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Investigation on Selected Minerals Content of Potato Tubers (*Solanum tuberosum* L.)
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*Penyelidikan dari Seleksi Isi Mineral Kentang (Solanum tuberosum L.)
dalam Penyimpanan Bersuhu 7°C yang Dipengaruhi oleh Aplikasi
Pemupukan Kalsium, Magnesium, dan Fosfat*

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Abstrak

Aplikasi pupuk kalsium mendapat perhatian khusus para petani kentang dan peneliti. Dalam penerapannya, untuk mengantisipasi interaksi antara kalsium dengan nutrisi tanaman lainnya yang mungkin menekan penyerapan kalsium, maka kalsium sering diaplikasikan secara bersama-sama dengan pupuk magnesium atau posfor, seperti juga yang diterapkan dalam penelitian ini. Diharapkan dengan pemberian kalsium dapat meningkatkan kandungan kalsium umbi kentang, yang pada gilirannya diharapkan dapat mempengaruhi kualitas umbi kentang selama penyimpanan. Hasil penelitian menunjukkan hingga konsentrasi pupuk yang diberikan tidak berdampak pada peningkatan beberapa mineral (kalsium, magnesium, posfor dan kalium) dalam umbi segar selepas panen. Selama penyimpanan terjadi mobilisasi mineral terutama dimulai pada periode penyimpanan 18 minggu, di mana dari segi fisiologisnya dormansi mulai terhenti dan memasuki proses pertunasan.

Kata kunci: *Solanum tuberosum*, pemupukan, kalsium, magnesium, fosfat, penyimpanan

Abstract

Recently, there is a growing interest on calcium application on potato crops especially among researches and the farmers. However, to anticipate the interaction of calcium with other nutrients, which may suppressed the effect of calcium, calcium was often applied together with other fertilizers, such as with magnesium and phosphorus as applied in this research. The goal of calcium application was to increase the calcium content of potato tubers and further would affect the tubers toward a better quality during storage. Up to level of given fertilizers, there was no increase of minerals contents of the fresh harvested tubers, i.e. calcium, magnesium, phosphorus, and potassium, have been found. Meanwhile, during 18 weeks of investigated storage there was no significant changes of minerals content, but after the 18-th week of storage the result showed a significant mobilization in accordance with the dormancy-breaking phase.

Keywords: *Solanum tuberosum*, fertilizer, calcium, magnesium, phosphorus, storage

Introduction

Potato (*Solanum tuberosum* L.) is an economical and healthy food crop containing high starch and substantial amounts of protein, ascorbic acid and minerals (McCay *et al.*, 1987). The biochemistry activity in tubers is reflected by the changes of substance present in tubers, which directly influenced the quality of tubers. A dynamic variation in dry matter occurred during storage time,

which included the minerals mobilization (Blenkinsop *et al.*, 2002).

Technologically, storage at low temperatures is one of methods normally used to retard the softening and sprouting process, and to maintained potato tuber quality (Burton, 1989). Slowing rate of respiration and substance decomposition are the main goals of the storage at 7°C. Considering the fact that increasing calcium level may reduce

ethylene evolution and reduce respiration rate (Ben-Arie *et al.*, 1995; Recasens *et al.*, 2004), it is expected to access the influence of the applied calcium-magnesium-phosphorus fertilizer on calcium level in tubers, and subsequently on decomposition rate in tubers.

Materials and Methods

Plant Material Treatments

Potato tubers cv. Saturna were grown under different combination of phosphorus-calcium-magnesium fertilizer at industrial field of Best Food – Unilever at Wittingen, Germany during trial in 2000 and 2001. The field plot was characterized as sandy loam. In 2000 and 2001, pre plant soil values were 5.90 and 5.97 pH, 13 and 16.6 mg/kg P, 10 and 12.1 mg/kg K, and 5.0 and 5.7 mg/kg Mg, respectively. Plant spacing, herbicides and fungicides were applied according to local practice.

As supplement to based nitrogen and potassium fertilizers (90 kg/ ha N - 120 kg/ ha K₂O), two rates of phosphorus fertilizer (80 and 160 kg/ha P₂O₅) in form of Superphosphate [Ca(H₂PO₄)₂] and two rates of calcium fertilizer (500 and 1500 kg/ha CaO) in form of Burn lime (CaO) were combined with two rates of magnesium fertilizer (25 and 75 kg/ha MgO) in form of Kieserite (MgSO₄.H₂O). Fertilizers were hand-applied on the surface of strips in a single application before planting time.

The experimental design were a randomised block with three replicates of eight treatments (T-1 to T-8) in 2000 and ten treatments (T-1 to T-10) in 2001, as had been performed for this study (Table 1).

Sample Preparation and Analysis

Two centre rows of each plot were harvested within each experiment and fresh

harvested tubers were used for sample preparation. Potato samples from each replication of treatments were kept in cold storage at 7 °C and 96% relative humidity throughout the experiment. The samples were then brought out of the cold storage after 6, 8, 12, 18, 24, and 32 weeks for sampling and analysis. About 30 tubers from each group were removed randomly from the cooler at every storage time.

The mineral elements calcium, magnesium, potassium, and phosphorus were determined by using AAS (Atomic Absorption Spectrometer), FES (Flame Emission Spectrometer) and Spectrophotometer, each element was analyzed with appropriate apparatus according to operation instruction of apparatus. To 0.4 g sample of known moisture content, which was weighed in the reaction vessel, 4 ml 65% nitric acid was added. Digestion process took place in oven, which was allowed to stand at 175 °C for 12 hours in order to remove the organic matter in the sample. The solution was collected by rinsing the digestion vessel, and made up to a 10 ml in volumetric flask. The flask was kept under cool temperature before using to measure the mineral element.

Data Analysis

Analytical determinations were conducted in duplicate. For statistical evaluation of results between treatments, a two-way analysis of variance (ANOVA) with fertilizer treatments as the main plots and storage as sub plots. Based on F values, treatment means were separate by Turkey's comparisons at 5% level. Statistical analysis was carried out with statistical software Sigma Stats, SPSS Inc, version 2.03.

Table 1: Calcium-magnesium-phosphorus treatments

Treatments	Fertilizer Rates		
	P ₂ O ₅ (kg/ha)	MgO (kg/ha)	CaO (kg/ha)
T-1	80	0	0
T-2	160	0	0
T-3	80	25	500
T-4	80	75	500
T-5	80	25	1500
T-6	80	75	1500
T-7	160	25	1500
T-8	160	75	500
T-9	0	0	0
T-10	0	75	0

Results and Discussions

Investigation on selected mineral nutrients demonstrated its involvement on tuber development during storage. Statistically, application of calcium, magnesium and phosphorus in form of fertilizer did influence tuber levels of calcium and magnesium during storage, as shown by the significant interaction between year, treatment and storage time. The result was not found for phosphorus and potassium content. Since there was inconsistency of the effect, detailed results on individual minerals are presented.

The level of calcium did change during 32 weeks of storage (Fig. 1). At 7 °C, the calcium content was remained stable during 8 weeks storage period at 15.65 mg/g dry weight, followed by markedly increase thereafter and decrease during the final stage of storage of 2000 experiment. A similar manner was found in the second years and the level remained in average of 12.20 mg/g until 8 weeks, followed with some variations between treatments thereafter, which occurred between 12–18 week, as shown by significant interaction between treatment and storage. In 12 weeks of storage, calcium level of T-2, T-3, T-3, and T-4 were different significantly from T-8. No difference had been found on level of calcium in tubers after 18 weeks of storage until 32 weeks of storage.

The calcium level in tubers of 2000 was higher than of 2001 (Fig. 1), however, the mobility of the calcium during storage was more remarkable in 2001 experiments, especially during 8-18 week of storage. Ross & Davies (1985) have investigated the importance of calcium during sprouting. In their experiment using nutrition solution, omitting the calcium from solution resulted in reduced calcium level in sprouting, and there was competition between the sprouting on calcium uptake. Suspecting whether calcium level in tuber of 2001 was lower enough to drive highly mobility of the calcium before and during sprouting due to competition of sprout, should be supported by number and sprout condition. Due to lack of consistency, it is suggested that differences among treatments during storage reflected the high difference in mobility of the calcium, which have started at 8 weeks of storage until 18 weeks, rather than as actual effect of treatment.

Averaging levels of magnesium level over all treatments, at harvest (0 week) and during storage, were not significant between the planting years. In tubers of 2000 (Fig. 2), the slightly decrease of magnesium was found during 8 weeks of early storage time, increased slightly until 12 weeks, decreased again before increased at the end of storage. This profile changed slightly in 2001, in which after 8 weeks the magnesium was increased until 24 weeks of storage and decreased there after. This might be due to

the difference in physiological properties at harvest, since all respective year profil echanges.

No significant difference in phosphorus level among the tubers from different treatments, at harvest and subsequently during storage was detected. Each treatments showed similar profiles of change, in which the phosphorus almost at

the same level, with a slightly but not significant dynamic of increase and decrease over 32 weeks of storage. As to magnesium and calcium, years had also significant effect on phosphorus. Phosphorus level of tubers of 2000 ranged between 43.37 and 44.63 g/100g (Fig. 3), but in the tubers of 2001 it ranged between 50.64 and 53.53 g/100g.

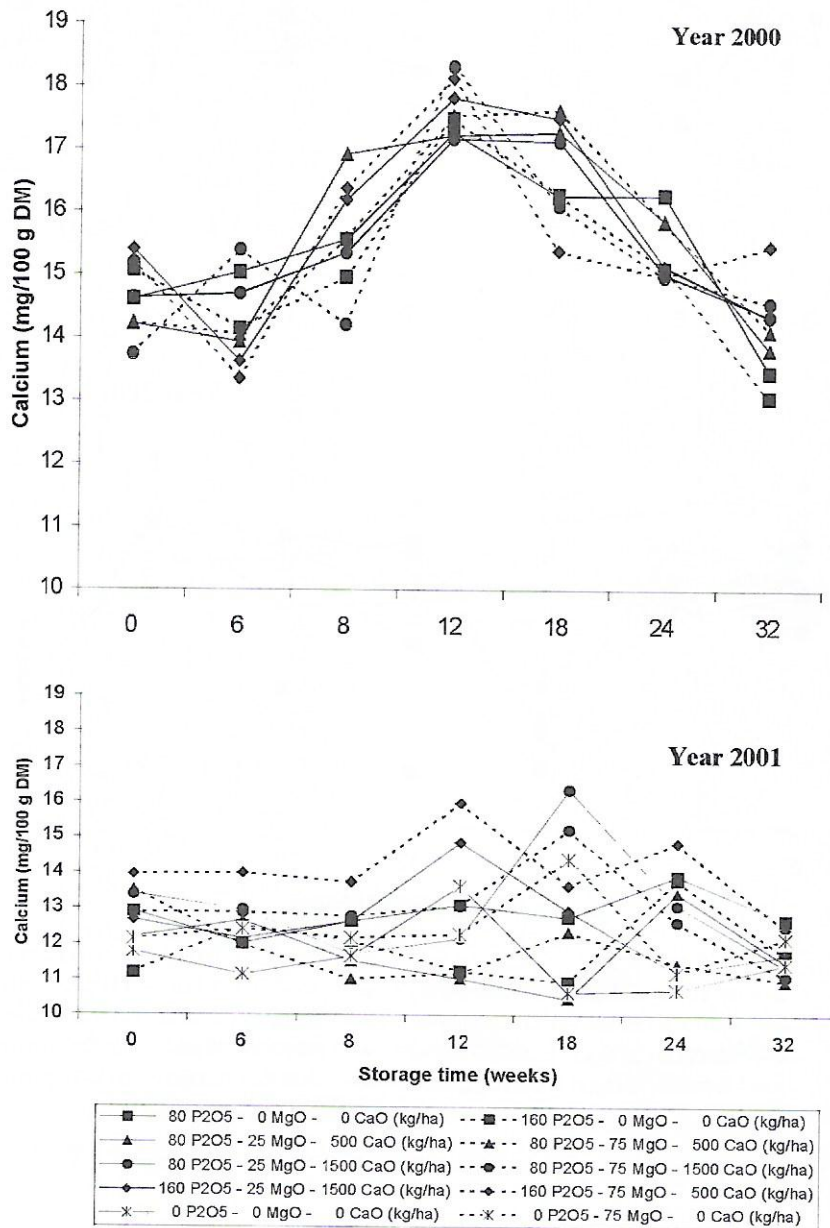


Figure 1. Calcium of potato tuber during 32 weeks of storage at 7°C

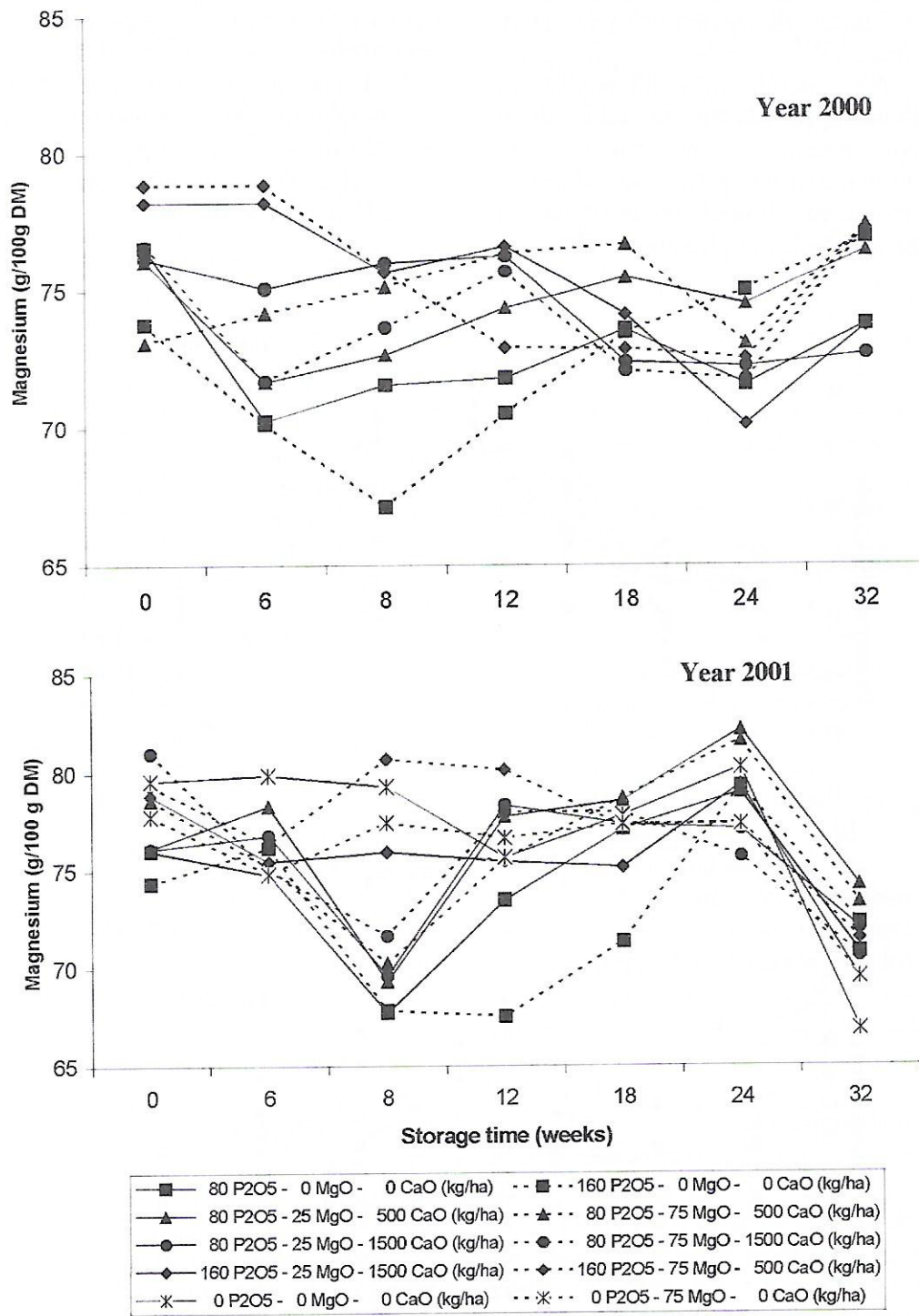


Figure 2. Magnesium of potato tuber during 32 weeks of storage at 7°C

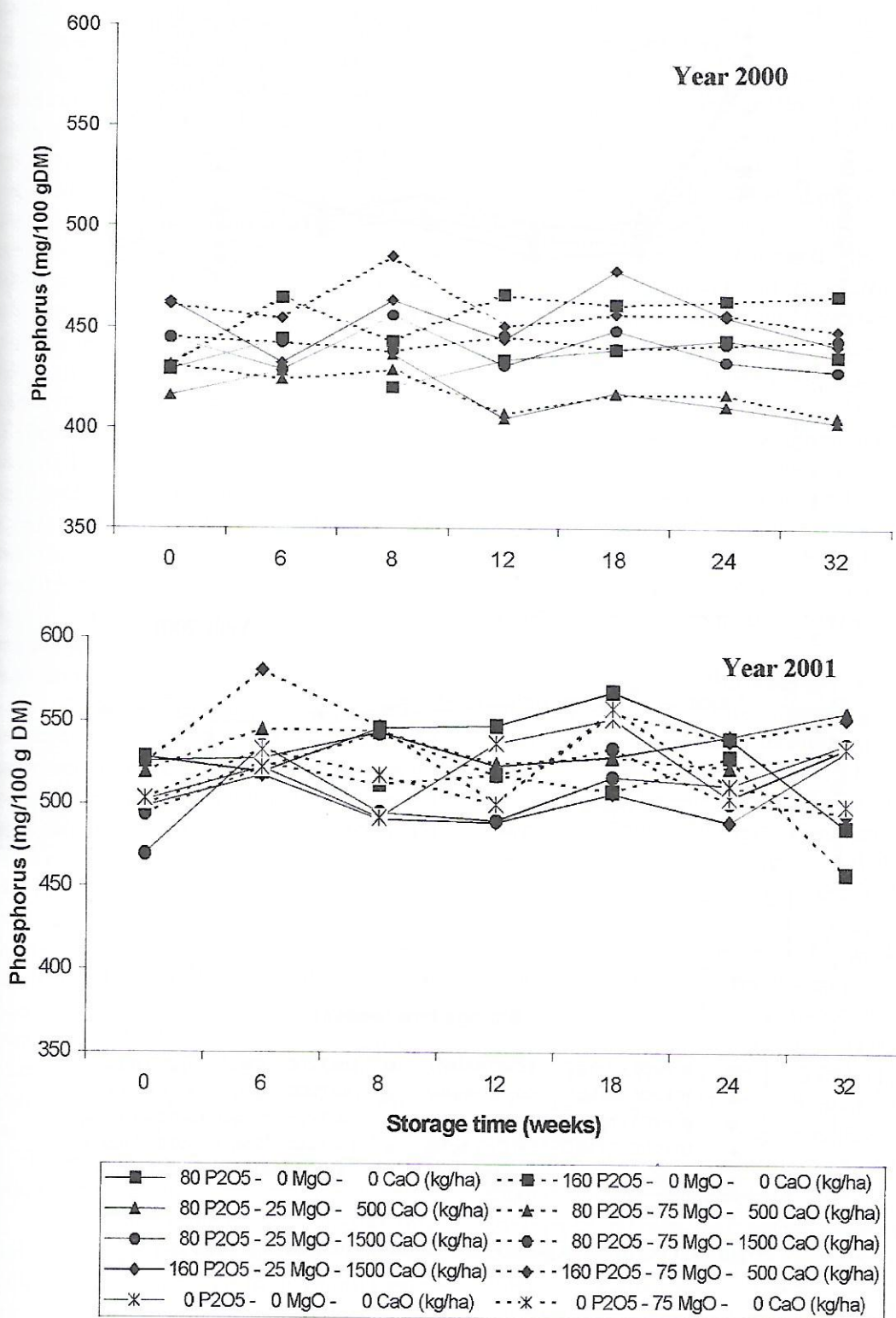


Figure 3. Phosphorus of potato tuber during 32 weeks of storage at 7°C

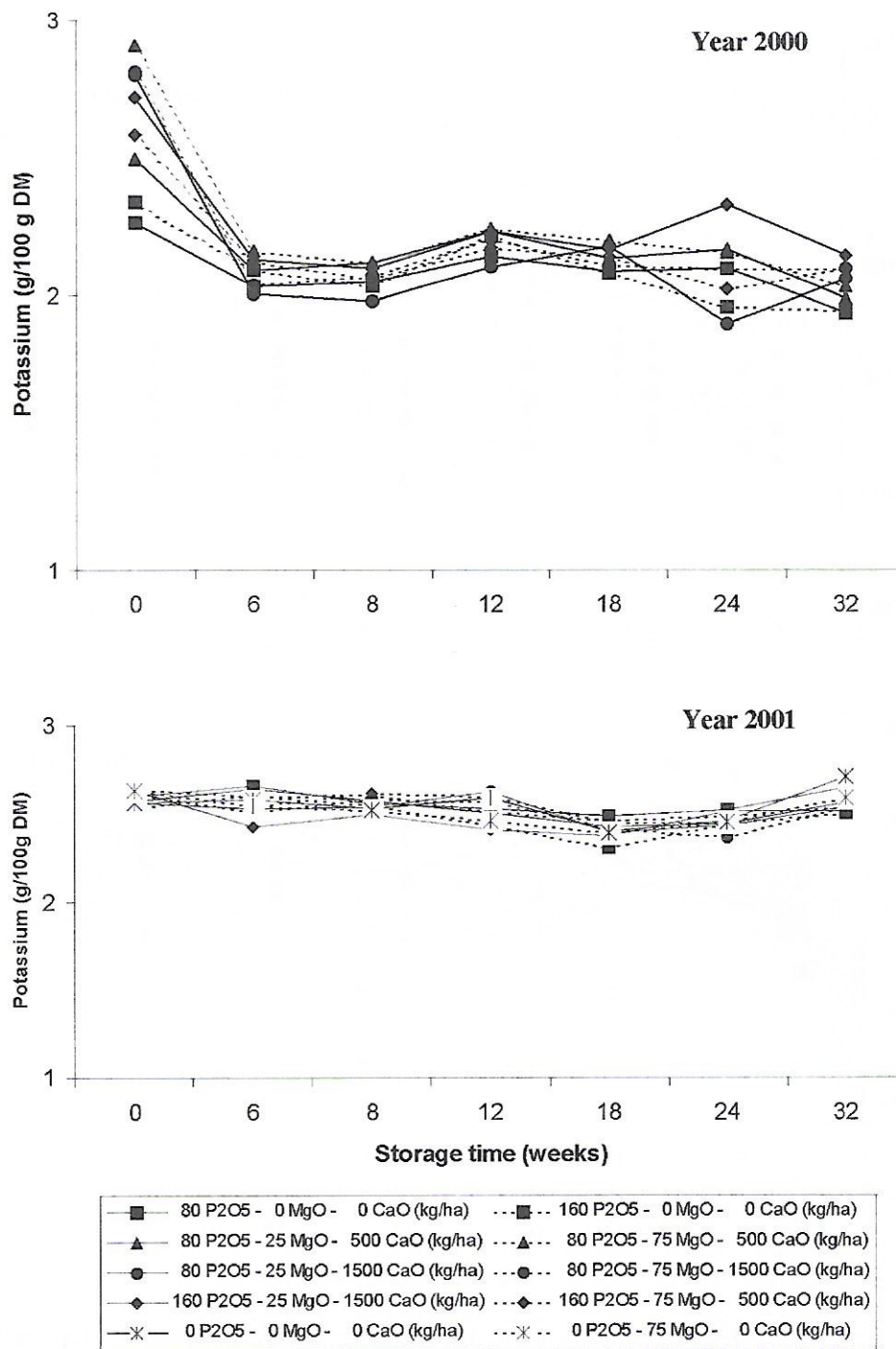


Figure 4. Potassium of potato tuber during 32 weeks of storage at 7⁰C

Potassium in tubers of 2000 (Fig. 4) showed a significant decrease during 6 week of storage, and followed by a relative constant during storage. Meanwhile in tubers of 2001 the pattern was different and showed no significant change during the storage, with only a small gradually decrease until 24 weeks before rising at the end of the storage period. The difference during as early as 6 weeks of storage may be a result of difference in tuber properties, such as stage maturity, in both years. Potassium was a relative mobile cation and moved normally passively according to diffusion gradient in tubers. In early stage of storage, in tubers of 2000, potassium mobilization might be occurred outward to the periderm due to potential difference across membrane to avoid an excessive loss due to curing process, as shown by characteristic of change during first six weeks of storage. Again, after 24 weeks of storage moved inward to accomplish the change in tuber flesh, in both years.

Status of mineral during dormancy and its contribution to the sprouting could be figure out from in this study. During storage, mobilization of minerals nutrient was occurred especially on the onset of sprouting. According to Marschner (1986), in early seedling growth the embryo requires a large amount of minerals nutrient, including magnesium, potassium and phosphorus. In potato, there was a marked positively gradient of movement of phosphorus, potassium as well as magnesium toward the eyes and later to the sprout. Our result showed that dynamic change of examined minerals occurred mostly between the 18 and 32-th week of storage, accompanied by the sprouting process, but to an earlier variation on calcium.

It is important to note, that in this study, mineral was determined from the peeled tissue rather than from whole tissue, the result therefore did not indicate the concentration of the mineral in tuber periderm. Prior to the onset of sprouting the

mobilization of mineral has occurred in most buds/eyes area, which concentrated in periderm. Since mineral was normally found in higher amount in periderm, it is more likely a reasonable explanation that caused mineral in tubers flesh relatively small level and decreased in relatively slow rate. Variation of calcium level during storage showed a more dynamic mobilization of calcium between periderm and flesh area during storage. Related to dynamic movement of mineral during sprouting, Decock *et al.* (1975) reported that large amount of phosphorus, potassium, and magnesium found in sprout, but only very little calcium move from the tuber or set into the sprout, although calcium is necessary for merismatic growth and cell elongation. Since no significant decrease of magnesium, phosphorus and magnesium levels at the end of storage have been detected, probably respectively minerals have been mostly mobilized from the periderm area toward the sprout.

Related to the changes level of minerals nutrient during storage produce from this study, there was an indication that until 6 to 8 week of storage the tubers was in the stage of physiologically dormant, with a slight different between the treatment but not found significantly. This indication was clearly supported by the characteristic of the starch and protein content, in which during the 8 weeks of storage only a relative small starch change and only minor change of protein occurred.

The length of the rest period is genetically determined (Suttle, 2004), and for the same cultivar could also vary from year to year depend on the storage condition after harvesting. Dormant period after harvest is shorter if the humidity of the storage atmosphere is high and higher temperature shortened the rest period (Linneman *et al.*, 1985). Furthermore, very variable environmental condition could cause large fluctuations on tuber development and maturity and subsequently on the length of

rest period. Termination of dormancy, therefore, is specific to cultivar and all condition during cultivation and after harvest. Compilation data from 1946-1948 presented by Hemberg (1985) showed that rest period could range between 7-16 weeks depend on the variety. Potato tubers in this study have shown to be completely sprouted between 18 and 24 weeks, which indicated that breaking of dormancy could have been started before 18 weeks of storage. Discrepancy on result of many studies may be due to difference of related factors previously discussed.

The important implication of degradation of substance during storage is related to quality of tubers. It is not only related to the texture of tubers, but also to the quality of intended potato-based products. The levels of accumulated reducing sugars and free amino acids, as result of starch and protein decomposition, is significantly influence the colour of French fries and potato chips caused by Maillard reaction (Agblor & Scanlon, 2002; Olsson *et al.*, 2004). Newly evidence of acrylamide forming by reaction of highly suspected asparagic acid and glucose was also related to the decomposition of starch and protein in tubers during storage (Olsson *et al.*, 2004).

Conclusions

By tracking the profiles of reserve substance catabolism as well as mineral mobility during storage, as indicators of quality change, it has been found no significant different in level among tubers from different treatments. Moreover, harvested tubers from different treatments showed a similar characteristic of substances change during 32 weeks of storage. Summarizing, this study have demonstrated that no effect of treatments on quality of tubers during storage, and the quality during storage is mainly dependent on the at-harvest quality attributes.

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