the green leaf seedlings was 28 days longer than the mean for the nearest red leaf class.

The more intense red the solid or variegated pattern, the shorter the FDP mean. However, the solid pattern has a somewhat greater effect than the variegated pattern. It is proposed that the solid-2 class would include 2 other classes that cannot be distinguished, solid-2 variegated-1 and solid-2 variegated-2. Apparently the variegated pattern is obscured by the intense color of the solid pattern. This may explain why the range of the solid-2 pattern is greater than all the other non-green patterns. Two intense red seedlings, ripening about 50 days after bloom, were scored as solid-2; these could have been solid-2 variegated-2 or solid-2 variegated-1.

The high heritability of a short FDP and the high genetic correlation of both red leaf characters with a short FDP should be useful in planning future crosses in a breeding program for peaches and nectarines where a short FDP is a major goal. No simple genetic explanation has been deduced from an analysis of segregating progenies. Preliminary data suggests color is due to an complex interaction of a minimum of 3 genes with genetic action distorted by lethality.

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Influence of Magnesium Concentrations in Nutrient Solution on Growth, Tissue Concentration, and Nutrient Uptake of Peach Seedlings[1]

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Additional index words. Prunus persica, nutrient deficiency, plant nutrition

Abstract. **Seedlings of 'Babygold 5' peach [*Prunus persica* (L.) Batsch] were grown for 50 days in nutrient solutions with 0.4, 21, 42, 125, 250, 500 μM Mg. Magnesium deficiency symptoms were observed 19 days after initiation of the Mg treatments in the seedlings in 0.4 μM Mg solutions. The relative growth rate was significantly increased for the first increment of Mg concentration with no further increases at higher Mg concentrations. Increasing Mg in the nutrient solution significantly increased Mg concentration in the leaves, stems, and roots, but Mg tissue concentration decreased at all levels of Mg in the nutrient solution as physiological age increased. Visible Mg deficiency symptoms were observed on mature leaves at the 125 μM Mg treatment, but when the Mg concentration exceeded 250 μM, Mg concentration in mature leaves was increased above the threshold for appearance of Mg deficiency symptoms. No Mg deficiencies were observed on 'Babygold 5' seedlings when the Mg concentrations in the leaves exceeded 2000 μg/g dry weight and Mg uptake rate was 2.5 μmoles/g fresh wt./ day.**

The soils of the Southeastern Coastal Plains region are highly leached and inherently infertile. Frequent applications of many nutrients are required to alleviate nutrient deficiencies or imbalances for high production levels. Soil nutrient levels can be easily corrected to alleviate deficiences and imbalances in the production of annual crops, but the problems are compounded with a perennial crop such as peaches, because applications of fertilizer, lime or other amendments are generally restricted to the soil surface after the 2nd leaf stage of growth.

Much research has been conducted (3, 4, 5, 6, 10, 11, 12) on the role of K and Mg on tree growth, yield, and quality of the fruit of 'Elberta' peaches. High rates of Mg reduced fruit firmness, color, and storage quality, and high rates of K had the reverse affect (11). Application of K or Mg reduced the Ca concentration in most portions of the tree sampled (6). In a 5-year study, application of K and Mg to the soil increased the foliage concentration of K and Mg, but K application was not associated with a growth response (3, 4).

Under field conditions, the supply of Mg to the peach root depends mainly upon the equilibrium between the exchangeable Mg and the Mg in soil solution. This equilibrium is influenced by the

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secondary clay minerals in the soil and Mg amendments (1). The Mg in soil solution found in selected soils in the Southeast ranges from 210 to 750 μM of Mg (2). Because of this wide range in Mg levels in soils, it is important to establish concentration ranges for the Mg in solution and to associate them with the tissue Mg concentrations that do not limit peach production. The objectives of this study were to determine the critical concentration in nutrient solution where Mg deficiencies begin to occur, and to determine the threshold concentrations in nutrient solution and tissue where Mg does not inhibit growth.

Materials and Methods

'Babygold 5' peach seeds were germinated in a sterilized soil mixture, and seedlings were grown in a greenhouse for 21 days to a height of 12 to 16 cm. During the 21 days of growth, seedlings were fertilized once with Peters[4] 25–20–20 (25N–4.3P–8.3K) fertilizer. At the end of this period, seedling roots were washed in distilled water for 2 hr and then transferred to 15-liter tanks. Each tank contained 4 seedlings.

When seedlings were transferred, Mg treatments of 0.4, 21, 42, 125, 250, and 500 μM Mg were initiated by adding $MgSO_4$ to the nutrient solution. The experimental design was 5 replicates of six Mg treatments in a randomized complete block. Concentrations of other nutrients were as follows: 0.25 mM KH_2PO_4, 0.25 mM $CaCl_2$, 0.5 mM KNO_3, 75 μM FeDTDA, 47 μM B, 9 μM Mn, 0.8 μM Zn, 0.3 μM Cu, and 0.05 μM Mo. Solution pH was measured daily and maintained at 5.6 by adding HCl or NaOH. Concentration of nutrients in the vigorously aerated nutrient solutions, maintained at constant volume, was monitored every 3 days, and solutions were changed every 7 days. During this period, the concentration of nutrients did not vary more than 5% from the original concentration. Temperature was maintained at 24 ± 5°C, and sunlight was supplemented with fluorescent light to produce a minimum of 4 klx at the canopy for a 16 hr day.

Uniform seedlings were selected for the experiment, and representative samples were harvested, weighed, and chemically analyzed. All 4 seedlings in the 0.4 μM Mg treatment and 2 seedlings from each of the other Mg treatments were harvested 29 days after the seedlings were transferred to the tanks. All other seedlings were harvested 50 days after transferral. Plants were separated into leaves, stems, and roots, and were freeze dried. The freeze-dried samples were ground to pass a 40-mesh screen. The concentrations of Mg and other nutrients in the tissue were determined by atomic absorption spectrophotometry. Magnesium uptake rates were calculated using the change in total elemental content and the change in the fresh weight of seedling roots (8).

Root volume was determined on peach seedlings using a water-displacement method. Relative growth rates (RGR) of seedlings were calculated according to the equation of Loneragen et al. (9). Data were subjected to an analysis of variance and the significant effects are reported. The 0.4 μM Mg treatment was not included in the analysis of variance tables for the second harvest because all of those seedlings were harvested at the first harvest.

Results and Discussion

Magnesium deficiency symptoms in the foliage of peach trees have been reported (10), and the symptoms for shoots of 1-year-old peaches have been described (7). The Mg deficiency symptoms reported here were associated with their development at various concentrations in nutrient solutions, with growth responses, and with Mg distribution in 'Babygold 5' peach seedlings.

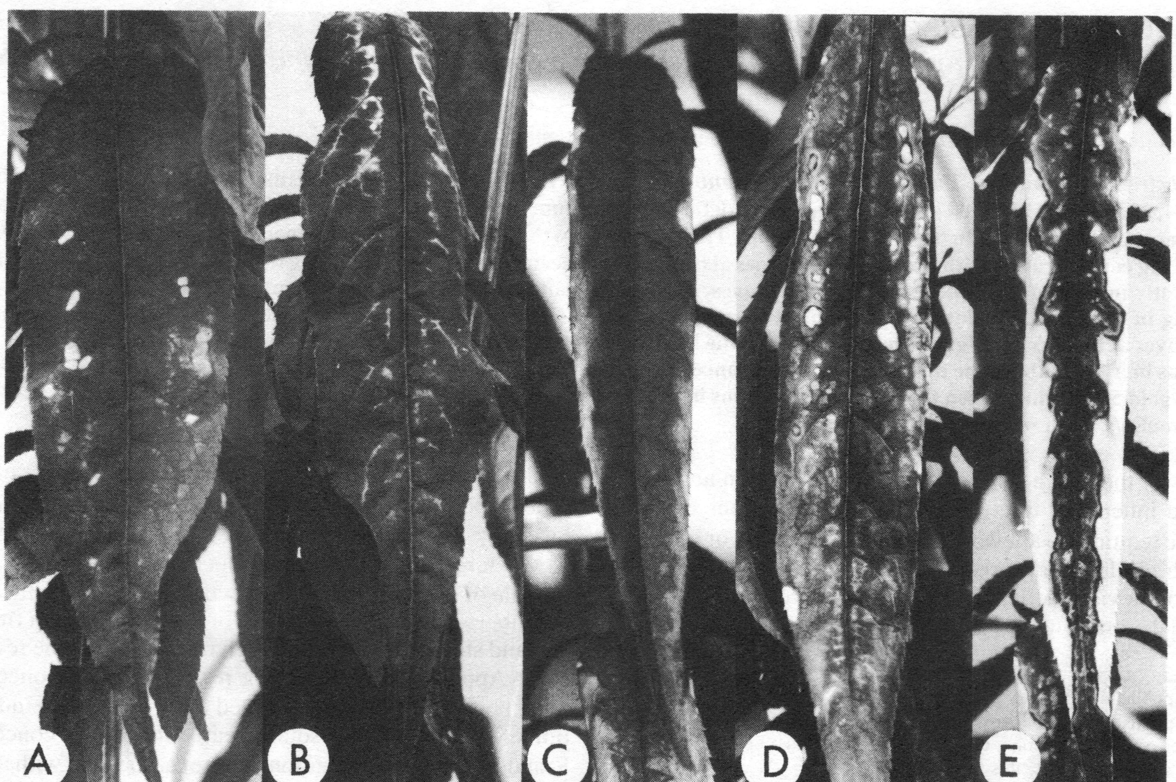

Fig. 1. Magnesium deficiency symptoms of 'Babygold-5' leaves illustrating 5 stages of development. (A=beginning necrotic spots; B=beginning marginal and internal chlorosis; C=beginning of marginal necrosis; D=necrosis expanding; E=abscised leaf.)

Shoot deficiency symptoms. After the seedlings were transplanted, Mg deficiency symptoms developed in seedlings in the 0.4 μM Mg treatment at 19 days, in the 21 μM Mg treatment at 25 days, in the 42 μM Mg treatment at 28 days, and in the 125 μM Mg treatment at 38 days. The initial stage of Mg deficiency in the 0.4 μM Mg treatment was observed in mature leaves first (Fig. 1). The mature leaves became dark green and developed a water-soaked appearance that evolved into small interveinal necrotic spots (Fig. 1a), which enlarged toward the midrib and margin of the leaf. Sometimes chlorosis developed at the inner boundaries of the water-soaked area (Fig. 1b) and advanced toward the leaf margin with necrosis following the same pattern. Marginal necrosis with little chlorosis also developed (Fig. 1c) and advanced toward the midrib. These deficiency symptoms progressed with necrotic spots and margins with chlorosis (Fig. 1d) or progressed directly to necrotic margins with little chlorosis (Fig. 1e) before the leaf fall.

Leaves that developed after the first symptoms of Mg deficiency appeared were abnormally thin and showed some chlorosis at the leaf apex. Deficient leaves fell 4 to 6 days after the first Mg deficiency symptoms were observed in the 0.4 μM Mg treatment. Defoliation was not observed on seedlings in the 21 μM Mg treatment. In the 42 and 125 μM Mg treatments, deficiency symptoms were observed only in the mature expanded leaves. The Mg supplied from the external solution in this concentration range did not meet the Mg requirements of the apical region of the peach seedling, and Mg was mobilized from the mature leaves to help satisfy the Mg requirements in the terminals. The concentration range of 42 to 125 μM Mg can be classified as marginal for development of deficiency symptoms in young peach seedlings.

Root deficiency symptoms. The Mg concentration in the solution for the 0.4 μM Mg treatment increased to 3.84 μM during the first 5 days after transplanting, but when the solution was changed on the 7th day, the Mg concentration did not increase. The efflux of Mg from the root in the 21 and 42 μM Mg treatments followed the same pattern of increased Mg in the solution for the first 5 days, but with no further efflux after the nutrient solution was changed. The efflux of Mg from roots in the 0.4, 21, and 42 μM Mg treatments was probably enhanced by damage to the seedling root system in the washing before seedlings were transferred to the nutrient solution. After the generation of new roots, no further Mg efflux was observed. No visible root deficiency symptoms were observed at any Mg concentration.

Growth. The greatest increase in terminal length, cross-sectional area, root volume, and dry weight of leaves, stems and roots at the first harvest occurred between the 0.4 and 21 μM Mg treatments (Table 1). There was no significant effect on these growth parameters at Mg concentrations above 21 μM, even though deficiency symptoms developed on seedlings in the 21, 42, and 125 μM Mg treatments.

When the growth period was increased to 50 days, the number of laterals, cross-sectional area, and dry weight of stems were again significantly increased by the first increment of Mg concentration (harvest 2) (Table 1). Root volume and dry weight of leaves and roots were significantly increased in comparison with 0.4 μM Mg (harvest 1) treatment only when the Mg concentration was increased to 500 μM Mg.

Tissue-Mg concentration. The Mg concentrations in the leaves, stems and roots were 4438, 2688, and 6944 μg/g dry weight when the seedlings were transferred to tanks on the 21st day after germination. These tissue concentrations of Mg were higher than are found in field-grown peach leaves and stems where concentrations usually range from 3500 to 4000 μg/g in the leaves and 2200 to 2600 μg/g dry weight in the stem. This high Mg concentration in the seedling organs may reflect uptake from the soil that the seedlings were grown in before the Mg treatments began.

The change in Mg concentration with physiological age of peach seedlings is shown in Fig. 2. The greatest decrease occurred in the roots during the period after transplanting until first harvest 29 days later (day 21 to day 50 after germination); very little change occurred between first and second harvest (day 50 to day 71 after germination). Some of the decrease in Mg concentration in the roots (day 21 to day 50 after germination) was attributed to injury during the washing procedure used initially to remove soil particles from roots before transferring them to the nutrient solution. Injury to the root system during the washing procedure caused Mg to the leached from the roots during the first 5 days of Mg treatment. The tissue Mg concentration in the leaves and stems decreased over the entire treatment period.

The influence of Mg concentration in nutrient solution on tissue Mg concentration for each harvest date is shown in Fig. 3. Tissue Mg concentration on the dry weight basis decreased between first and second harvest in every Mg treatment and the decrease was much greater in the leaves than in the stems or roots. However, the small change in Mg concentration on the roots over the 50

Table 1. The influence of magnesium concentration in nutrient solution on growth of 'Babygold-5' seedlings. Seedlings were transferred to solution 21 days after germination. Harvest 1 was 29 days and harvest 2 was 50 days after transplanting.

Mg concn in nutrient solution (μM)	Terminal length (cm)	No. of laterals	Trunk x-sect area (mm^2)	Root vol. (cm^3)	Dry wt (g) of 2 plants		
					Leaves	Stem	Roots
			Harvest 1				
0.4	97	0.9	1.4	3.2	0.59	0.23	0.21
21	177	2.1	2.4	5.4	1.18	0.47	0.37
42	159	1.9	2.6	6.2	1.13	0.43	0.46
125	167	3.2	2.6	6.6	1.19	0.46	0.47
250	163	3.2	2.4	6.2	1.12	0.42	0.44
500	165	2.7	2.3	6.6	1.32	0.49	0.48
LSD 5%	26	NS	0.76	1.10	0.28	0.13	0.11
			Harvest 2				
21	411	5.6	7.7	10.4	4.02	1.62	1.28
42	432	8.1	10.7	12.0	3.83	2.18	1.49
125	439	8.4	10.8	13.2	4.40	2.19	1.68
250	450	7.6	10.0	13.2	4.62	2.13	1.71
500	450	10.0	11.3	14.8	5.20	2.54	1.84
LSD 5%	NS	1.97	2.34	2.83	1.11	0.44	0.38

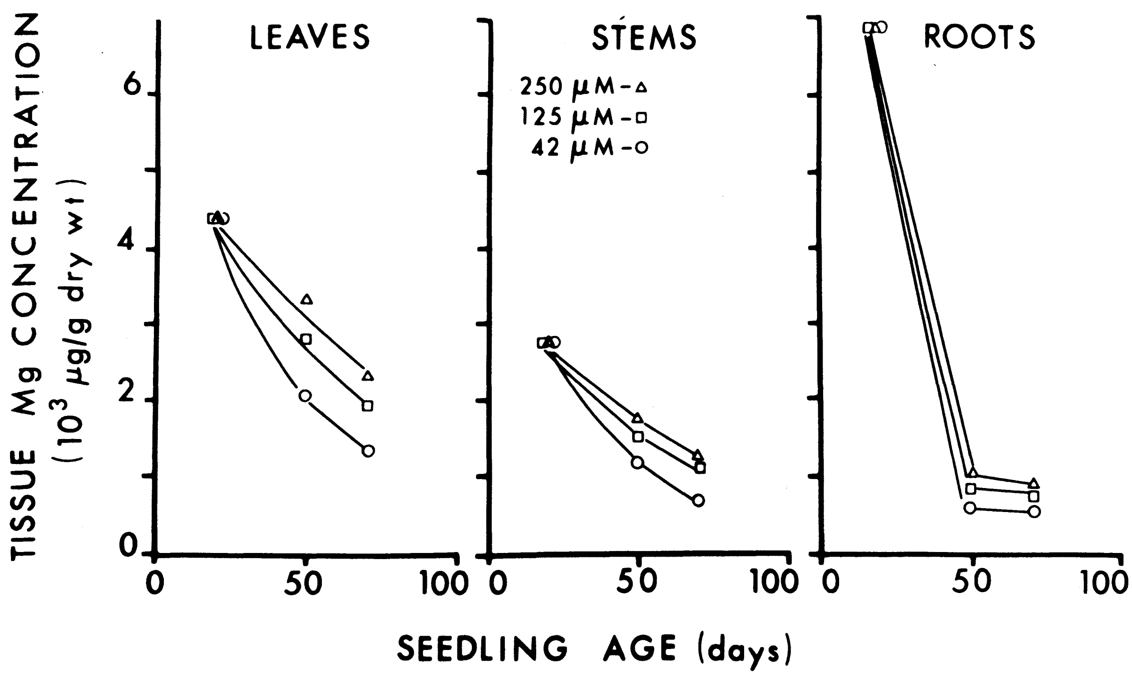

Fig. 2. The influence of physiological age on Mg concentration in the leaves, stems, and roots of 'Babygold 5' peach seedlings grown in nutrient solution at three Mg levels.

50 days after transferral to the nutrient solution suggested that the Mg was preferentially translocated to the leaves. Neither the roots or stems appeared to be storage organs for Mg.

The Mg concentrations in leaves, stems, and roots decreased from the original concentrations at transplanting of 4438, 2688, and 6944 µg/g dry weight to 2000, 1200, and 600 µg/g dry weight in the 42 µM Mg treatment by the first harvest (day 29 of treatments). Because the deficiency symptoms had been observed the previous day, this Mg concentration probably represents the marginal level for Mg deficiency. The tissue Mg concentrations of seedlings grown for 50 days (harvest 2) at 125 µM Mg were similar to the concentrations of seedlings at 42 µM Mg at 29 days (Fig. 3). These Mg levels are thus probably the marginal levels for deficiency symptoms to develop.

Relative growth rate. The relative growth rate (RGR) was significantly less for the 0.4 µM Mg treatments at harvest 1 after 29 days of growth in the nutrient solution, than at higher Mg concentrations (Fig. 4). During the period from harvest 1 to harvest 2 (29 to 50 days), the RGR for the 500 µM Mg treatment was significantly higher than that for the 42 µM Mg treatment, and it was significantly higher for the 250 µM Mg treatment than for the 21 µM Mg treatment. The small effects of Mg concentration of 125 µM and higher suggested that even though deficiency symptoms develop on seedlings, marginal levels of Mg may not have any adverse effect on growth of peach seedlings.

Mg uptake rate. Magnesium uptake rates increased, in comparison with the 0.4 µM Mg treatments, with higher Mg concentration within each harvest date and were linearally related to Mg

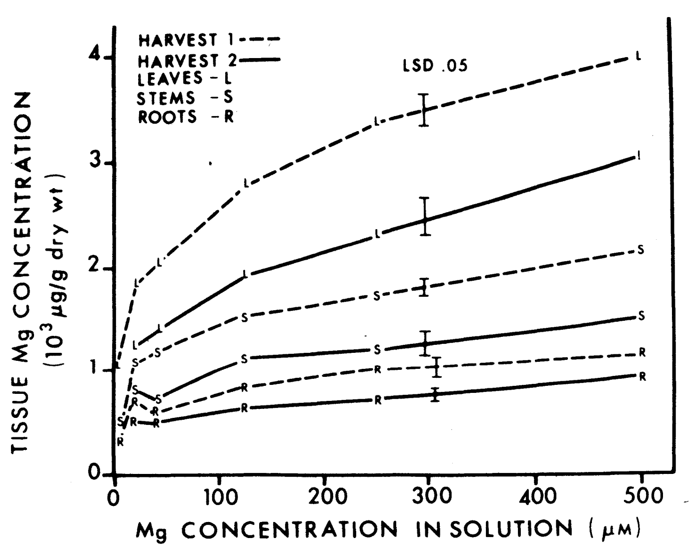

Fig. 3. Influence of Mg concentration in nutrient solution on Mg tissue concentration of 'Babygold 5' seedlings for two harvest dates.

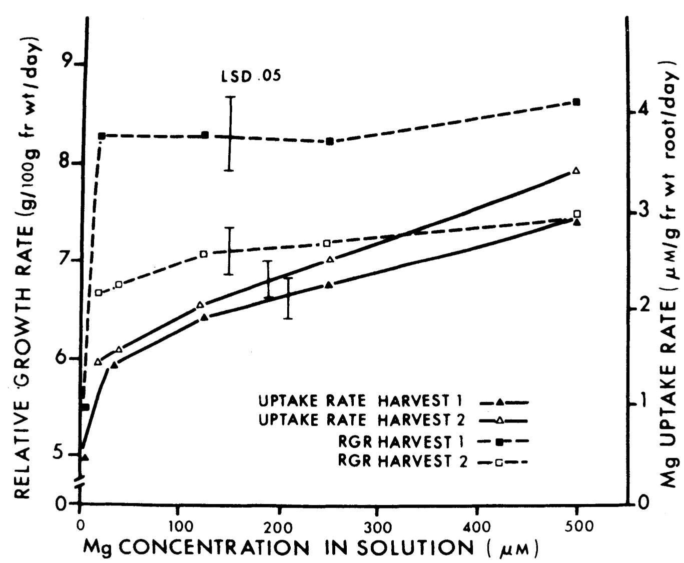

Fig. 4. Influence of Mg concentration in nutrient solution on Mg uptake rate and relative growth rate (RGR) of 'Babygold 5' seedling for two harvest dates.

concentration in the nutrient solution (Fig. 4). There was one exception at 21 µM Mg treatment — the relation of uptake rates to those at 0.4 µM Mg was significantly different from that of other Mg concentrations at harvest 1. The Mg uptake was significantly higher in all Mg treatments for the period from harvest 1 to harvest 2. This suggested that peach roots become more efficient in uptake of Mg as they increase in physiological age.

Magnesium distribution. Distribution of Mg within the seedlings changed drastrically during treatment from the initial 21-day-old seedlings where leaves accounted for only 42% total Mg. During the treatment period, the leaves accounted for 70 to 75% of the total Mg in the 'Babygold 5'. The leaves appeared to be the organ where Mg was accumulated. The solution Mg concentrations did not appear to influence the distribution of Mg found in the seedling even though Mg deficiency symptoms developed on plants in the 21, 42, and 125 µM Mg treatments.

There was no clear delineation of the Mg concentration needed in nutrient solution to maintain adequate Mg levels in the seedling tissue to prevent deficiency symptoms, but general trends were apparent. The 125 µM Mg treatment appeared to supply enough Mg to prevent a significant decrease in growth during the period from first to second harvest (day 50 to 71 after germination). However, since deficiency symptoms were observed on day 59 after germination at this level and did not develop on seedlings at higher Mg levels, we concluded that the 125 µM Mg concentration was a marginal level for Mg supply. Leaf Mg concentrations were about 2100 µg/g of dry weight for the 42 µM Mg treatment at harvest 1 and 1900 µg/g dry weight for the 125 µM Mg treatment at harvest 2. Thus, it appears that leaf Mg concentration of 2000 µg/g dry weight is the marginal range where visible deficiency will develop but growth of peach seedlings will not be decreased. When the Mg concentration in the nutrient solution was less than 42 µM, the seedlings were solely dependent on the external Mg supply to meet growth requirements after the initial supplies of Mg from the embryo and accumulated from the soil before Mg in that treatment were depleted. Thus, a Mg concentration in the nutrient solution of 0.4 to 42 µM appears to be the range of critical Mg deficiency in 'Babygold' peach seedlings.

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Seasonal Changes of Free and Hydrolyzable Abscisic Acid in Vegetative Apple Buds[1]

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Additional index words. Dormancy, rest, *Malus domestica*

***Abstract.* Levels of free and hydrolyzable abscisic acid (ABA, H-ABA) in vegetative apple (*Malus domestica* Borkh.) buds were measured by electron capture gas chromatography. ABA level was high during midsummer both before and after entry into dormancy, increased to a maximum just prior to leaf fall, and decreased to a minimum just prior to bloom. H-ABA level was low during midsummer, increased gradually during fall and winter, reached a maximum during the early stages of bud development, and then decreased very rapidly just prior to full bloom.**

Inhibitor theories of plant dormancy have been studied extensively. Early work (6, 10, 17) showed parallel variation of the B-inhibitor, major component = ABA, (4, 5) and dormancy in maple (*Acer pseudoplatanus* L.), and potato (*Solanum tuberosum* L.). Decreasing concentrations of the B-inhibitor have been found to parallel the progress of chilling in ash (*Fraxinus excelsior* L.) buds (2). Harrison and Saunders (7) found that ABA level was highest in the fall and that a close parallel variation occurred between decreasing free ABA levels and time required for bud break in *Betula verrucosa*, Ehrh; H-ABA increased during chilling and suggested that the mechanism for removing growth inhibition could be conjugation of ABA as the glucose ester. Wright (29) reported that ABA content in black currant (*Ribes nigrum* L.) and beech (*Fagus sylvatica* L.) was highest during autumn at

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