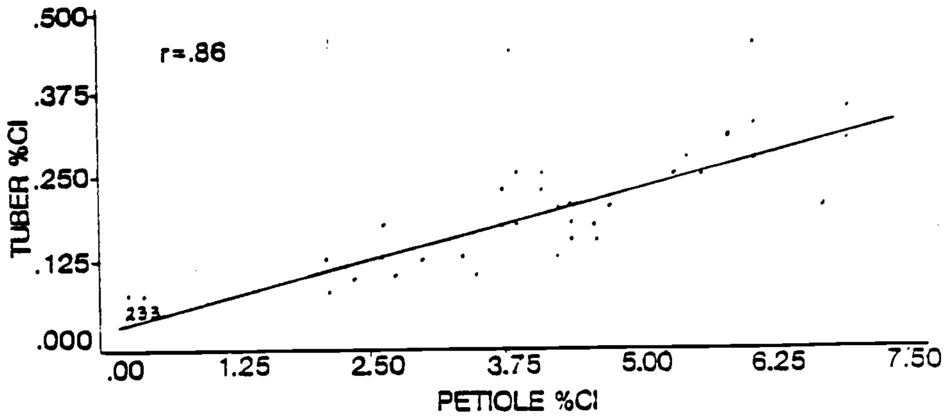

Figure 12: Relationship between petiole Cl and tuber Cl. July 19, 1983. McDevitt

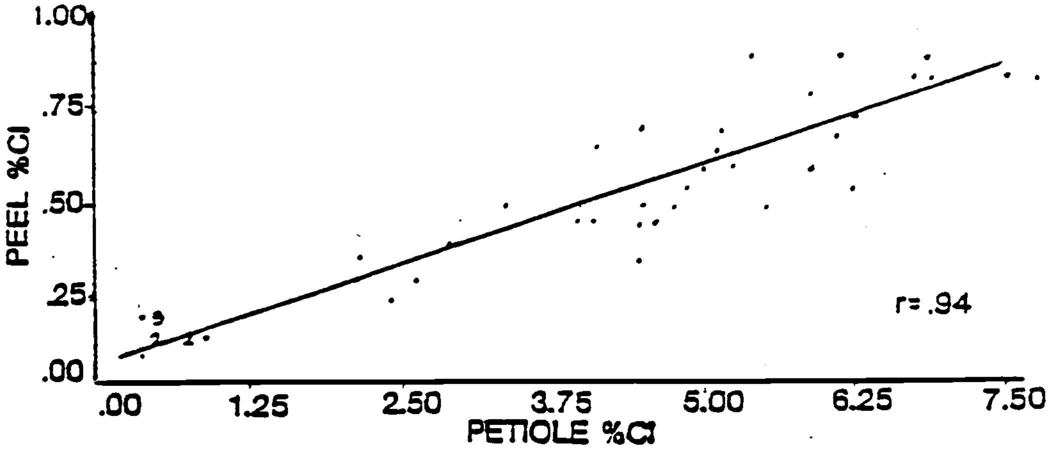

Figure 13: Relationship between petiole Cl on August 16 and tuber peel Cl at harvest. McDevitt, 1983.

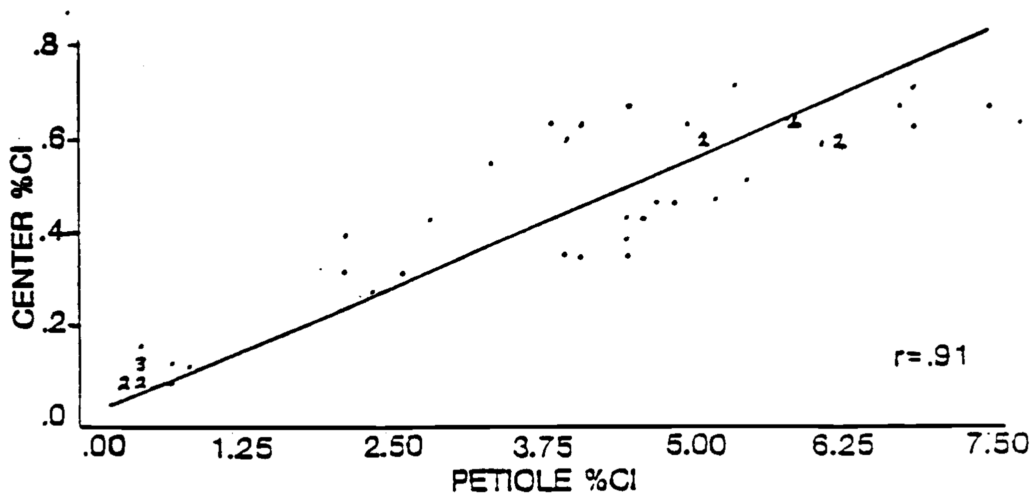

Figure 14: Relationship between petiole Cl on August 16 and tuber center Cl at harvest. McDevitt, 1983.

Table 20: Potash and Cl effects on Cl levels in whole tubers on June and July sampling dates and in bud and stem ends of tubers at harvest. McDevitt, 1983.

K Treatment					Cl concentration			
Date of appl				Cl	Whole tuber		Center	Peel
20/4	28/6	19/7	Source	Applied	28/6	19/7	harvest	harvest
---- lb/A ----					------------- % -----------			
0	0	0	None	0	.06	.07	.04	.03
83	0	0	KCl	80	.21	.17	.10	.12
249	0	0	KCl	240	.41	.32	.23	.35
249	0	0	K_2SO_4	0	.06	.08	.04	.04
83	498	0	KCl	80/480	.33	.37	.25	.29
83	249	249	KCl	80/240/240	.38	.33	.22	.34
			P value		.0000	.0000	.0000	.0000
			LSD .01		.06	.08	.07	.12
			LSD .05		.04	.06	.05	.09
			LSD .10		.04	.05	.04	.08

Table 21: Potash rate and source effects on tuber K, Ca, and Mg concentrations. June 28 and July 19 sampling dates. McDevitt, 1983.

K Treatment				Nutrient concentrations					
				Sampling date					
Date of appl				28June			19July		
20/4	28/6	19/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----				%					
0	0	0	None	2.5	.05	.10	2.0	.04	.10
83	0	0	KCl	2.6	.06	.10	1.9	.04	.09
83	0	0	K_2SO_4	2.4	.06	.10			
249	0	0	KCl	2.8	.06	.10	2.1	.04	.09
249	0	0	K_2SO_4	2.6	.06	.10	2.1	.04	.10
83	498		KCl				2.2	.05	.10
83	249	249	KCl				2.3	.05	.10

Table 22: Potassium, Ca, and Mg concentrations in different tuber parts at harvest. McDevitt, 1983. Averaged from all K treatments.

Tuber Part	K	Ca	Mg
	%		
Peel	3.10	.178	.147
Stem end	1.20	.042	.074
Bud end	1.65	.044	.084
Center ID	1.54	.027	.095
Center no ID	1.80	.028	.092
P value	.0000	.0000	.0000
LSD .05	.13	.005	.008
LSD .10	.11	.004	.007

Table 23: Potash rate and source effects on K, Ca, and Mg concentrations in tuber parts. McDevitt, Harvest, 1983.

K Treatment				Tuber Part					
Date of appl					Stem	Bud	Center	Center	Center
20/4	28/6	19/7	Source	Peel	End	End	ID	no ID	no ID-ID
---- lb/A ----				K conc.(%)					
0	0	0	None	2.76	0.90	1.46	1.38	1.50	.12
83	0	0	KCl	2.88	1.08	1.54	1.26	1.62	.36
249	0	0	KCl	3.18	1.18	1.62	1.74	2.10	.36
249	0	0	K_2SO_4	2.98	1.26	1.62	1.56	1.60	.04
83	498		KCl	3.32	1.42	1.84	1.52	1.98	.46
83	249	249	KCl	3.46	1.36	1.86	1.78	1.98	.20
			P value	.001	.012	.004	.021	.000	
			LSD .05	.30	.25	.21	.32	.22	.25
			LSD .10	.25	.21	.17	.27	.18	.21
				Ca conc.(%)					
0	0	0	None	.150	.026	.032	.020	.020	
83	0	0	KCl	.146	.034	.032	.016	.020	
249	0	0	KCl	.174	.036	.040	.024	.030	
249	0	0	K_2SO_4	.154	.038	.038	.020	.022	
83	498		KCl	.188	.048	.050	.038	.030	
83	249	249	KCl	.234	.068	.066	.044	.032	
			P value	.000	.002	.000	.006	.586	
			LSD .05	.029	.017	.014	.014	---	
			LSD .10	.024	.014	.012	.012	---	
				Mg conc.(%)					
0	0	0	None	.144	.074	.088	.104	.092	
83	0	0	KCl	.150	.078	.092	.098	.098	
249	0	0	KCl	.158	.086	.098	.100	.100	
249	0	0	K_2SO_4	.150	.078	.092	.100	.100	
83	498		KCl	.178	.090	.092	.106	.106	
83	249	249	KCl	.190	.096	.108	.102	.098	
			P value	.14	.52	.68	.98	.92	
			LSD .05	.034	---	---	---	---	
			LSD .10	.028	---	---	---	---	

ID = internal disorder, hollow heart and/or brown center

In the stem end samples (Table 23), K concentration was significantly lower in the check treatment than in all treatments that received 249 lb K/A or more. In the bud end samples, treatments with 249 lb K/A were higher than treatments with 0 and 83 lb K/A but they were not significantly different even at the .10 level. Treatments with 581 lb K/A, however, were significantly (.05) higher in K than all the other treatments.

Potassium levels in the center ID samples do not show any clear trend; 249 and 83+249+249 lb K/A, KCl treatments were significantly higher than the K check (1.74 and 1.78 vs 1.38) while 249 lb K/A, K_2SO_4 (1.56) and 83+498 lb K/A, KCl (1.52) treatments were not. In the samples from centers without any disorder, the check, 83 lb K/A, KCl, and 249 lb K/A, K_2SO_4 treatments were significantly lower in K than the 249, 83+498, and 83+249+249 lb K/A, KCl treatments (1.50, 1.60, 1.60 vs 2.10, 1.98, 1.98, respectively.) (K check and K_2SO_4 treatments were highest in hollow heart).

While tuber parts center ID and center without ID are significantly different for all treatments combined, this is not the case for all the treatments taken individually. Table 23 shows the differences between center ID and center without ID for each treatment. Using a tuber part X treatment LSD (.05= .25, .10=.21), centers with and without ID in treatments with 0 and 249 lb K/A, K_2SO_4 were not significantly different in K. Treatments with 83, 249, and, 83+498 lb K/A, as KCl had significantly (.05) different K concentrations in the centers and the 83+249+249 lb K/A, KCl treatment approached significant (.10) center K differences.

In tuber peels, the 249, 83+498, and 83+249+249 lb K/A, KCl treatments were significantly higher (.05) in K than the check and 83 lb K/A, KCl treatments. The 249 lb K/A, K_2SO_4 treatment was intermediate in K, between the check treatment and 249 lb K/A, KCl treatment.

Calcium in the peel was significantly (.05) higher than in all the other tuber parts (Table 22). Stem and bud end Ca (.042 and .044), while not different from each other, were significantly higher than centers with ID and centers without ID (.027 and .028). Tuber part X treatment effects are shown in Table 23. Increased levels of

Ca are found in all tuber parts as K levels are increased with KCl treatments.

Magnesium levels in harvest tubers did not, in most cases, vary widely in response to treatment. This is reflected in the high P values in Table 23. The overall effect of treatment showed a higher level of Mg in the high K rates (581 lb K/A) than in the treatments with lower K rates.

Different levels of Mg were found in the various tuber parts (Table 22). The peel was significantly higher in Mg than the other tuber parts. This was true for K and Ca. Both centers with ID and centers without ID were higher (.05 level) in Mg than the stem and bud ends. The bud end of the tuber had significantly more Mg than the stem end.

The levels of tuber nutrients K, Ca, Mg, and Cl were converted to milliequivalents (meq/100g dw) to better evaluate their relative effect on total salts in the tuber. Table 24 shows these nutrients in meq/100g as well as totals for K, Ca, and Mg and for K, Ca, Mg, and Cl for the July 19 sampling date. As expected, the high K and Cl rates (581 lb K/A, as KCl) have higher total meq of cations. The differences in meq between treatments is even clearer from the samples taken at harvest (which were analysed by tuber parts). Table 24 shows the meq values for the tuber centers (as well as those of the average of all the tuber parts). The totals are higher for the 249, 83+498, and 83+249+249 lb K/A, KCl treatments and lower for for check, 249 lb K/A, K_2SO_4, and 83 lb K/A, KCl treatments. (The K check and K_2SO_4 treatments had higher amounts of hollow heart and brown center.)

Table 24: Potash rate and source effects on tuber K, Ca, Mg, and Cl concentration in meq/100g. McDevitt, 1983.

K Treatment				Nutrient Concentrations					
Date of appl									
20/4	28/6	19/7	Source	K	Ca	Mg	Cl	K+Ca+Mg	K+Ca+Mg+Cl
--- lb/A ---				meq/100g dw					
				- - - -Whole tuber, 19 July, 1983- - - - -					
0	0	0	None	51.2	2.0	8.2	1.4	61.4	62.8
83	0	0	KCl	48.6	2.0	7.4	3.4	58.0	61.4
249	0	0	KCl	53.7	2.0	7.4	6.5	63.1	69.6
249	0	0	K_2SO_4	53.7	2.0	8.2	1.4	65.3	66.7
83	498	0	KCl	56.3	2.5	8.2	8.7	67.0	75.7
83	249	249	KCl	58.8	2.5	8.2	7.9	69.5	77.4
				- - - - - - - Tuber center, harvest- - - - -					
0	0	0	None	38.4	1.0	7.6	2.8	47.0	49.8
83	0	0	KCl	41.4	1.0	8.1	9.6	50.5	60.1
249	0	0	KCl	53.7	1.5	8.2	17.8	63.4	81.2
249	0	0	K_2SO_4	40.9	1.0	8.2	3.1	50.1	53.2
83	498	0	KCl	50.6	1.5	8.7	18.9	60.8	79.7
83	249	249	KCl	50.6	1.5	8.1	18.6	60.2	78.8
				- -Tuber average (of all parts), harvest- -					
0	0	0	None	40.9	2.5	7.4	2.8	50.8	53.6
83	0	0	KCl	43.0	2.5	7.7	9.6	53.2	62.8
249	0	0	KCl	50.1	3.0	7.6	17.8	60.8	78.6
249	0	0	K_2SO_4	46.3	2.5	7.2	3.1	56.0	59.1
83	498	0	KCl	51.7	3.4	9.4	18.9	64.6	83.5
83	249	249	KCl	53.4	4.4	9.8	18.6	67.6	86.2

Levy Experiment

Yield and Hollow Heart

The effect of fertilizer treatments on yield, grade, size, and % hollow heart are given in Tables 25 and 26. Variability in yield and grade within treatments was high on this location.

Application of potash did not increase yield nor decrease hollow heart or brown center on this location. The K check treatment plots produced some of the highest total yields and yield of 6+ oz tubers. Also, the check treatment had the lowest % hollow heart and brown center. Soil samples taken at the site before the experiment was established showed 325 ppm K while soil K levels at the Powell Butte and McDevitt sites were 130 and 211 ppm K, respectively. There was a residual level of 160 lb of Cl/A in the surface 2 ft of soil; in contrast, the McDevitt location had about 60 lb of Cl/A for a comparable depth. Response from K and Cl, with the high soil analysis values for K and Cl, were not comparable to the other two locations.

There was a high degree of variability in yields on the Levy field. The field had a calcareous layer at about a 24 inch depth. In some areas of the field and in the experimental plots this layer was closer to the surface and undoubtedly caused some stress to plants in these areas. It is not known if the stress was due to Ca-induced P or Fe deficiency, although samples from this location had lower petiole P than the other two locations. High levels of Ca were found in the petioles. "Early dying" also contributed to plant stress in plants adjacent to the experiment and "early dying" may have affected plants already stressed in plots that were affected by the shallow calcareous layer. Because of these soil and disease stresses, conclusions about K response (or lack of) in this experiment cannot be made.

Petiole Nutrient Levels

Petiole K remained high throughout the season and actually rose slightly on the August sampling date (Tables 27 and 28). The check treatment petiole K level (10.4%) was essentially the same as for the K treatments. Petiole Ca was high (up to 2.8%) on July and August sampling dates (Table 28).

Table 25: Potash rate and source effects on potato yield and grade (size). Levy, 1983.

K Treatment				Yield		
Date of Appl						
6/4	28/6	19/7	Source	Total	6+oz	<4oz
----	lb/A	----		----------	T/A	--------
0	0	0	None	29.4	14.2	7.9
83	0	0	KCl	28.6	12.5	8.3
249	0	0	KCl	26.8	10.8	8.5
249	0	0	K_2SO_4	27.6	12.3	7.5
83	498		KCl	29.3	14.5	7.7
83	249	249	KCl	27.3	10.5	8.0
83	83	83	KCl	28.9	12.9	8.0
83	83	83	KCl	27.6	13.8	6.8
83	83	83	K_2SO_4 KCl,KCl	29.7	13.7	7.3
			P value	.77	.08	.79
			LSD .05	---	---	---

Table 26: Potash rate and source effects on hollow heart and brown center. Levy, 1983.

K Treatment				In twenty largest		In forty largest	
Date of appl							
6/4	28/6	19/7	Source	HH	HH+BC	HH	HH+BC
----	lb/A	----		----------	%	--------	
0	0	0	None	2	5	1.5	3.0
83	0	0	KCl	1	15	3.0	12.0
249	0	0	KCl	1	10	2.0	7.0
249	0	0	K_2SO_4	1	8	2.5	7.0
83	498		KCl	0	13	4.5	12.0
83	249	249	KCl	2	15	5.0	13.0
83	83	83	KCl	1	11	2.0	8.5
*83	83	83	KCl	2	12	3.0	9.0
83	83	83	K_2SO_4 KCl,KCl	2	12	3.0	9.0
			P value	.88	.39	.76	.07
			LSD .05	---	---	---	6.5
			LSD .10	---	---	---	5.4

*Treatment received 40 lb N/A as ammonium sulfate

Table 27: Potash effects on June petiole K, Ca, and Mg concentrations. Levy, 1983.

Treatment		June 15			June 28		
K	Source	K	Ca	Mg	K	Ca	Mg
lb/A				%			
0	None	12.2	1.24	.54	11.4	1.58	.58
83	KCl	12.3	1.25	.49	12.1	1.65	.56
249	KCl	13.0	1.25	.53	12.3	1.54	.50
249	K_2SO_4	12.3	1.22	.49	11.8	1.56	.54
83	K_2SO_4	12.4	1.23	.55	11.8	1.66	.61
P value		.77	.94	.003	.62	.24	.09
LSD .05		--	--	.045	--	--	.08
LSD .10		--	--	.037	--	--	.08

Table 28: Potash rate and source effects on July and August petiole K, Ca, and Mg concentrations. Levy, 1983.

K applied				July 19			August 16		
6/5	28/6	19/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----						%			
0	0	0	None	9.7	2.0	.94	10.4	2.2	.99
83	0	0	KCl	9.8	2.1	.87	10.2	2.4	.96
249	0	0	KCl	11.0	1.9	.79	10.6	2.2	.87
249	0	0	K_2SO_4	10.2	1.9	.82	10.6	2.4	.97
83	498	0	KCl	11.1	2.1	.83	11.3	2.4	.89
83	249	249	KCl	10.4	2.1	.89	10.6	2.8	.94

Petiole and tuber Cl levels are shown in Table 29. The K check and K_2SO_4 (249 lb K/A) treatments both had substantial amounts of Cl in both petioles and tubers (up to 2.4 and 2.6% in petioles and .25 and .29% in tuber centers).

Tuber Nutrient Levels

Tuber K, Ca, and Mg levels are shown in Tables 30 and 31. The 83 lb K/A, KCl treatment had high levels of K in tubers (average of stem end, bud end, and center) and in the tuber center alone. In the tuber center the check treatment had K levels (1.48%) comparable to the 249 lb K/A treatments but were exceeded by the 83 lb K/A and the 581 lb K/A treatments (1.70%). Potassium levels were highest in the tuber center, followed by the bud end, and then the stem end. Calcium was lowest in the center while Mg levels were highest in the centers.

Table 29: Potash and Cl effects on Cl levels in petioles and tubers. Levy, 1983.

K Treatment				Cl concentration				
Date of appl				Petiole				Tuber
				Sampling date				Center
20/4	28/6	19/7	Source	15/6	28/6	19/7	16/8	harvest
---- lb/A ----				%				
0	0	0	None	1.9	2.4	2.1	2.3	.252
83	0	0	KCl	3.0	3.6	3.2	2.6	
249	0	0	KCl	4.6	4.9	4.4	3.3	.464
249	0	0	K_2SO_4	1.8	2.6	2.4	2.2	.292
83	498	0	KCl	3.0	3.6	5.8	4.5	
83	249	249	KCl	3.0	3.6	5.4	5.4	

Table 30: Potash treatment effects on tuber K, Ca, and Mg concentrations at harvest. Levy, 1983.

K applied				Tuber average			Tuber center		
6/5	28/6	19/7	Source	K	Ca	Mg	K	Ca	Mg
---- lb/A ----				%					
0	0	0	None	1.19	.048	.087	1.48	.036	.096
83	0	0	KCl	1.50	.045	.087	1.78	.036	.096
249	0	0	KCl	1.34	.050	.084	1.50	.030	.090
249	0	0	K_2SO_4	1.29	.047	.087	1.44	.040	.098
83	498	0	KCl	1.55	.059	.087	1.70	.042	.092
83	249	249	KCl	1.46	.065	.086	1.58	.040	.088
P value				.05	.12	.62	.45	.15	.20
LSD .05				.22	--	--	--	--	--
LSD .10				.18	--	--	--	--	--

Table 31: Tuber Part K, Ca, and Mg at harvest. Levy Farm, 1983.

Tuber Part	K	Ca	Mg
	%		
Stem End	1.06	.057	.079
Bud End	1.50	.060	.085
Center	1.60	.038	.092
P value	.0000	.0000	.0000
LSD .05	.08		
LSD .10	.06		

DISCUSSION

McDevitt and Powell Butte Experiments

Yield, Hollow Heart, and Nutrients

The total yields produced in the Columbia Basin experiments, 34-35 T/A at the McDevitt farm (and 27-29 T/A at the Levy farm), compared well with reported yields in the region (Rizzio et al., 1983; Kunkel,1969). The 6+ oz tuber yields produced at the McDevitt farm (from 20.8 T/A for the K check treatment up to 26.4 T/A) were quite high for potatoes following alfalfa but with four previous potato crops. Potassium treatments at high rates (581 lb K/A) increased the yield of 6+ oz tubers in this experiment. The maximum yields in the Powell Butte experiment, 25.6 T/A total yield and 12.6 T/A 6+oz tubers, were very good for Central Oregon region with its shorter growing season. There was a yield response to all K fertilizer treatments, even with the low (83 lb K/A) K treatments. In contrast, yield increases with low K rates were not found at the McDevitt experiment. This difference was probably due to differences in residual soil K at the two sites, 211 ppm K at McDevitt and only 130 ppm K at Powell Butte.

Hollow heart and brown center were reduced with K fertilization in the McDevitt experiment and by K and N fertilization in the Powell Butte experiment. At both sites KCl reduced hollow heart more than K_2SO_4. The reduction of hollow heart and brown center by K fertilization has been reported in the literature (Kallio,1960; Nelson,1970) and has been explained by a K influence on water uptake and retention and on carbohydrate mobilization and phloem transport. The mechanism for this reduction, however, has not been described. The greater reduction of the disorder by KCl over K_2SO_4 has not been previously reported and explained. It may be hypothesized that KCl (more than K_2SO_4) reduced the osmotic potential in the upper plant and tubers and thus reduced the impact of water deficits. In support of this idea, comparisons of petiole and tuber nutrient levels from the two experiments show higher K, Ca, and Cl in KCl treatment petioles over K_2SO_4 and check treatments and higher K and Cl in tuber centers and stem ends. Nitrate-N was higher in K_2SO_4 and check treatment petioles. It has been reported that inorganic ions are often important contributors to osmotic potential (Jones et al.,1980). When these nutrient levels are converted (see Appendix for calculations) to osmotic potential using the Van't Hoff relation (Nobel,1974) the following partial osmotic potentials (π) are found:

Treatment		π Petiole		π Tuber
K	Source	K,Cl,NO_3	K,Cl	K,Cl
lb/A			bars	
0	None	-10.2	-3.9	-2.1
83	KCl	-12.5	-8.2	-2.6
83	K_2SO_4	-10.0	-4.9	-2.1
249	KCl	-15.5	-12.5	-3.2
249	K_2SO_4	-12.4	-7.5	-2.4

The calculated petiole (partial) osmotic potential due to K, Cl, and NO_3 in the KCl treatments is lower than in the K_2SO_4 treatment. Osmotic potentials in the roots of the KCl plant would be expected to also be lower than in the K_2SO_4 plant. It would be predicted that water would be more readily removed from soil by the KCl plant, with lower root osmotic potential, than by the K_2SO_4 plant.

Assuming that KCl fertilized plants have higher water contents in the upper plant as well as in the tubers, and that the leaves have higher turgor, the following could be predicted. The KCl plant could remain turgid at lower soil water potentials than a K_2SO_4 plant. The rate of photosynthesis would be greater allowing for more photosynthate and water translocation in the phloem to the tuber. In this way soluble sugars might also be higher, without converting starch reserves, and significantly reduce the osmotic potential. Implications of this in regard to hollow heart are: 1) if the potato plant is water stressed, starches in the tuber may have to be converted to sugar to lower water potential, possibly initiating hollow heart and, 2) if the plant is water stressed and photosynthesis is reduced, minerals and carbohydrates may be reabsorbed from the tuber and translocated to the upper plant, also possibly initiating hollow heart. In order to obtain better foundations for these ideas, certain measurements need to be made: 1) osmometer readings--to obtain total leaf osmotic potential and total tuber osmotic potential, 2) leaf pressure bomb--to obtain total leaf water potential, and 3) psychrometer--to obtain total tuber water potential.

In both experiments, differences in tuber center (and stem end) K and Cl levels were found between KCl and K_2SO_4 (at the 249 lb K/A rate) (and check) treatments. They may result not only in different osmotic potentials but also in differences in K-mediated starch conversion and mobilization that could affect the initiation of the disorder. This is an area of potato physiology that needs more study. Levels of Ca in tubers were not significantly different due to treatment and no relationship between tuber Ca and hollow heart was found (as reported by Poovaiah et al., 1983). Any difference in K + Mg : Ca ratios were due mainly to differences in K levels.

In the Powell Butte experiment, applications of high N at mid-season resulted in higher levels of hollow heart and brown center. These results agree with those reported in the literature (Kallio,1960; Nelson,1970). The increases in hollow heart and brown center due to N nutrition are probably due to excessive vine growth during rapid tuber growth causing a temporary nutritional deficiency which initiated the development of the disorder (Krantz and Lana,1942).

In the McDevitt and Powell Butte experiments, KCl fertilizers reduced the levels of petiole NO_3-N due to the Cl-NO_3 uptake competition (Lundegardh,1959; De Wit et al.,1963; Murarka et al.,1973, Saffigna and Keeney,1977) without reducing yields. These results provide more evidence for the need to monitor petiole Cl along with NO_3-N when considering crop N-fertilizer need. Mid-season N-fertilizer applications, which may induce hollow heart, may be found to be unneeded or to be required at a lower rate.

In both experiments, high KCl treatments reduced the specific gravities of the tubers without affecting the processing quality. The reduction of specific gravity was due to increased water content and was not caused by any affect on the starch:sugar ratio which would have resulted in discoloration in the fry test.

CONCLUSIONS

Potash fertilization increased yields over a range of soil K. Yields were increased with all rates of K in the Powell Butte experiment, with soil K of 130 ppm, but only high rates of K increased yields in the McDevitt experiment, with 211 ppm K. Application of potash did not increase yield nor decrease hollow heart or brown center at the Levy experiment where soil K and Cl (325 ppm K and 30 ppm Cl) were higher than at the other sites.

Hollow heart and brown center were reduced with potash fertilizers in Powell Butte and McDevitt experiments. Reductions were greater with KCl than K_2SO_4. In the Powell Butte experiment, applications of 120 lb N or more on July 7 (mid-season) resulted in higher incidence of hollow heart and brown center.

Potassium levels in petioles from check plots in the McDevitt experiment were above suggested critical levels and remained high throughout the season. In the McDevitt and Powell Butte experiments, potash fertilization increased petiole K with KCl treatments being more effective in increasing K concentrations than comparable rates of K_2SO_4. Petiole Ca levels were reduced in the K_2SO_4 treatments. Levels of total cations (K, Ca, Mg in meq/100g dw) were higher in petioles from KCl treatments than from comparable K_2SO_4 treatments.

Potash fertilization increased K levels in tubers with Ca and Mg also being increased with high K rates. Competitive interactions between K and Ca or Mg were not found. Potassium source did not significantly affect Ca and Mg levels in tubers and there was no relationship between these nutrients and the incidence of hollow heart and brown center. Low K levels in tuber centers and stem ends were found in check and K_2SO_4 treatments, however, suggesting some relationship to the disorder.

Petiole Cl levels correlated well ($r=0.9$) with Cl applied. Low concentrations of NO_3-N were associated ($r= -.9$) with high Cl concentrations in petioles without reductions in yield. Concentrations of Cl in petioles correlated well ($r=0.9$) with Cl found in tubers throughout the season. Tubers from treatments receiving high KCl rates had lower specific gravities than tubers from check and low K treatments without affecting processing quality.

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APPENDICES

Appendix Table 1A: Potash rate and source effects on french fry quality (color test). Powell Butte,1983.

K Treatment								
Date of appl				Color rating*				
18/4	7/7	27/7	Source	0	1	2	3	4
---- lb/A ----				-------------- % -------------				
0	0	0	None	15.0	55.0	27.5	2.5	0
83	0	0	KCl	25.0	55.0	20.0	0	0
83	0	0	K_2SO_4	37.5	50.0	12.5	0	0
249	0	0	KCl	45.0	52.5	2.5	0	0
249	0	0	K_2SO_4	27.5	72.5	0	0	0
83	83	83	KCl	57.5	35.0	2.5	0	0
83	83	83	K_2SO_4 KCl,KCl	42.5	42.5	15.0	0	0
83	166	166	KCl	70.0	25.0	2.5	2.5	0
83	332	0	KCl	67.5	32.5	0	0	0
249	166	166	KCl	87.5	12.5	0	0	0

*Color ratings range from 0, representing light fry color, to 4, representing dark or brown fry color. Ratings of 0 and 1 are desirable, 2 is intermediate, and 3 and 4 are undesirable.

Appendix Table 1B: Nitrogen time and rate effects on french fry quality (color test). Powell Butte,1983.

N Treatment								
Date of appl			KCl	Color rating*				
18/5	7/7	27/7	Applied	0	1	2	3	4
---- lb/A ----			lb/A	-------------- % -------------				
0	60	0	249	47.5	45.0	7.5	0	0
60	0	0	249	42.5	57.5	0	0	0
0	120	0	249	45.0	52.5	2.5	0	0
120	0	0	249	35.0	55.0	10.0	0	0
0	60	60	249	57.5	42.5	0	0	0
0	120	120	249	60.0	40.0	0	0	0
0	240	0	249	62.5	32.5	0	0	0
240	0	0	249	72.5	22.5	5.0	0	0
0	120	0	0	15.0	55.0	27.5	2.5	0
120	0	0	0	22.5	40.0	37.5	0	0

*Color ratings range from 0, representing light fry color, to 4, representing dark or brown fry color. Ratings of 0 and 1 are desirable, 2 is intermediate, and 3 and 4 are undesirable.

Appendix Table 2: Potash rate and source effects on french fry quality (color test) McDevitt, 1983.

K Treatment				Color Rating[*]				
Date of appl								
20/4	28/6	19/7	Source	0	1	2	3	4
---- lb/A ----				%				
0	0	0	None	92	4	4	0	0
83	0	0	KCl	100	0	0	0	0
249	0	0	KCl	96	4	0	0	0
249	0	0	K_2SO_4	100	0	0	0	0
83	498		KCl	88	10	2	0	0
83	249	249	KCl	94	4	2	0	0
83	83	83	KCl	100	0	0	0	0
83	83	83	K_2SO_4 KCl	100	0	0	0	0

[*]Color ratings range from 0, representing light fry color, to 4, representing dark or brown fry color. Ratings of 0 and 1 are desirable, 2 is intermediate, and 3 and 4 are undesirable.

Appendix Table 3: Calculations and assumptions for estimating partial osmotic potential due to inorganic ions.

Van't Hoff relation: $\pi = icRT$ or $\pi = RT \; i_j c_j$

π = osmotic pressure

i = activity coefficient (assumed to be 1 however activities probably are of consequence)

c = concentration (moles/l used)

R = gas constant (.083141)

T = temperature (288 K = 15° C arbitrarily chosen)

Calculations of concentrations -- from % values

Petioles: %K (g/100g) / 100 = g K/g dry material

X .14 dry wt/wet weight = g K/g wet weight

wet weight is assumed to be $1 g/cm^3$ or ml

so X 1000 ml/l = g K/l / 39.1 g/mole K = moles K/l

Tubers: calculated the same way except that the ratio of dry weight to wet weight was assumed to be 0.2. A second ratio could be used for KCl in order to allow for less dry matter content. It was assumed that the NO_3 concentrations in tubers are too low to add to osmotic concentration.

Appendix Table 4: Potash effects on petiole NO_3-N and Cl concentrations. Powell Butte,1983.

K Treatment				Sampling date					
Date of appl				7/7		27/7		18/8	
18/5	7/7	27/7	Source	Cl	NO_3-N	Cl	NO_3-N	Cl	NO_3-N
---- lb/A ----				%					
0	0	0	None	0.6	2.8	0.4	2.6	0.9	2.7
83	0	0	KCl	4.2	2.3	3.0	1.7	4.0	1.6
83	0	0	K_2SO_4	0.6	2.9	0.3	2.1	0.6	2.3
249	0	0	KCl	6.7	2.3	5.6	1.3	7.2	1.0
249	0	0	K_2SO_4	0.6	3.0	0.4	2.0	0.6	1.5
83	83	83	KCl	4.2	2.3	4.6	1.3	6.3	1.1
83	83	83	K_2SO_4 KCl,KCl	0.6	2.9	2.1	2.0	4.7	1.6
83	166	166	KCl	4.2	2.3	5.3	1.5	8.0	1.2
83	332	0	KCl	4.2	2.3	6.4	1.4	7.2	1.1
249	166	166	KCl	6.7	2.3	7.3	1.2	8.9	1.0
			P value	.000	.000	.000	.000	.000	.000
			LSD .01	.90	.33	1.1	0.4	1.5	0.6
			LSD .05	.66	.24	0.8	0.3	1.1	0.4
			LSD .10	.55	.20	0.7	0.2	0.9	0.4

Appendix Table 5: Nitrogen time and rate effects on petiole NO_3-N and Cl concentrations. Powell Butte,1983.

N Treatment			KCl	Sampling date			
Date of appl				27/7		18/8	
18/5	7/7	27/7	Applied	Cl	NO_3-N	Cl	NO_3-N
---- lb/A ----			lb/A	%			
0	60	0	249	6.4	0.9	8.5	0.5
60	0	0	249	6.3	1.2	8.4	0.4
0	120	0	249	5.6	1.3	7.2	1.0
120	0	0	249	5.0	2.0	6.3	1.2
0	60	60	249	6.9	0.6	7.5	1.1
0	120	120	249	6.1	1.5	5.7	1.9
0	240	0	249	5.0	2.0	5.0	2.0
240	0	0	249	3.9	2.2	5.7	1.9
0	120	0	0	0.4	2.6	0.9	2.7
120	0	0	0	0.3	2.7	0.5	2.6
			P value	.000	.000	.000	.000
			LSD .01	1.1	0.4	1.5	0.6
			LSD .05	0.8	0.3	1.1	0.4
			LSD .10	0.7	0.2	0.9	0.4

Appendix Table 6: Nitrogen and Cl effects on specific gravity and Cl levels in whole tubers on July and August sampling dates and in bud and stem ends of tubers at harvest. Powell Butte, 1983.

N Treatment					Cl concentration			
Date of appl			KCl	Specific	Whole tuber		Bud end	Stem end
18/5	7/7	27/7	Applied	Gravity	27/7	18/8	harvest	harvest
---- lb/A ----					------------ % ------------			
0	60	0	249	1.0858	.44	.42	.27	.42
60	0	0	249	1.0839	.42	.33	.24	.37
0	120	0	249	1.0838	.41	.32	.23	.35
120	0	0	249	1.0824	.44	.34	.19	.29
0	60	60	249	1.0831	.48	.39	.24	.38
0	120	120	249	1.0834	.46	.41	.22	.32
0	240	0	249	1.0828	.40	.32	.18	.28
240	0	0	249	1.0819	.32	.26	.17	.24
0	120	0	249	1.0931	.06	.07	.04	.03
120	0	0	249	1.0910	.04	.05	.03	.02
			P value	.0000	.0000	.0000	.0000	.0000
			LSD .01		.09	.10	.07	.09
			LSD .05	.0044	.07	.07	.05	.07
			LSD .10	.0037	.06	.06	.04	.06

Appendix Table 7: Potash rate and source effects on petiole P, Zn, and Mn. Powell Butte, July 7, 1983.

Treatment			Concentrations		
N	K	Source	P	Zn	Mn
-- lb/A --			%	-- ppm --	
0	0	None	.325	38	55
0	83	KCl	.335	39	79
0	83	K_2SO_4	.290	42	60
0	249	KCl	.330	47	97
0	249	K_2SO_4	.295	46	70
60	249	KCl	.318	45	118
120	249	KCl	.348	44	119
240	249	KCl	.312	45	126
120	0	None	.310	39	80
		P value	.179	.167	.001
		LSD .05	---	---	29
		LSD .10	---	---	24

Appendix Table 8: Potash effects on petiole Zn, Mn, and P concentrations. Powell Butte, 1983.

K Treatment				Sampling date					
Date of appl				27July			18Aug		
18/5	7/7	27/7	Source	Zn	Mn	P	Zn	Mn	P
---- lb/A ----				-- ppm -		%	-- ppm -		%
0	0	0	None	23	63	.127	20	118	.113
83	0	0	KCl	22	83	.132	20	137	.117
83	0	0	K_2SO_4	25	67	.110	19	128	.102
249	0	0	KCl	27	112	.147	17	190	.114
249	0	0	K_2SO_4	32	91	.112	22	166	.100
83	83	83	KCl	30	111	.128	16	212	.122
83	83	83	K_2SO_4	24	67	.135	18	131	.121
			KCl,KCl						
83	166	166	KCl	25	100	.135	18	205	.111
83	332	0	KCl	33	133	.130	20	244	.130
249	166	166	KCl	30	125	.155	15	226	.133

Appendix Table 9: Nitrogen time and rate effects on petiole Zn, Mn, and P concentrations. Powell Butte, 1983.

N Treatment				Sampling date					
Date of appl			KCl	27July			18Aug		
18/5	7/7	27/7	Applied	Zn	Mn	P	Zn	Mn	P
---- lb/A ----			lb/A	-- ppm -		%	-- ppm -		%
0	60	0	249	27	130	.140	17	206	.114
60	0	0	249	33	186	.128	21	263	.102
0	120	0	249	27	112	.147	17	190	.114
120	0	0	249	29	175	.145	17	285	.117
0	60	60	249	26	128	.122	18	225	.111
0	120	120	249	24	138	.138	28	242	.112
0	240	0	249	28	120	.132	14	205	.139
240	0	0	249	31	187	.140	16	333	.119
0	120	0	0	23	63	.127	20	118	.113
120	0	0	0	23	103	.150	17	160	.124

Appendix Table 10: Nitrogen time and rate effects on petiole K, Ca, and Mg concentrations. Powell Butte, 1983.

N Treatment				Sampling date					
Date of appl			KCl	27July			18Aug		
18/5	7/7	27/7	Applied	K	Ca	Mg	K	Ca	Mg
----	lb/A	----	lb/A			%			
0	60	0	249	8.2	1.70	1.75	7.2	2.01	2.27
60	0	0	249	8.8	1.69	1.81	6.8	1.82	2.36
0	120	0	249	8.7	1.70	1.62	7.7	1.74	2.01
120	0	0	249	9.4	1.70	1.74	7.9	1.80	2.25
0	60	60	249	8.5	1.64	1.62	7.5	1.78	2.35
0	120	120	249	8.7	1.73	1.83	6.9	1.98	2.29
0	240	0	249	9.0	1.70	1.72	7.8	1.70	2.04
240	0	0	249	8.1	1.55	1.71	7.4	1.72	2.02
0	120	0	0	4.1	2.07	2.33	2.7	1.80	2.77
120	0	0	0	4.3	1.79	2.30	2.5	1.83	2.80
			P value	.000	.067	.000	.000	.360	.000
			LSD .05	1.4	0.30	0.30	1.6	---	0.32
			LSD .10	1.2	0.25	0.25	1.4	---	0.27

Appendix Table 11: Nitrogen time and rate effects on tuber K, Ca, Mg, and Cl concentrations. Powell Butte, July 27, 1983.

N Treatment				Nutrient Concentrations			
Date of appl			KCl				
18/5	7/7	27/7	Applied	K	Ca	Mg	Cl
---- lb/A ----			lb/A	----------- % ----------			
0	60	0	249	2.14	.058	.092	.44
60	0	0	249	2.20	.059	.093	.42
0	120	0	249	2.19	.051	.089	.41
120	0	0	249	2.42	.072	.100	.44
0	60	60	249	2.20	.063	.091	.48
0	120	120	249	2.04	.060	.089	.46
0	240	0	249	2.16	.066	.091	.40
240	0	0	249	2.15	.062	.094	.32
0	120	0	0	1.68	.046	.084	.06
120	0	0	0	1.70	.057	.087	.04
			P value	.000	.20	.13	.000
			LSD .05	.26	--	--	.07
			LSD .10	.22	--	--	.06

Appendix Table 12: Nitrogen time and rate effects on tuber K, Ca, Mg, and Cl concentrations. Powell Butte, August 18, 1983.

N Treatment				Nutrient Concentrations			
Date of appl			KCl				
18/5	7/7	27/7	Applied	K	Ca	Mg	Cl
---- lb/A ----			lb/A	----------- % ----------			
0	60	0	249	1.72	.035	.100	.42
60	0	0	249	1.72	.035	.095	.33
0	120	0	249	1.70	.040	.095	.32
120	0	0	249	1.98	.045	.105	.34
0	60	60	249	1.79	.035	.095	.39
0	120	120	249	1.88	.042	.105	.41
0	240	0	249	1.80	.038	.100	.32
240	0	0	249	1.72	.040	.090	.26
0	120	0	0	1.30	.042	.085	.07
120	0	0	0	1.26	.040	.090	.05
			P value	.000	.45	.21	.000
			LSD .05	.21	--	--	.07
			LSD .10	.17	--	--	.06

Appendix Table 13: Potash effects on tuber Zn, Mn, and P concentrations. Powell Butte, 1983.

K Treatment				Sampling date				
Date of appl				27July			18Aug	
18/5	7/7	27/7	Source	Zn	Mn	P	Zn	Mn
---- lb/A ----				-- ppm -		%	-- ppm -	
0	0	0	None	12	10	.20	12	10
83	0	0	KCl	13	12	.20	11	10
83	0	0	K_2SO_4	12	10	.19	12	10
249	0	0	KCl	12	10	.20	12	10
249	0	0	K_2SO_4	12	8	.20	12	10
83	83	83	KCl	14	13	.23	13	10
83	83	83	K_2SO_4 KCl,KCl	12	10	.20	14	11
83	166	166	KCl	13	13	.20	14	11
83	332	0	KCl	13	14	.22	14	12
249	166	166	KCl	14	12	.21	14	11

Appendix Table 14: Nitrogen time and rate effects on tuber Zn, Mn, and P concentrations. Powell Butte, 1983.

N Treatment				Sampling date				
Date of appl			KCl	27July			18Aug	
18/5	7/7	27/7	Applied	Zn	Mn	P	Zn	Mn
---- lb/A ----			lb/A	-- ppm -		%	-- ppm -	
0	60	0	249	15	12	.20	13	11
60	0	0	249	14	12	.21	14	11
0	120	0	249	13	10	.20	12	10
120	0	0	249	13	17	.24	14	13
0	60	60	249	15	13	.20	13	12
0	120	120	249	15	12	.19	15	12
0	240	0	249	13	12	.20	14	12
240	0	0	249	15	15	.22	14	14
0	120	0	0	12	10	.20	12	10
120	0	0	0	15	11	.21	12	11

Appendix Table 15: Potash effects on June petiole Zn, Mn, and P concentrations. McDevitt, 1983.

Treatment		Nutrient concentrations					
		Sampling date					
		15June			28June		
K	Source	Zn	Mn	P	Zn	Mn	P
lb/A				%			
0	None	66	104	.432	58	73	.341
83	KCl	69	135	.478	61	98	.422
249	KCl	82	169	.447	62	116	.415
249	K_2SO_4	69	140	.444	69	93	.327
83	K_2SO_4	65	116	.414	59	74	.342
	P value	.003	.114	.48	.508	.006	.016
	LSD .05	8	47	--	---	23	.064
	LSD .10	7	39	--	---	19	.053

Appendix Table 16: Potash rate and source effects on petiole Zn, Mn, and P concentrations. McDevitt, July and August, 1983.

K Treatment				Nutrient concentrations					
Date of appl				Sampling date					
				19July			16Aug		
20/4	28/6	19/7	Source	Zn	Mn	P	Zn	Mn	P
---- lb/A ----						%			
0	0	0	None	42	166	.142	38	209	.138
83	0	0	KCl	38	191	.156	33	214	.138
249	0	0	KCl	38	200	.168	37	276	.142
249	0	0	K_2SO_4	43	188	.144	34	243	.128
83	498		KCl	45	239	.152	42	366	.134
83	249	249	KCl	45	224	.156	48	429	.138
83	83	83	KCl	39	205	.162	45	336	.138
83	83	83	K_2SO_4 KCl	46	197	.156	38	292	.140
			P value	.059	.000	.282	.072	.000	.866
			LSD .05	7	24	---	10	83	---
			LSD .10	1.0	20	---	8	69	---

Appendix Table 17: Potash effects on June petiole Zn, Mn, and P concentrations. Levy, 1983.

Treatment		Nutrient concentrations					
		Sampling date					
		15June			28June		
K	Source	Zn	Mn	P	Zn	Mn	P
lb/A		----------------		%	----------------		
0	None	46	59	.431	30	69	.429
83	KCl	47	64	.398	34	64	.359
249	KCl	50	70	.394	29	70	.380
249	K_2SO_4	53	56	.390	31	60	.331
83	K_2SO_4	53	60	.440	29	63	.404
	P value	.558	.001	.152	.558	.000	.267
	LSD .05	---	19	---	---	15	---
	LSD .10	---	15	---	---	12	---

Appendix Table 18: Potash rate and source effects on petiole Zn, Mn, and P concentrations. Levy, July and August, 1983.

K Treatment				Nutrient concentrations					
Date of appl				Sampling date					
				19July			16Aug		
20/4	28/6	19/7	Source	Zn	Mn	P	Zn	Mn	P
---- lb/A ----				----------------		%	----------------		
0	0	0	None	22	117	.160	33	174	.178
83	0	0	KCl	22	121	.140	26	150	.162
249	0	0	KCl	23	140	.144	32	233	.173
249	0	0	K_2SO_4	23	118	.142	28	216	.154
83	498		KCl	25	139	.152	35	266	.174
83	249	249	KCl	24	137	.140	33	289	.170
83	83	83	KCl	20	159	.154	34	302	.159
83	83	83	K_2SO_4 KCl	20	133	.166	25	245	.187