Fertigation of Prmocane-Fruiting Raspberry – Leaf and Soil Nutrient Content between Applications

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Abstract

Amongst the agrochemicals, fertilizers have been the most frequently applied through microirrigation systems (fertigation). Although the method has been developed to a high technical level, there is yet a lack of information concerning the optimum timing and the doses under multiple fertilizer applications. The subject of the present article is the fertilizers' fate in the root zone and the raspberry plants' nutritional status between the fertigation events, under three levels of drip water supply – 100%, 75%, and 50% of the estimated crop evapotranspiration. The study was based on laboratory analyses of soil, soil solution and plant samples. It was found that fertigation maintained constant and sufficient concentrations of N, P, and K in the soil providing optimum mineral nutrition for the raspberry plants. Proper irrigation and fertigation management could successfully retain the fertilizers in the root zone, thus preventing losses and eventual pollution of soil and groundwater.

INTRODUCTION

When microirrigation is in use, it is a common practice to introduce fertilizers into root zone with the irrigation water (fertigation). The fertilizer application rate is usually split into parts and applied according to the biological curve of crop nutrient assimilation during the vegetation period (Branson et al., 1981; Decroix, 1988; Burt 2003). Although the fertigation has been developed to a high technical level, there is yet lack of knowledge concerning the optimum timing and the doses under multiple fertilizer applications. Water is the main carrier of nutrients and to a great extent determines the fertilizers' migration and localization in the root zone. Hence, the optimum plant nutrition, as well as the risk of eventual chemical pollution of both soil and groundwater, depends on an improved irrigation scheduling and management.

Nitrogen fertilizers are often used for fertigation. Nitrates move easily with the wetting front and, after larger water applications, the nitrate nitrogen may be washed below the root zone, thus decreasing the fertilization efficiency and increasing the risk of groundwater pollution (Bucks et al., 1982). Unlike nitrogen, phosphoric fertilizers are known to have an extremely low mobility in the soil and, if applied in traditional ways, these move downward with the irrigation water not more than 2 or 3 cm (Bucks et al., 1982; Rolston et al., 1986). The mobility of orthophosphates in the soil is considerably greater when they are applied through a drip-irrigation system (Rauschkolb et al., 1976; Stoilov et al., 1999). Under drip irrigation, the available potassium is limited to that in the moist soil (Rolston et al., 1986). Thus, potassium deficiency occurs very soon. It can be compensated by fertigation.

Apparently, proper fertigation management requires taking into consideration of many different factors, such as crop nutrient requirements, soil characteristics, fertilizer mobility and its possible transformations in the soil, root absorption, irrigation scheduling and, respectively, soil and plant water regime. The subject of this article is the fertilizers vertical migration and depletion in the soil in a raspberry plantation, as well as the nutritional status of raspberry plants, in the periods between fertigations and in the conditions of full and regulated-deficit drip irrigation (RDI). The experimental work was carried out in 2006-2007 at the Fruit Growing Institute in Plovdiv, Bulgaria. The presented results are part of a larger investigation project aimed at optimizing the water and the nutritional regime of raspberry plants under regulated deficit irrigation and fertigation (Koumanov et al., 2006).

MATERIAL AND METHODS

The experiment was carried out in a 400 m^2 raspberry (*Rubus Idaeus, L.*) plantation of the 'Lyulin' primocane-fruiting cultivar. The plantation was established in 1989 with distance between rows of 2.30 m and 0.50 m plant spacing in the rows. The soil in the plantation was *Fluvisol*. The soil phosphorus and potassium content as well as the soil pH, estimated at the beginning of the experiment, are shown in Table 1. The soil had layered structure with a more compacted upper layer, one permeable layer at 60-70 cm depth, and an underlying layer of low permeability at 90-105 cm. Soil bulk density varied from 1.45 to 1.66 Mg m^{-3}.

Plants were supplied with water by a drip irrigation system with one lateral per row and a 0.30 m dripper spacing along the laterals. The dripper discharge was 1.7 L h^{-1} (5.7 L h^{-1} m^{-1}). Irrigation was scheduled according to the reference evapotranspiration (ET_0) values estimated upon the readings of a 'Class A' evaporation pan with a pan coefficient K_P = 0.8. The evapotranspiration of the raspberry crop (ET_C) was calculated using the FAO values of the crop coefficient K_C (Allen et al., 1998). The coefficient of reduction was accepted, K_R = 1.0 for a crop canopy shadowing above 60% (Fereres et al., 1982). The irrigation was scheduled on a daily basis, except for the days after rainfalls.

Seven irrigation regimes were investigated during the main phenophases – F1) intensive growth, F2) blossom, and F3) fruit ripenning – the water applications being regulated by variants as follows: Vc-100 – 100% of ET_C (control); V1-75 – 75% of ET_C in F1; V1-50 – 50% of ET_C in F1; V2-75 – 75% of ET_C in F2; V2-50 – 50% of ET_C in F2; V3-75 – 75% of ET_C in F3;and V3-50 – 50% of ET_C in F3.

Fertilizers were injected in the irrigation water (fertigation) using a proportional dosind pump (DOSATRON INTERNATIONAL, Bordeaux, France). Fertilizer application rates were estimated on the basis of leaf analyses and were identical for all variants of irrigation. The fertilizers were respectively of the 'Kristalon' series of YARA in 2006, and 'Labin 15-15-15' of MACASA in 2007. The fertilizers, the annual fertilization rates and their partition by months during the vegetation are given in Table 2.

The investigation was carried out in variants Vc-100, V3-75 and V3-50. For that purpose, extractors of soil solution (tensionics) were installed in the root zone of the raspberry plants – in the middle of the row strip at depths of 10 cm, 30 cm, 50 cm, and 70 cm. In 2006, soil and plant sampling was done from 31 July till 15 August, in the phase of fruit ripening. Samples of soil solution were taken before the current fertilizer application, two hours after the fertigation, and daily – two hours after the current water application. The content of nitrate nitrogen, ammonium nitrogen, and phosphorus in the soil solution was measured using RQflex Reflectometer of MERK, and that of potassium was estimated by a flame photometer. In order to assess the fertigation effect on the raspberry plants, leaf samples were taken daily and analyzed for the content of nitrogen – by distillation, of phosphorus – colorimetrically with hydrazin-sulphate as a reducer, and of potassium – using a flame photometer. Two weeks after the fertigation, soil samples were taken in parallel with the soil solution sampling. The content of mineral nitrogen (N-NH_4^+ and N-NO_3^-) in soil samples was determined by the distillation method, after extraction by 1.0 % of KCl. The content of mobile phosphorus (P_2O_5) was estimated in a lactate extract (DL-method), colorimetrically, and that of potassium (K_2O) – by a flame photometer. The soil reaction (pH) was estimated potentiometrically, in a water extract (1:2.5).

The same experiment was repeated from 13 till 26 June 2007, in the phase of fruit ripening. In this period, however, the plants were receiving equal amounts of water and fertilizers in the three variants. Thus, eventual differences in the results would reflect some post-effects of the RDI like the root spatial distribution or the nutrient accumulation in specific zones of the wetted soil volume. Soil solution samples were taken one day before and two hours after the fertigation, as well as 1, 4, 7, and 12 days afterwards. Leaf sampling was done on the same days. Soil samples were taken on 13 and 26 June 2007.

RESULTS AND DISCUSSION

Results for the content of N, P, and K in the leaves are illustrated in Fig. 1. The concentrations of nitrates, phosphorus and potassium in the soil solution are shown in Figs. 2 and 3, for 2006 and 2007 respectively, and these in the soil – in Fig. 4.

Immediately after the fertigation, the content of nitrate nitrogen in the soil solution increased significantly only at a depth of 10 cm. More nitrates were retained for a longer period in the top soil layer of the RDI variants V3-75 and V3-50, Fig. 2. On the other hand, under full irrigation (Vc-100) there was leaching of nitrates downwards the profile. Because of the frequent application of fresh water, the concentration of nitrate-nitrogen in the soil solution at 10 cm depth decreased with time to very low values at the moment of the next fertigation event. At the other depths, however, the nitrates remained relatively constant during the whole two-week period between the fertilizer applications. The concentration of ammonium nitrogen was less than 5 mg L^{-1} in all samples.

Along the sampling period in 2006, the concentration of mobile phosphorus decreased twice at all depths of sampling and in all the variants, probably due to adsorption on soil colloids (Fig. 4) and to an active root extraction, Fig. 1. In 2007, the increased P application (Table 2) maintained the P levels relatively constant in the soil solution, in the soil, and in the leaves. The lowered (by 39%) K application in 2007, however, decreased the leaf K to the optimum's limit, Fig. 1. On the other hand, the content of K in both soil and soil solution wasn't affected by the fertigation and remained relatively constant until next application. In the soil of the RDI variants, the P and K distribution in depth was typical for a low-mobility element – high concentrations on the top, decreasing downwards, Fig. 4. Under full irrigation, the larger water application moved P and K to greater depths, thus providing their uniform distribution in the root zone. Fertigation maintained almost unchanged the N, P, and K levels in the raspberry plants, Fig. 1. Reduction in the application rates of P by 31% (2006) and of K by 39% (2007) resulted in a decrease in the content of these nutrients in the leaves.

CONCLUSIONS

When used properly, fertigation maintains constant and sufficient concentrations of N, P, and K in the soil providing optimum mineral nutrition for the raspberry plants.

Fertilizers applied through drip irrigation systems can be retained in the root zone by a proper irrigation management, thus preventing losses and eventual pollution of the soil and groundwater.

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<u>Tables</u>

Table 1 Content of phosphorus and potassium in the soil as well as soil pH at the beginning of the experiment.

Layer	Reaction	P_2O_5	K_2O
cm	pH	mg/100g	mg/100g
0 – 25	7.3	10	16
26 –50	7.1	3	11
51– 75	7.1	1	7

Table 2 Annual fertilization rates and their partition by months in 2006 and 2007.

Fertilizers/ Elements	Annual rates	Partitioning of the annual fertilization rates by months				
		April	May	June	July	August
	kg/ha	%	%	%	%	%
2006 'Kristalon'	12 doses	2 doses	3 doses	3 doses	2 doses	2 doses
N	132	18	19	29	26	8
P_2O_5	91	24	16	24	23	13
K_2O	145	16	15	30	29	10
MgO	16	12	15	32	30	11
2007 'Labin'	13 doses	3 doses	3 doses	3 doses	3 doses	1 dose
N	132	18	19	28	26	9
P_2O_5	132	18	19	28	26	9
K_2O	132	18	19	28	26	9
S	88	18	19	28	26	9

Figures

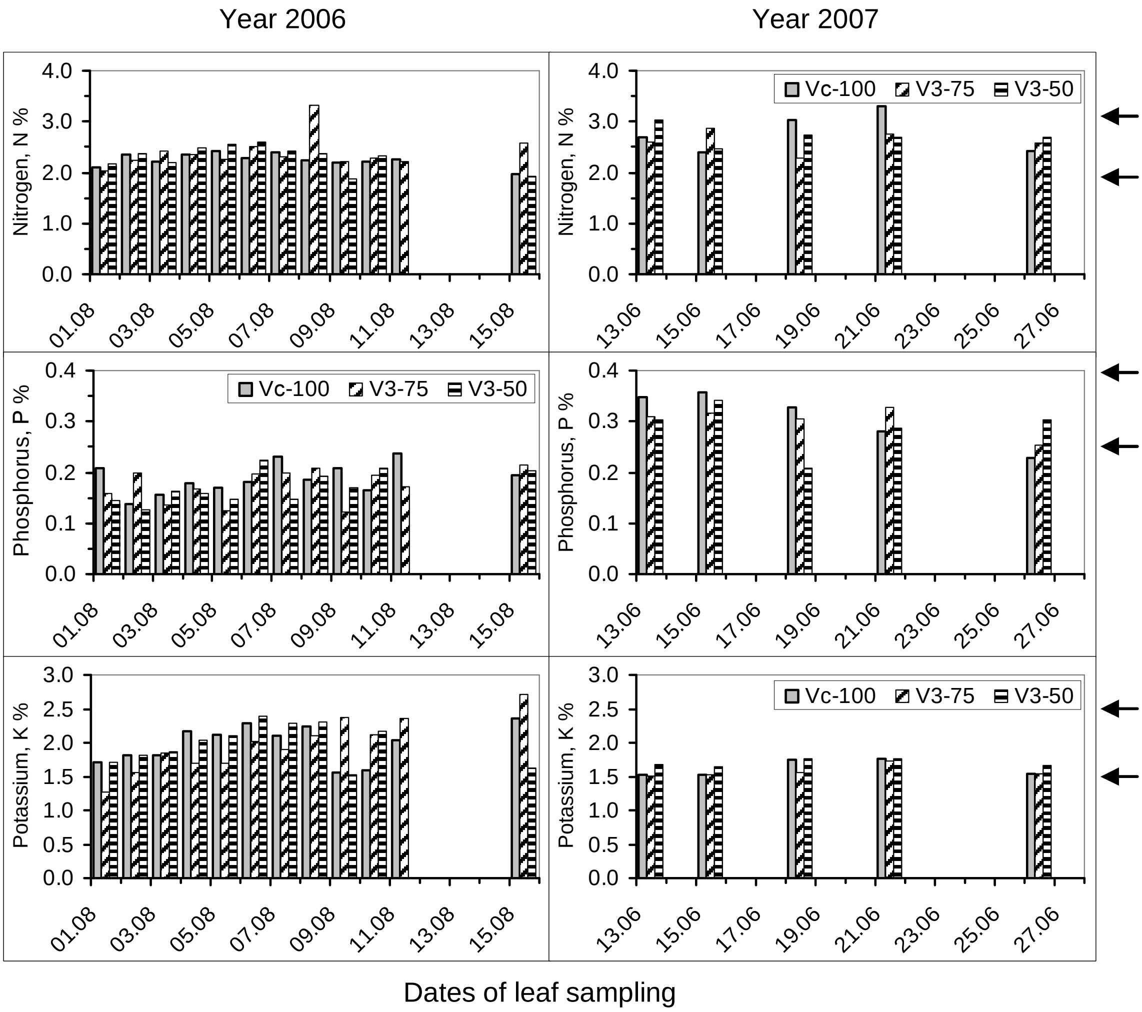

Fig. 1 Content of N, P and K in the leaves. Arrows mark the optimum limits.

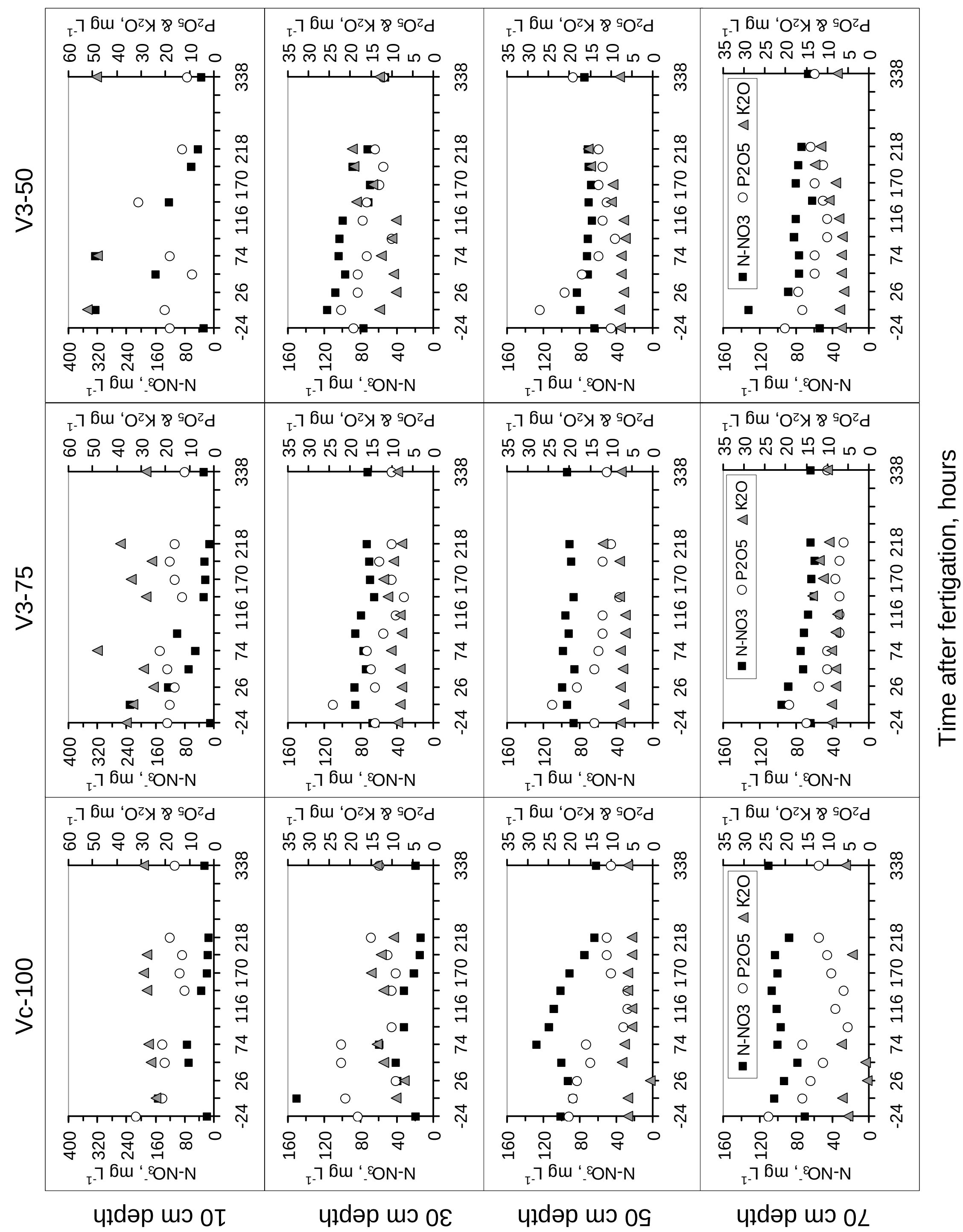

Fig. 2 Concentration of the nitrates, phosphorus and potassium in the soil solution under different irrigation regimes in the period between two fertigation events – phase of fruit ripening, 2006.

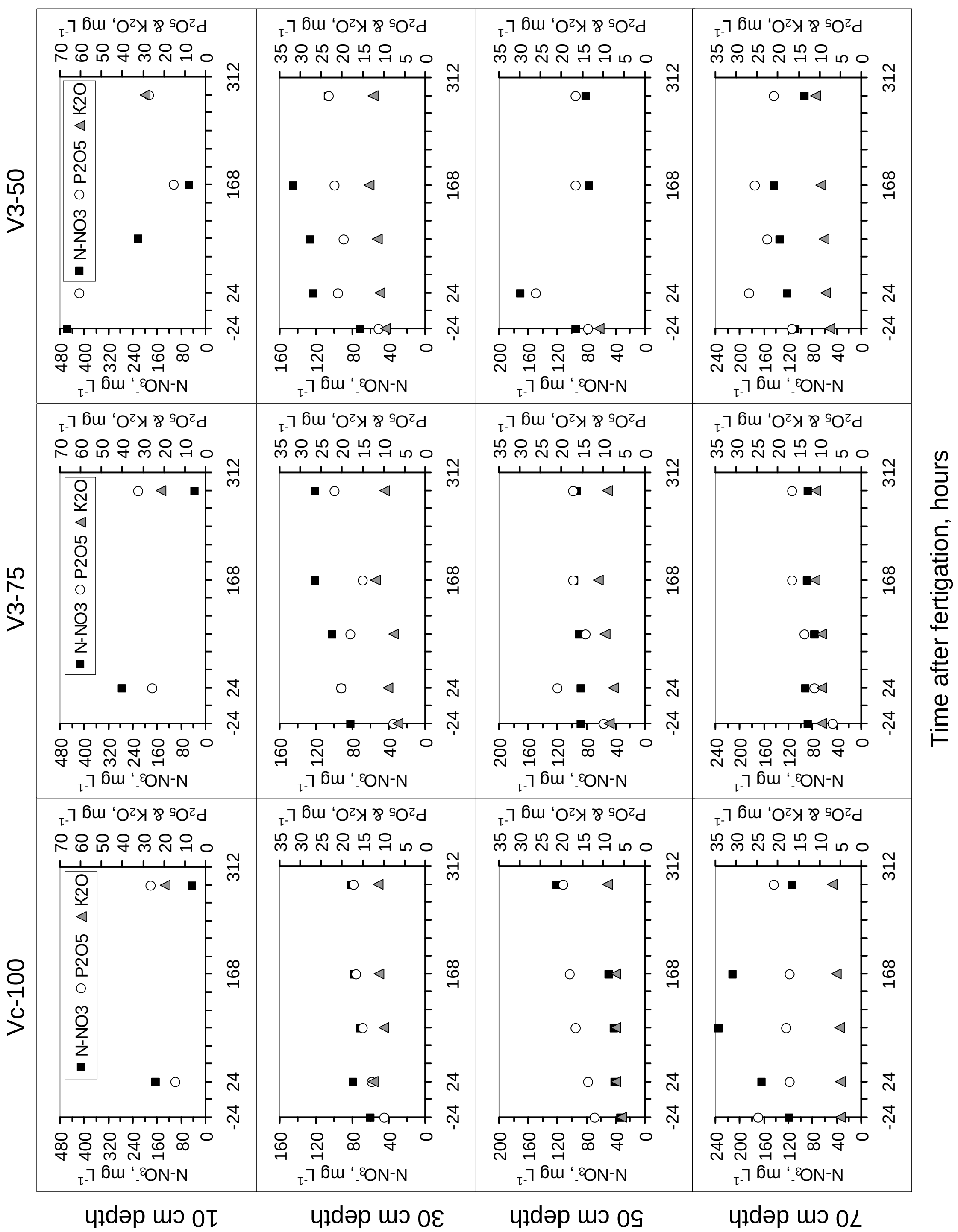

Fig. 3 Concentration of nitrate nitrogen, phosphorus and potassium in the soil solution under identical irrigation regimes in the period between two fertigation events – phase of intensive growth, 2007.

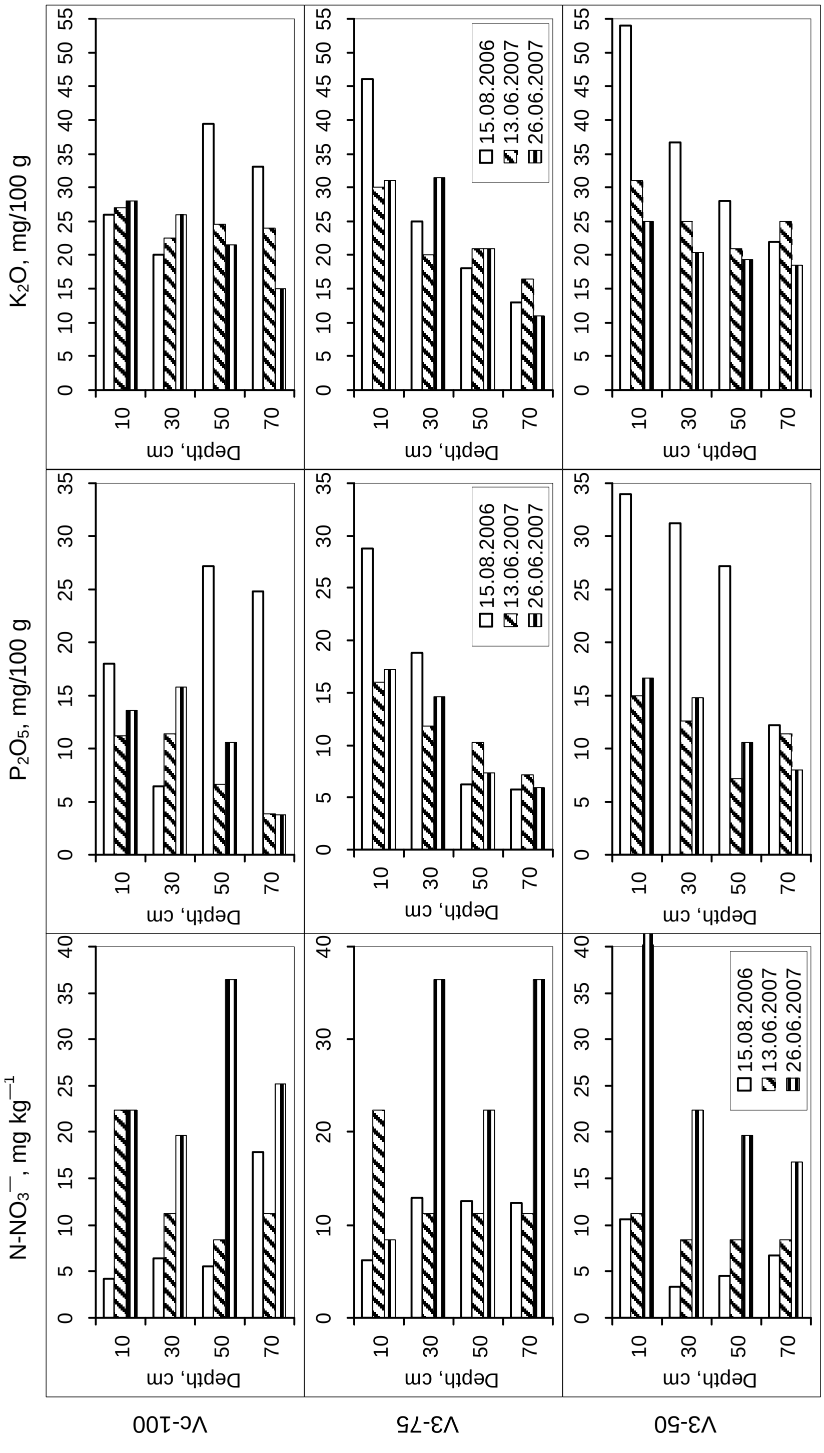

Fig. 4 Content of nitrate nitrogen, phosphorus and potassium in the soil samples taken before the current (13.06.2007) and the next (26.06.2007 and 15.08.2006) fertigation events.