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EFFECT OF CALCIUM/POTASSIUM RATIO AMMONIUM SUPPLY ON NUTRITION AND YIELDS OF CUCUMBER PLANTS

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ABSTRACT: A greenhouse experiment was conducted in order to study the influence of two calcium/potassium (Ca/K) ratios (0.75 and 0.33) and ammonium supply (0 and 1 mmol/L) in the nutrient solution on nutrient uptake, mineral composition, and productivity of cucumber plants grown in sand culture. There were not significant differences in nitrate consumption between the four treatments. Calcium and potassium consumptions were directly related with the Ca/K ratio in the nutrient solution. The treatment with Ca/K = 0.75 and ammonium supply, that showed the lowest potassium and nitrogen plant levels and the highest calcium uptake and concentration in plant, offered the highest yields.

INTRODUCTION

It is necessary to adequate the fertilization to specific nutritional requirements of each plant specie in order to obtain the highest yields (7). The nutritional requirements may be calculated from the plant analysis, but the results obtained by different researchers depend on the substrate and the environmental conditions (1,3). By growing plants in solution culture instead of in the soil, it is possible to simplify the measurement of nutrient demand. The analysis, at frequent intervals, of the nutrient ions concentrations in the nutrient solution makes possible to adjust their supply to balance the removal trough uptake by the plant (4).

With regard to pepper fertilizers dosage, different authors disagree about the optimum Ca/K ratio, whereas others have reported a profitable effect of ammonium supply (2,5,8,13). Mortvedt and Khasawned (10) stated that cationic ratios in plants are a linear function of the corresponding ratio in the nutrient medium. In this way, it will be interesting to define the cationic ratio that produce the best plant development.

As a consequence of this, the objective of this work was to study the influence of two Ca/K ratios (0.75 and 0.33) combined with two different forms of nitrogen supply (only as nitrate and nitrate plus ammonium) on nutrient uptake, mineral composition, and yields of pepper plants hydroponically grown.

MATERIALS AND METHODS

The experiment was carried out from April to July in a glasshouse with automatic control of climatic parameters. Cucumber plants (*Cucumis sativus* L., cv. Medusa) were cultivated in containers (six plants per container) with 200 kg of washed quartz sand of 2-4-mm particle size.

A hydroponic culture system with recirculating nutrient solution was employed. The nutrient solutions were pumped four times a day from four 1000-liter containers (one for each treatment) to the cultivation boxes.

The experimental design was a complete randomized system with three replications per treatment:

N-0.75 Treatment: Nitrogen supply only as nitrate and Ca/K ratio in the nutrient solution = 0.75.

N-0.33 Treatment: Nitrogen supply only as nitrate and Ca/K ratio in the nutrient solution = 0.33.

A-0.75 Treatment: Nitrogen supply as nitrate plus ammonium and Ca/K ratio in the nutrient solution = 0.75.

A-0.33 Treatment: Nitrogen supply as nitrate plus ammonium and Ca/K ratio in the nutrient solution = 0.33.

The nutrient solution composition for each treatment is showed in Table 1. The total N and microelements supplies were the same for all the treatments. Microelements concentrations (mg/L) were: Fe (1.00), Mn (0.50), Cu (0.25), Zn (0.25), B (0.50), and Mo (0.05).

Table 1. Nutrient solutions composition (mmol/L).

	Treatments			
Reagent	A-0.75	A-0.33	N-0.75	N-0.33
$Ca(NO_3)_2$	3.75	2.50	3.75	2.50
KNO_3	3.00	5.50	4.00	6.50
KH_2PO_4	0.00	0.00	1.00	1.00
K_2SO_4	0.50	0.50	0.00	0.00
KCl	1.00	1.00	0.00	0.00
$MgSO_4$	1.00	1.00	1.00	1.00
NaCl	0.20	0.20	0.20	0.20
$NH_4H_2PO_4$	1.00	1.00	0.00	0.00
Ca/K	0.75	0.33	0.75	0.33

The concentration of individual nutrients and the pH of the nutrient solutions was weekly controlled by colorimetric, spectrophotometric, and ionometric methods (12), making additions of adequate amounts of salts when necessary. Nutrients consumption was calculated from these data.

Plants were sampled at three times, 27, 41, and 61 days after planting. The youngest but totally developed leaves were collected and used for foliar and sap analysis (6,11).

Yields were evaluated as number and weight of fruits obtained from each treatment.

RESULTS AND DISCUSSION

Nitrate, potassium, and calcium consumption by plants is given in Figure 1. There were not significant differences in nitrate consumption between the four treatments. Calcium consumptions were directly related with the Ca/K ratio in the nutrient solution (0.75 treatments consumed more calcium than 0.33 treatments).

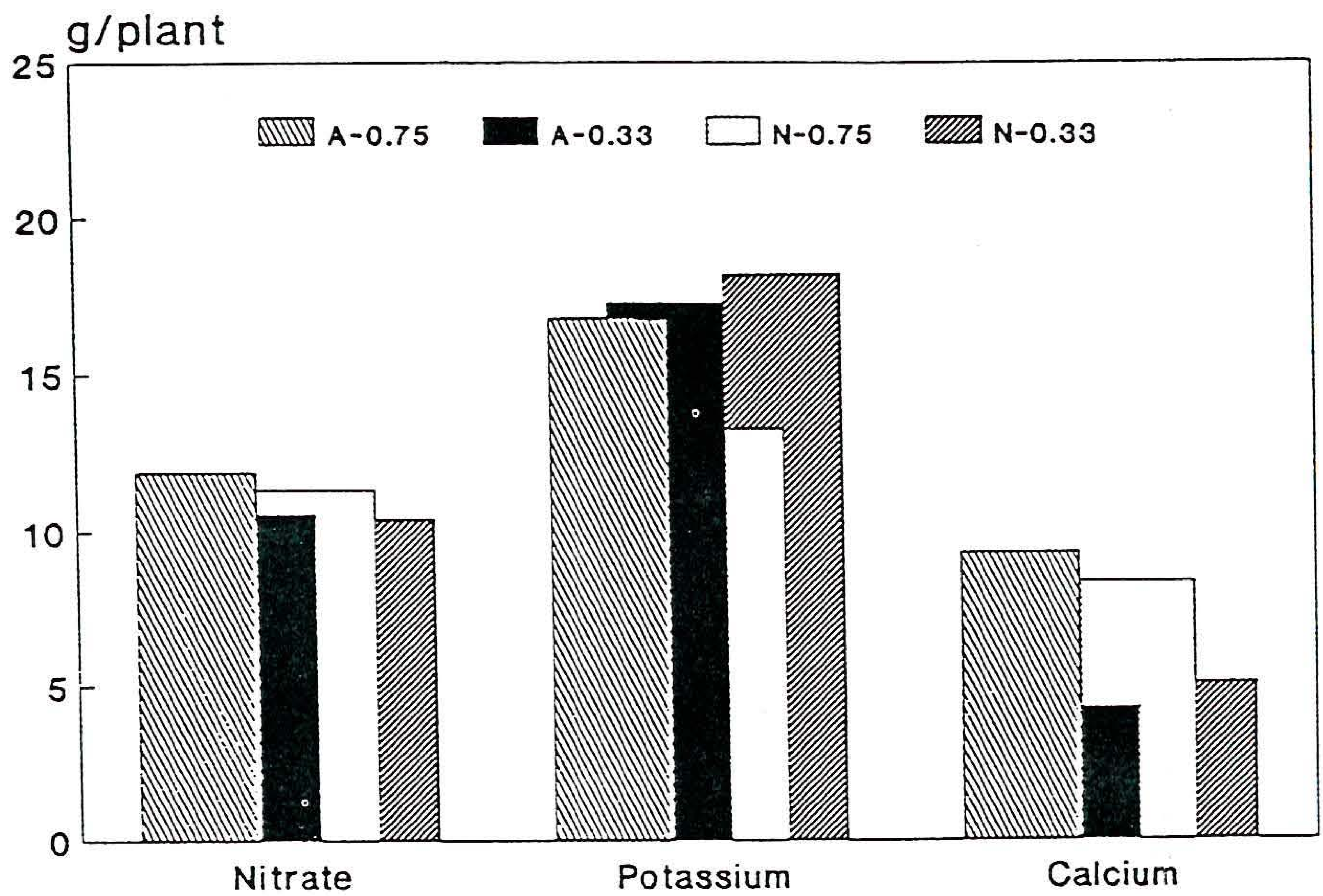

Figure 1. Nutrients consumption

However, potassium consumption was lower only in N-0.75 treatment. So, the presence of ammonium in the nutrient solution had no effect on the calcium and potassium uptake.

These results are different of those obtained by Alan (2) and Du et al. (5), who observed a potassium and calcium uptake reduction in the presence of ammonium. This disagreement may be due to the high tolerance to ammonium of cucumber plants (9) and to the low ammonium concentration in the nutrient solution employed, since Zornoza and Carpena (14) reported lower potassium and calcium concentrations in cucumber plants only when ammonium was supplied at high levels (40% of total N supply).

Tables 2 and 3 show the average nutrient contents throughout the cultivation cycle for each treatment in sap and leaves, respectively. Keeping in mind both tables, we may conclude that the greater effects of the treatments tested are

Table 2. Sap average nutrient contents for each treatment (mg/L). Different letters near the data indicate the existence of significant differences.

Element-Form	Treatments				LSD5%
	A-0.75	A-0.33	N-0.75	N-0.33	
N-NO_3	1651b	2724a	2866a	2791a	300
N-NH_4	22b	43ab	97a	67a	39
P-H_2PO_4	352a	234b	247b	253b	20
S-SO_4	719a	657a	399b	501ab	240
Cl	1268a	930b	693c	601c	148
Ca	1336a	1050b	1024b	805c	172
K	3829c	4616ab	4413b	5065a	478
Mg	161a	94b	103b	101b	16
Na	119	98	95	99	29

Table 3. Average nutrient contents in leaves (% d.m.) for each treatment. Different letters near the data indicate the existence of significant differences.

Element	Treatments				LSD5%
	A-0.75	A-0.33	N-0.75	N-0.33	
N	4.71b	5.65a	5.49a	5.50a	0.36
P	0.74	0.65	0.76	0.70	0.12
Ca	3.49	3.36	3.84	3.43	0.71
K	1.90c	3.12a	2.73b	3.16a	0.38
Mg	0.52b	0.54b	0.52b	0.61a	0.04
Na	0.05	0.05	0.05	0.05	0.01

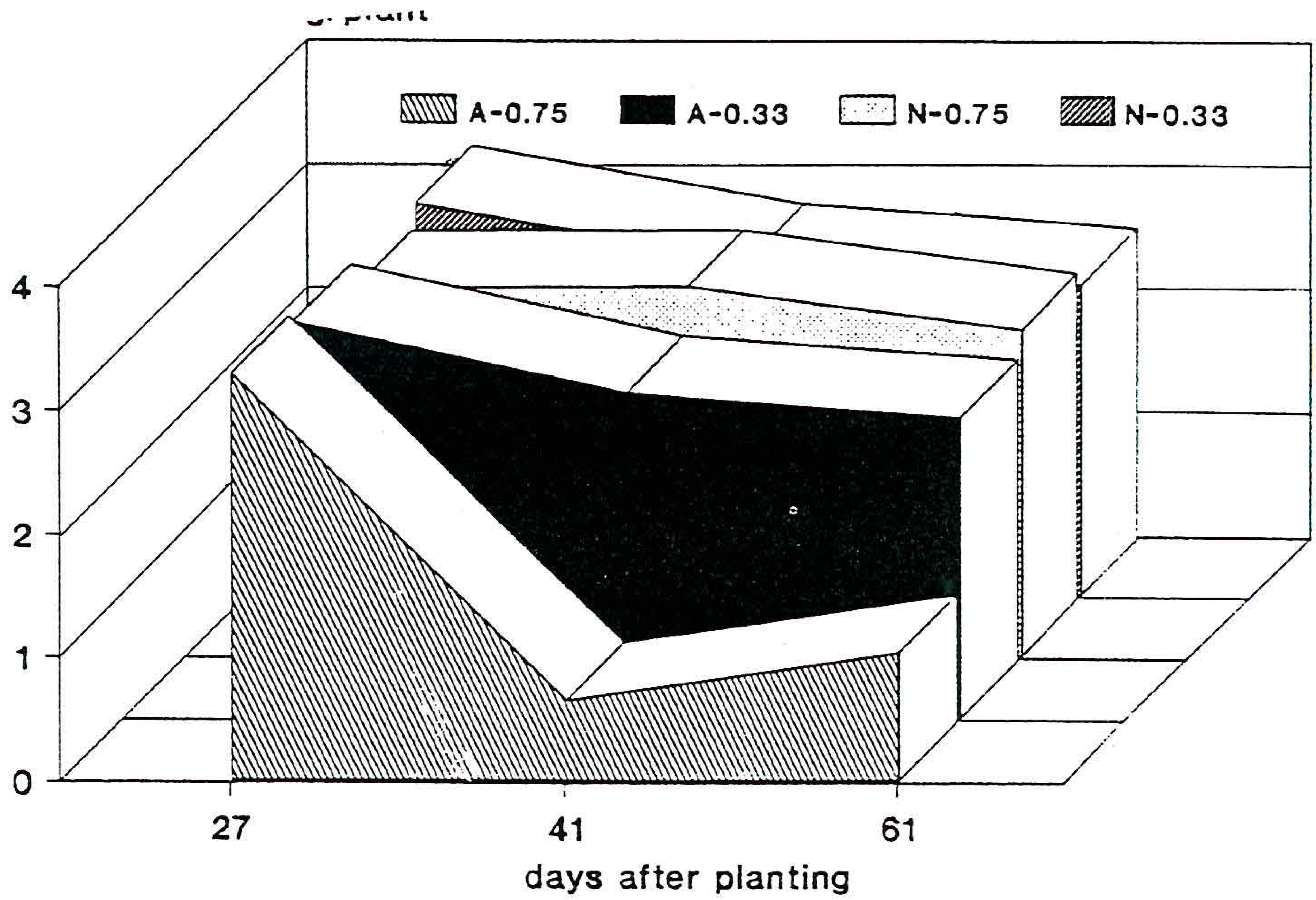

Figure 2. Nitrate content in sap

observed over nitrogen, calcium, and potassium. Therefore, we are going to study the evolution of these.

Nitrate, potassium, and calcium contents in sap at the three sampling times are showed in Figures 2, 3, and 4, respectively. The plants of A-0.75 treatment displayed the lowest nitrate concentration at the two last sampling times. With regard to potassium, the lowest levels were obtained with the 0.75 treatments, specially with the A-0.75 treatment.

Therefore, potassium levels in sap are directly related to Ca/K ratio in the nutrient medium and the presence of ammonium had a negative effect on potassium concentration only when Ca/K ratio was more advantageous to calcium. The low nitrate content observed in the A-0.75 treatment could be related to the decrease of potassium levels at the two last sampling times.

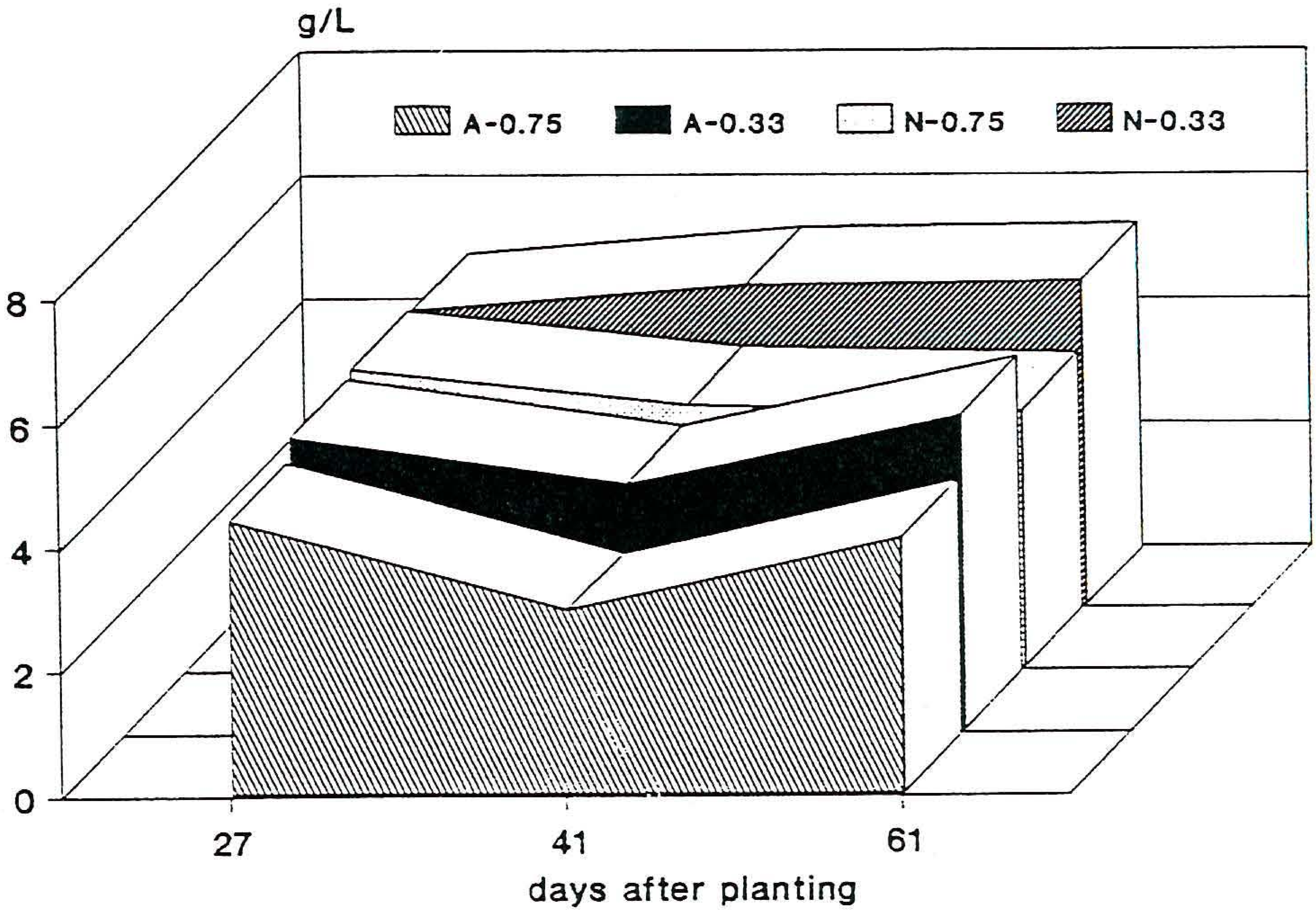

Figure 3. Potassium content in sap

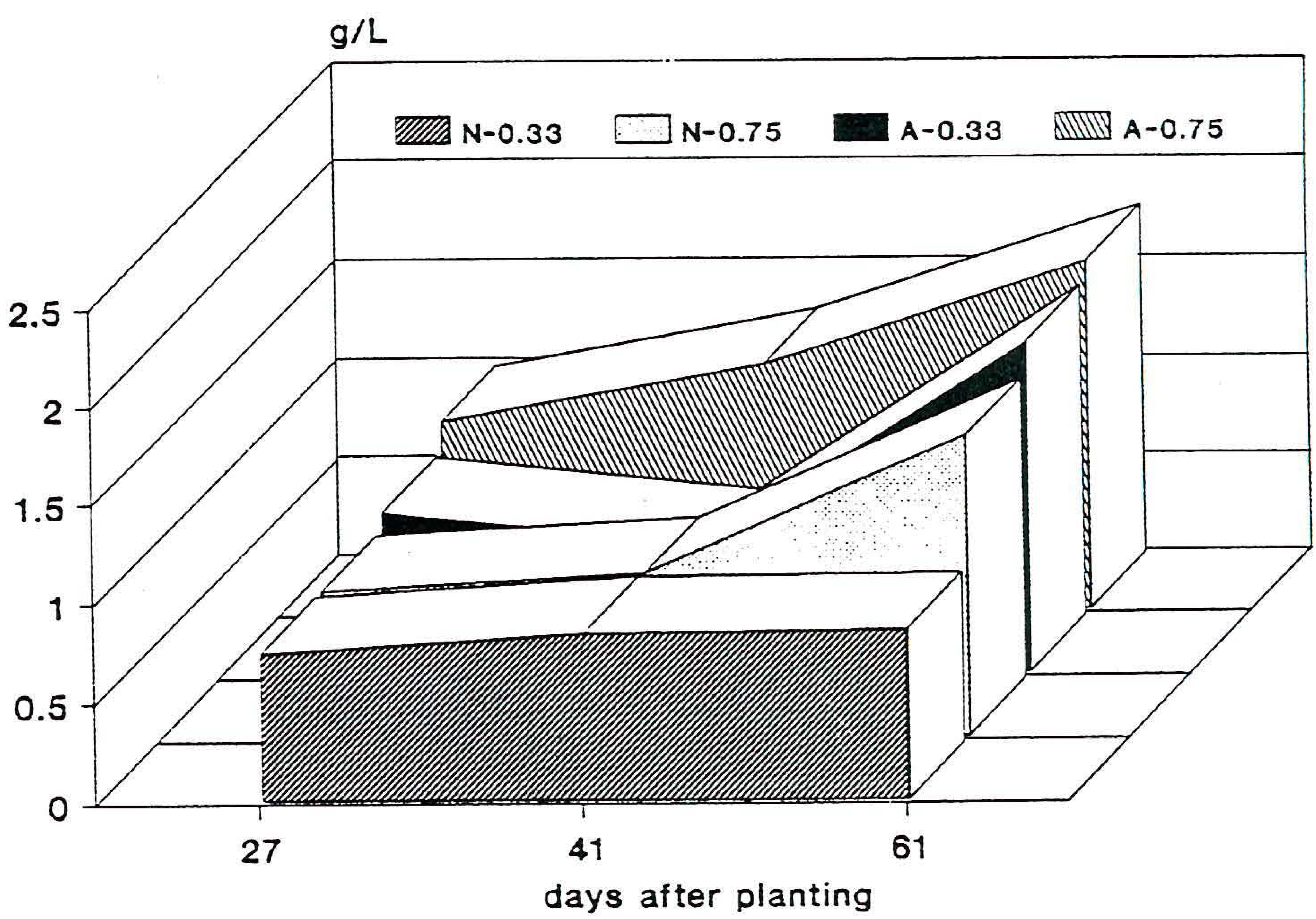

Figure 4. Calcium content in sap

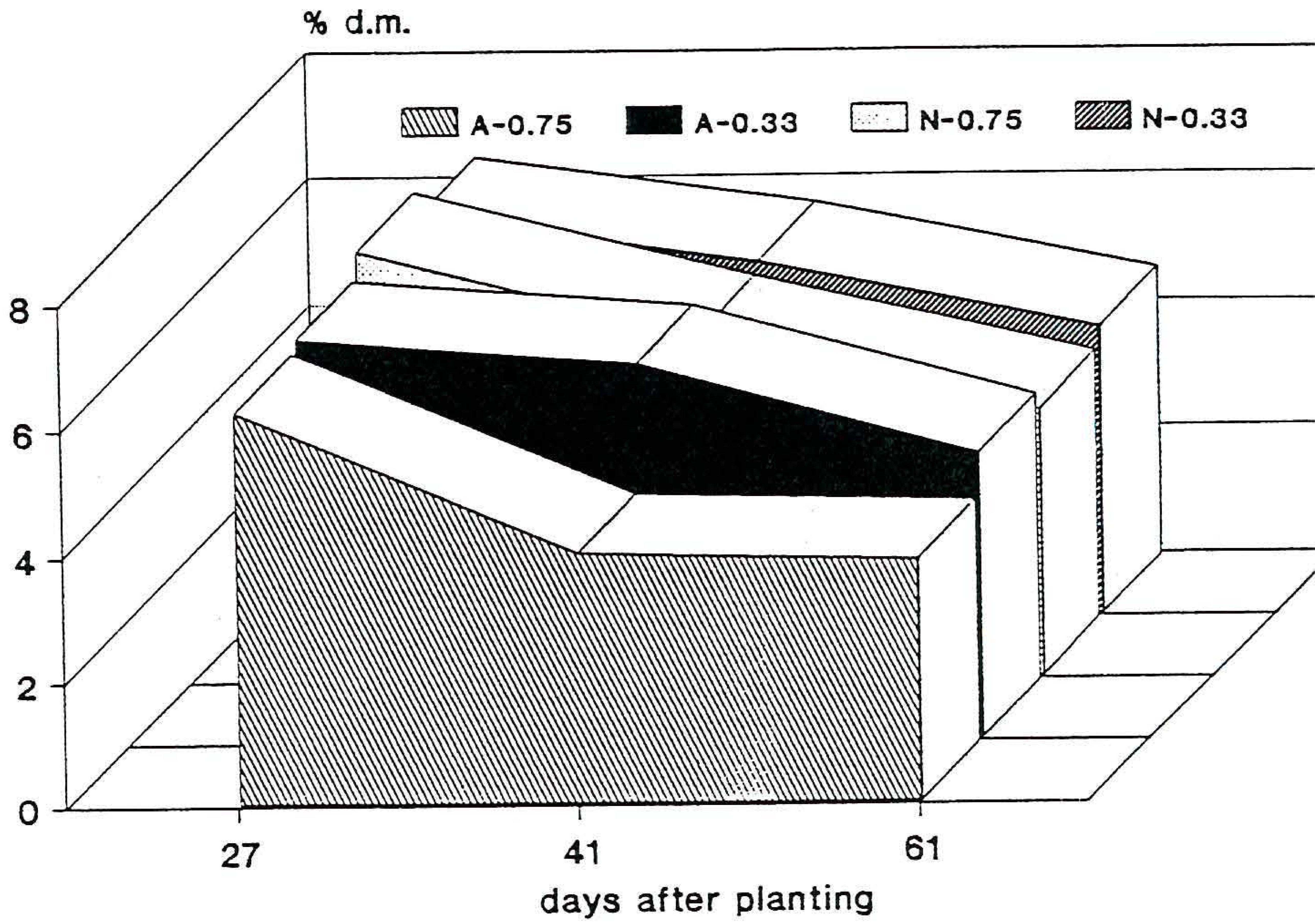

Figure 5. Nitrogen content in leaves

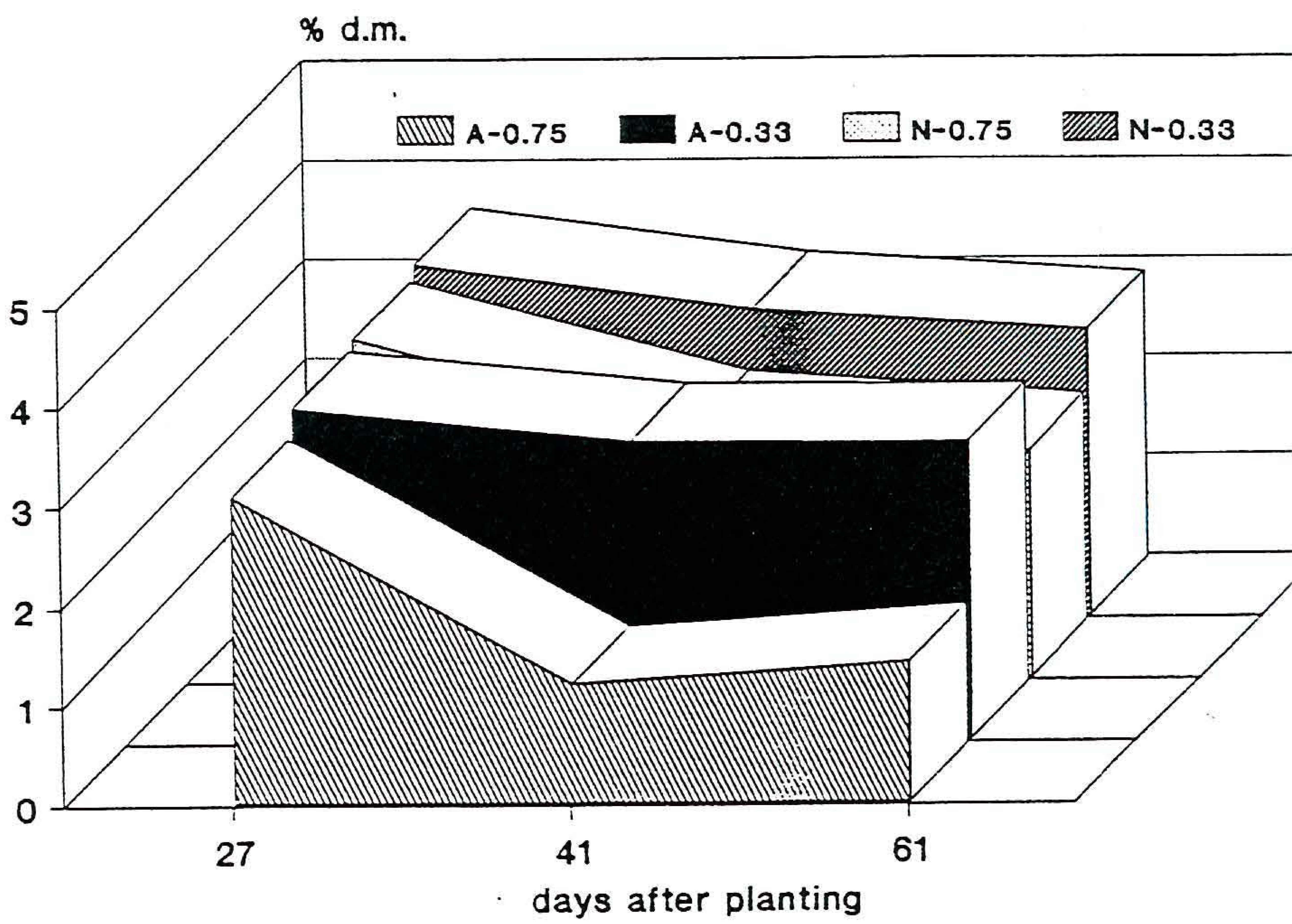

Figure 6. Potassium content in leaves

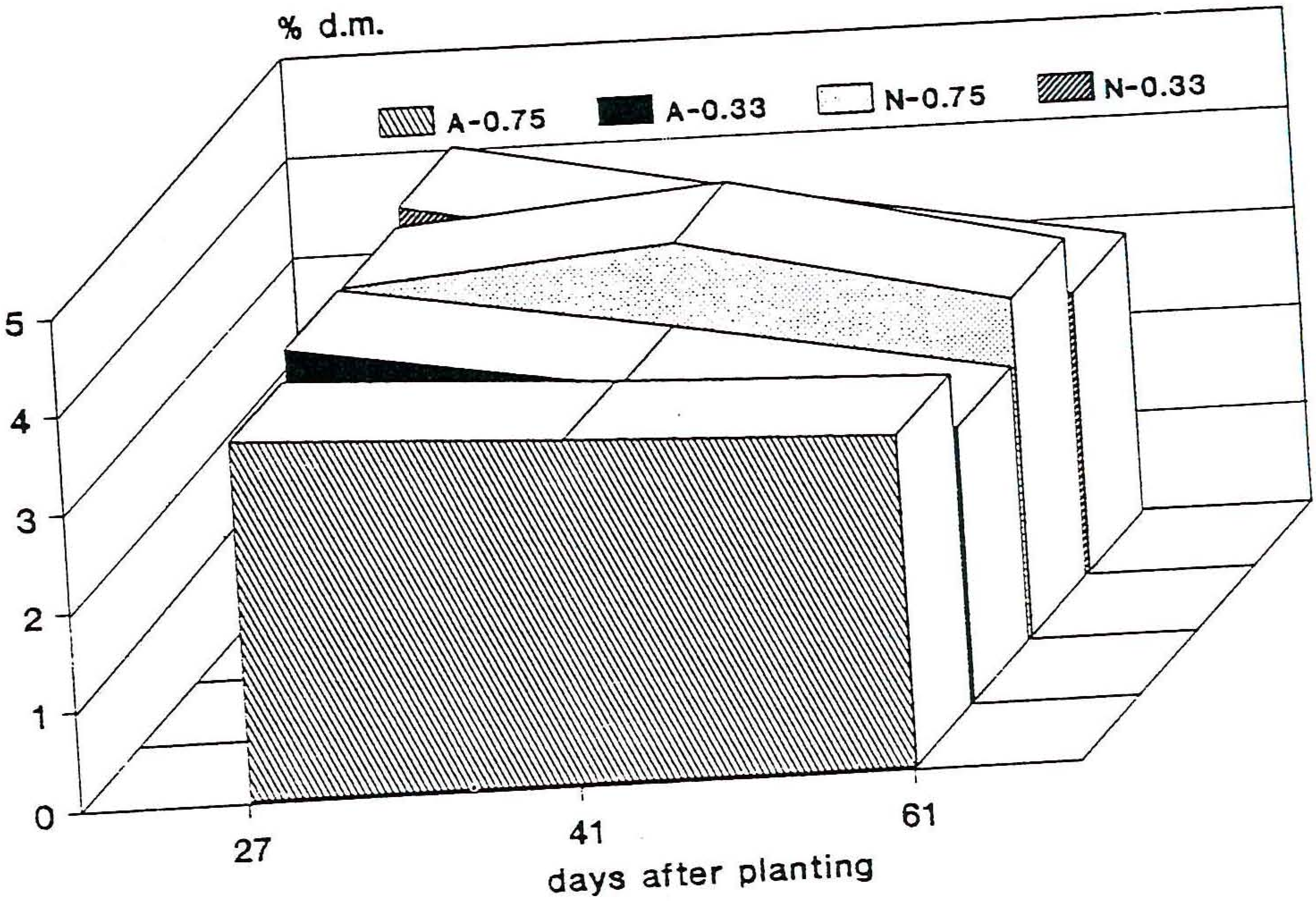

Figure 7. Calcium content in leaves

The opposite behaviour was observed concerning calcium levels with the plants of the A-0.75 treatment showing the highest values. Thus, the calcium concentrations are also closely connected with Ca/K ratio in the nutrient solution (10), and there was not observed a negative incidence of the ammonium supply on calcium levels in plants. Likewise it has been previously commented for nutrient uptake results.

Figures 5, 6, and 7 display the nitrogen, potassium and calcium levels in leaves at the three sampling times, respectively. The A-0.75 treatment show the lower nitrogen levels at the two last sampling times. The 0.75 treatments, specially the A-0.75 one, presented lower values of potassium. On the contrary, calcium levels in leaves were greater in the plants of the 0.75 treatments. So, the information and conclusions obtained from leaf analysis are the same as those obtained from sap analysis.

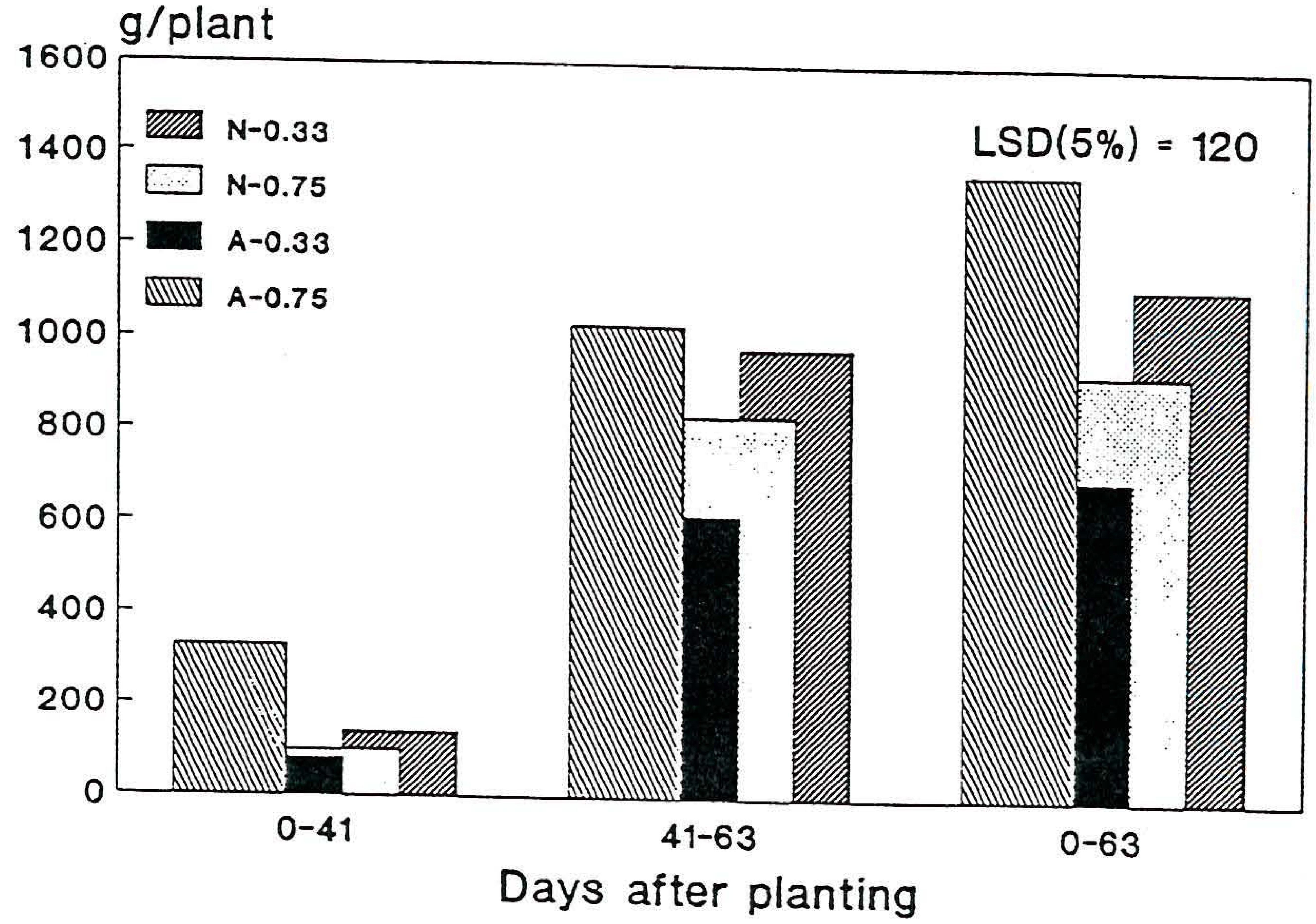

Figure 8. Yields (g of fruits/plant)

Figure 8 shows yields obtained from each treatment. The effect of ammonium supply was different depending on the Ca/K ratio in the nutrient solution employed with the highest Ca/K ratio the yields increased when ammonium was added (A-0.75 treatment yielded more than N-0.75 one); whereas with the lower Ca/K ratio, the addition of ammonium has a slight negative effect on yields (yields obtained from A-0.33 treatment were a little lower than those obtained from N-0.33 treatment).

Therefore, the A-0.75 treatment—that showed the lowest potassium and nitrogen plant levels and the highest calcium uptake and concentration in plant—offered the best results. Consequently, in order to obtain high yields from pepper cultivation, a Ca/K ratio in the nutrient medium higher than 0.33, combined with the addition of nitrogen as nitrate plus ammonium, is suggested.

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COMPENSATORY ROOT GROWTH IN WINTER WHEAT: EFFECTS OF COPPER EXPOSURE ON ROOT GEOMETRY AND NUTRIENT DISTRIBUTION

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ABSTRACT: Plants of winter wheat (*Triticum aestivum* L. cv. Starke II) were grown for seven days in split-root chambers containing nutrient solutions with various copper chloride ($CuCl_2$) concentrations [0.5/0.5 (controls), 0.5/2, 0.5/5, 0.5/7 and 0.5/10 µM]. At harvest (day 11), shoot dry weights were about the same in the different copper (Cu) treatments. Dry weights of the root parts exposed to 2-10 µM Cu (Cu-fed) decreased while they increased for the control roots. A Cu exposure of 2-10 µM severely retarded lateral root initiation and average lateral root length. Average seminal root length was also reduced. The control roots compensated for the retarded growth of the Cu-fed roots by increasing chiefly in lateral root number, but their average length remained similiar. Phosphorus (P) concentration decreased gradually in all determined plant parts (shoots, Cu-control and Cu-fed roots) with increased external Cu concentration. The potassium (K) concentration in the shoots was similarly affected, but it did not decrease in the Cu-fed roots until the external Cu concentration reached 10 µM. The Cu concentration in the Cu-fed roots increased proportionally to the external Cu concentration, but Cu was not exported to the other plant parts. The reasons for changes in root geometry and nutrient balance are discussed.

INTRODUCTION

The toxic nature of excessive Cu exposure has received a vast attention. Low pH, for example, can enhance Cu solubility in the soil (Tamm and Andersson,