Mineral Nutrients Compositions of *Daucus Carrota* Culture, in Different Stages of Morphogenesis

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This study was designed to determine the optimum fertilisers rates required for quality (Nt, P, K, Mg, Fe, Cu, Mn, Zn) of Daucus Carrota culture, in different stages of development. Field trials were conducted during the early seasons of 2011, on a black Chernozem soil. The experiment was a randomized complete block design with four replications. The experimental site was cleared and 28 beds of 1 x 1 m² each in sizes were prepared manually. The primary (macro) nutrients K, P, Mg and micronutrients (Fe, Cu, Zn and Mn) were determined by AAS method and Nt content (%) was determined with the help of Kjeldahl unit. Most of the mineral nutrients of analysed carrot samples, were significantly influenced by the sole application of NPK fertilizers rates and growth regulators (Aqzyme and Pervaide). To mature plants, the more the root system is stronger, with a greater capacity of absorption and exploit a larger volume of soil, the lower are requirements for soil nutrients and vice versa. Copper (Cu) content reveals a deficiency compared to the normal level, in variants v6 and v7. Highest Zn content was accumulated in variant with low NPK fertilization and in presence of Aqzyme. In all morphogenesis stages, the iron content of carrots decreases as the NPK fertilizers dose increases.

Keywords: macronutrients, micronutrients, Daucus carrota, fertilizers

The macro and micronutrients effect on vegetable plants is very complex and dependent on the quantity absorbed and the relationship between them. In the first stages of development vegetable species have higher requirements from mineral components [1-3]. This involves a good supply of soil, without losing sight that seedlings are sensitive to soil solution concentration. So, fertilization should be done in steps, especially those fertilizers with high solubility, such as nitrogen fertilizers. Slow leaching products such as phosphorus fertilizers, can be administered with the preparation of the soil [4].

Carrot (Daucus Carrota) belongs to root vegetables group and is considered as one of the most valuable vegetable because of its food value and that it can be eaten fresh all year [5]. Carrot roots contain 86.77% water, 12-14% dry substance, 6-9% carbohydrate, 0.2 to 0.3% fat, 0.8 to 1.4% crude protein and 1 to 1.9% minerals Ca, Fe, Mg, P, K and volatile substances. Consumption of 100 g carrot / day provides to the human body needs in vitamin A important in growth processes, improve vision in elderly people, maintain healthy skin and of the different organs of the human body [6]. Because carrot crop has high economic value, the fertilization management strategy seeks maximum yield by supplying all requirements of the crop [7].

Fertilization is the most important and controllable factor affecting nutritional value of vegetables. The type and value of fertilizer and the level of application directly influence the level of plant available nutrients and indirectly influence plant physiology and chemical content. Nitrogen is necessary for formation of amino acids, the building blocks of protein, is essential for plant cell division and vital for plant growth also is directly involved in photosynthesis [8].

Phosphorus plays an important role in germination and emergence, promotes early root formation and growth and improves vegetables quality. Phosphorus is a component of adenosine triphosphate which supplies the energy for plant processes [9,10]. Magnesium is a secondary nutrient and a key element of chlorophyll production, Improves utilization and mobility of phosphorus is and activator and component of many plant enzymes, increases iron utilization in plants and influences earliness and uniformity of maturity [11].

Heavy metals toxicity is influenced by the solubility of metal and metal compounds [12]. Literature studies have revealed a potentiating synergism between Cu and Zn, Cu and As, Cu and Sn, Zn and As, but an antagonism between these elements and Pb. Synergistic or antagonistic effects depend upon the dose and application duration of substances [13].

Copper is used in the phytosanitary treatment (green algae control in basins, diseases of the grape vine) and industry. It accumulate mainly in root vegetables (carrots). Plants require small amounts of Cu, an average for normal growth being situated between 5-20 mg kg. Over this value is copper considered toxic [14].

Previous investigations, [15, 16], showed that contamination of soils by macronutrients and heavy metals is one of the environmental problems that the agriculture faces today. From soils these elements are taken by plants influencing the nutritive values of products. Other investigations presented the influence of nitrogen rates, rate of N or foliar nutrition on the concentration of nutritive components in carrot roots. Results were showing the effects of the interaction between foliar nutrition and diverse doses of nitrogen fertilization [17].

The aim of this research was to determine the effect of growth regulators in connection with diversified fertilization (concerning the form, the doses and kind of fertilizer) on the content of mineral nutrients compositions of *carrot* culture, in different stages of morphogenesis.

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Experimental part

Material and method

Field trials were conducted during the early seasons of 2011, on a black Chernozem soil.

The experiment was a randomized complete block design with four replications.

The experimental site was cleared and 28 beds of 1 x 1 m^2 each in sizes were prepared manually. The experimental variants used were: v1 - $N_0P_0K_0$, v2 - $N_{60}P_{60}K_{60}$, v3 - $N_{90}P_{90}K_{90}$, v4 -$N_{120}P_{90}K_{90}$, v5 - $N_{60}P_{60}K_{60}$ + Aqzyme 1 l/ha, v6 - $N_{60}P_{60}K_{60}$ + 2 x Pervaide 1 l/ha, v7 - Manure 20 t/ha. The fertilizers used were NPK complex type 16:16:16, and NH_4NO_3. De Nantes seed was used as carrots test crop. The seeds were sown in 7 April and after 30 days the culture was thinned down. Weeds were controlled by hoeing and herbicide Dual Gold application. Aqzyme growth regulator contains Fungi enzymes (99%), cooper (0.05%), iron (0.10%), manganese (0.05%), zinc (0.05%). The state of macro and micronutrients of soil supply was proper, for phosphorus (P) registered 121 mg/kg, the range for vegetables grown in the field, is between 108.1 – 144.0 according to studies of literature [1]. Nt % soil supply state was medium 0.185 %, framing in range 0.141 – 0.270 %, quoted in other studies [2]. The copper (Cu) concentration determined in soil samples from the experimental field 0.25 mg/kg, lower than 0.5 mg/kg noted in literature studies as a medium Cu in soil for growing vegetables [16]. The same studies indicate the average content of Zn in soil between 1.5 - 3.0 mg/kg. Zn content determined in the experimental field was 1.9 mg / kg, the soil being medium supplied with Zn.

The carrot samples were collected in 3 major stages of culture morphogenesis: thinned down of culture, when plants had 5-6 leaves in the rosette (1st morphogenesis stage), beginning of root thickening (2nd morphogenesis stage) and full maturity when roots were at least 1.5-2 cm thick in the upper part (3rd morphogenesis stage).

The analyses were performed in the Laboratory of Soil Science and Plant Nutrition, Faculty of Agriculture, USAMVB Timisoara. The macro nutrients K, P, Mg and micronutrients (Fe, Cu, Zn and Mn) were determined by AAS (Varian 220 FAA equipment). Method detection limit (MDL mg/L) for analyzed nutrients was 0.02 mg/L for Mg and Mn; 0.06 mg/L for Fe; 0.03 mg/L for K; 0.04 for Zn; 0.01 mg/L for Cu.

The Nt % was determined with the help of Kjeldahl mineralization - distillation unit (Velp Scientific 127) digested in H_2SO_4 distilled and titrated with 0.1M NaOH [18].

According to Order no. 640 of 19/09/2001 [19] maximum admitted limit of heavy metals in fresh vegetables, are Cu 5 mg/kg, Zn 15 mg/kg.For Mn and Fe were not established maximum allowable limits but studies in the literature reveals values between 3-5 mg/kg (Mn) and 5 mg/kg (Fe) [20; 21].

The year 2011 was characterized by a higher than average monthly temperature (in April, May and June) and lower total rainfall occurring drought. All data obtained were statistically analyzed by OriginPro 8.1 SR 1 software for Microsoft Windows.

Results and discussions

The results concerning the determination the mineral elements in carrot samples are indicated in tables 1-4. Most of the mineral nutrients of analysed carrot samples were significantly influenced by the sole application of NPK fertilizers rates and growth regulators.The quality attributes increased as the N rates increased with the highest contents recorded at 120 kg N/ha of fertilizer application. Total nitrogen content (Nt%) carrot roots, in the 1st morphogenesis stage, ranged from 0.090% to unfertilized control variant to 0.412% to variant 4 fertilized with 120 kg N (table 1).

Nitrogen requirements of carrots are relatively low. Nitrogen is an essential element for healthy plant growth, being a constituent of proteins and chlorophyll. In all morphogenesis stages, the highest nitrogen content was determined at the application of $N_{120}P_{90}K_{90}$. There is a proportional increase of the nitrogen content of carrots with the increasing dose of nitrogen fertilizer applied. Similar results were found by Westerveld et al., 2006 [22]. Carrots are capable of taking up and removing much more nitrogen than is applied. Carrots absorb nitrogen throughout the vegetation period. The amount of nitrogen absorbed is reduced to seeds germination, but grows in phenophases were the main vegetative organs are formed. Presence of phosphorus and potassium applied as fertilizer favors nitrogen accumulation. High nitrogen content stimulates leaf growth at the expense of root development and yield, and also delays harvesting. Very lush leaf growth may also promote the development of diseases, such as Sclerotinia white mould.

The limits of variation of Nt (%) at full maturity of plants, frame between 0.290 – 0.592% (table 1).

Regarding plant content in K (mg/kg) content, all experimental variants registered inferior amounts than control variant (V1); NPK fertilization did cause significant changes in potassium (mg/kg) content in carrot, especially in variants with high K dose of 90 kg/ha (v3 – 3511.42 mg/kg and v4 – 3872.28 mg/kg) (table 2).

However, a notable effect of organic fertilization on the concentration of K in carrot was registered in variant v7

Table 1

MINERAL NUTRIENTS COMPOSITIONS (***N* %**) OF *DAUCUS CARROTA* CULTURE IN DIFFERENT MORPHOGENESIS STAGES

Experimental variants	*Nt %*			Average	Standard deviation
	1st morphogenesis stage	2nd morphogenesis stage	3rd morphogenesis stage		
$N_0P_0K_0$	0.090	0.260	0.290	0.213	*±0.1078*
$N_{60}P_{60}K_{60}$	0.219	0.322	0.369	0.303	*±0.0767*
$N_{90}P_{90}K_{90}$	0.325	0.465	0.490	0.426	*±0.0889*
$N_{120}P_{90}K_{90}$	**0.412**	**0.539**	**0.592**	**0.514**	*±0.0925*
$N_{60}P_{60}K_{60}$ + Aqzyme 1 l/ha	0.350	0.450	0.470	0.423	*±0.0643*
$N_{60}P_{60}K_{60}$ + 2 x Pervaide 1 l/ha	0.336	0.436	0.476	0.416	*±0.0721*
Manure 20 t/ha	0.238	0.483	0.518	0.413	*±0.1525*

Results for Nt % (1st; 2nd; 3rd morphogenesis stages) are given as mean of 4 determinations.

Table 2
MINERAL NUTRIENTS COMPOSITIONS (***K mg/kg***) OF *DAUCUS CARROTA* CULTURE IN DIFFERENT MORPHOGENESIS STAGES

Experimental variants	*K mg/kg*			Average	Standard deviation
	1st morphogenesis stage	2nd morphogenesis stage	3rd morphogenesis stage		
v1 - $N_0P_0K_0$	1485.37	1271.69	1041.32	1266.13	*±222.07*
v2-$N_{60}P_{60}K_{60}$	2996.20	2529.06	2062.33	2529.19	*±466.93*
v3 -$N_{90}P_{90}K_{90}$	**3971.22**	**3401.86**	**3161.20**	**3511.42**	*±415.97*
v4-$N_{120}P_{90}K_{90}$	**4528.26**	**3807.72**	**3280.88**	**3872.28**	*±626.19*
v5-$N_{60}P_{60}K_{60}$ + Aqzyme 1 l/ha	3473.78	2620.24	2108.42	2734.15	*±689.77*
v6-$N_{60}P_{60}K_{60}$ + 2 x Pervaide 1 l/ha	3194.50	2490.37	2288.80	2657.89	*±475.52*
v7-Manure 20 t/ha	3877.11	2047.55	1967.49	2630.71	*±1080.15*

Results for K mg/kg (1st; 2nd; 3rd morphogenesis stages) are given as mean of 4 determinations.

(manure 20 t/ha), in the 1st morphogenesis stage being recorded 3877.11 mg/kg (table 2). But then during the growth of the culture, the concentration decreases being recorded 2630.71 mg/kg, to full maturity of the plant, value in accordance with results obtained in other literature studies [16].

Phosphorous (P) and potassium (K) content, increased with increasing K and P up to 90kg/ha, variant v3 ($N_{90}P_{90}K_{90}$) and v4 ($N_{120}P_{90}K_{90}$). In the first stages of development, (table 2) were registered 3971.22 ppm (V3) and 4528.26 ppm (v4) for potassium content and thereafter declined being recorded at full maturity 3161.20 ppm (v3) respectively 3280.88 ppm (v4) (table 2).

Carrots have a particularly high potassium (K) requirement and sufficient K must be applied to meet crop needs. High potassium ensures a better quality - crisper, better coloured roots – and also enhances keeping quality after harvesting; wilting is retarded. Potassium (K) uptake in roots occurs mainly through active and only the ionic form. Potassium ions (K+) are absorbed into the roots in larger quantities than other nutrients ions. Thus the root system of plants has a considerable content of K. Sanderson and Sanderson, 2006, indicated that increasing rates of applied potassium linearly increased the potassium content of carrots [23], results that are similar with ours. Kadar (2008) found that potassium uptake was improved by potassium fertilizer application [24]. Researches confirm that rise of potassium (K) concentration in carrots is due to rise of nitrate levels in soil and plant tissue. After application of high nitrogen doses, potassium has in plant neutralization role of high nitrate concentration.

Regarding phosphorus (P) content, in the first stages of plant development were registered higher values (v3 - 454.63 ppm; v4 - 473.10 ppm), than to the complete plant

Table 3
MINERAL NUTRIENTS COMPOSITIONS (***P mg/kg)*** OF *DAUCUS CARROTA* CULTURE IN DIFFERENT MORPHOGENESIS STAGES

Experimental variants	*P mg/kg*			Average	Standard deviation
	1st morphogenesis stage	2nd morphogenesis stage	3rd morphogenesis stage		
v1 - $N_0P_0K_0$	265.12	244.23	200.28	236.54	*±33.09*
v2-$N_{60}P_{60}K_{60}$	349.16	316.00	305.17	323.44	*±22.92*
v3 -$N_{90}P_{90}K_{90}$	454.63	411.33	398.29	421.42	*±29.49*
v4-$N_{120}P_{90}K_{90}$	**473.10**	**425.37**	**386.05**	**428.17**	*±43.59*
v5-$N_{60}P_{60}K_{60}$ + Aqzyme 1 l/ha	369.18	328.14	287.64	328.32	*±40.77*
v6-$N_{60}P_{60}K_{60}$ + 2 x Pervaide 1 l/ha	372.15	336.15	294.71	334.34	*±38.75*
v7-Manure 20 t/ha	381.20	324.28	270.33	325.27	*±55.44*

Results for P mg/kg (1st; 2nd; 3rd morphogenesis stages) are given as mean of 4 determinations.

Table 4
MINERAL NUTRIENTS COMPOSITIONS (***Mg mg/kg)*** OF *DAUCUS CARROTA* CULTURE IN DIFFERENT MORPHOGENESIS STAGES

Experimental variants	*Mg mg/kg*			Average	Standard deviation
	1st morphogenesis stage	2nd morphogenesis stage	3rd morphogenesis stage		
v1 - $N_0P_0K_0$	348.38	228.70	132.12	236.4	*±108.33*
v2-$N_{60}P_{60}K_{60}$	501.63	203.39	199.35	301.46	*±179.36*
v3 -$N_{90}P_{90}K_{90}$	402.39	354.47	200.19	319.02	*±105.65*
v4-$N_{120}P_{90}K_{90}$	489.37	390.64	240.12	373.37	*±125.52*
v5-$N_{60}P_{60}K_{60}$ + Aqzyme 1 l/ha	**578.08**	**437.64**	**380.16**	**465.29**	*±101.81*
v6-$N_{60}P_{60}K_{60}$ + 2 x Pervaide 1 l/ha	435.83	402.53	195.99	344.78	*±129.93*
v7-Manure 20 t/ha	518.14	340.62	200.25	353.00	*±159.30*

Results for Mg mg/kg (1st; 2nd; 3rd morphogenesis stages) are given as mean of 4 determinations.

maturity were registered (398.29 ppm – v3), (386.05 ppm – v4) (table 3).

Phosphorus (P) promotes root development and thus ensures more vigorous growth. It is a very important element for all root crops. Most crop plants, such as carrot, absorb 60-75% of total phosphorus in the first quarter and sometimes in the first half of the vegetation period. This fact explains the higher phosphorus accumulation in first morphogenesis stage. Application of nitrogen fertilizers alongside phosphorus fertilization has a better influence upon phosphorus capitalization from soil and favourable changes root capacity to absorb phosphorus from soil and fertilizers.

Magnesium (Mg) is vital in chlorophyll and with magnesium deficit the chlorophyll and leads to lower concentration of carotenoids. It has an important role in carbohydrate synthesis which has important role in embryogenesis. Magnesium stimulates ribosome accumulation during protein synthesis and ATP production at phosphorelation process which are important for embryogenesis. Magnesium (Mg) absorption and therefore his content in plants, is influenced by the antagonist interaction that occurs between magnesium and other nutrients. Application of high potassium rates diminishes magnesium content in carrots. At highest potassium rate variant $N_{90}P_{90}K_{90}$, magnesium content was ranged between 200.19 ppm in the 3rd morphogenesis stage and 402.39 ppm in 1st morphogenesis stage. Also, application of high nitrogen rates, as ammonium ion, can lead to a decrease in magnesium content of plant. At highest nitrogen rate, associated with large potassium dose, variant $N_{120}P_{90}K_{90}$, magnesium content in carrots was ranged between 240.12 ppm and 489.37 ppm (table 4).

Vegetable species have large requirements for the mineral elements in the first stages of growth, because their root system is still underdeveloped and can not explore a large volume of ground.

Microelements values registered in all experimental variants are framing in variation limits cited in literature studies for each element analysed [20, 21].

Regarding copper content of analyzed carrot samples reveals a deficiency compared to the normal level, in the samples of the following variants v6 ($N_{60}P_{60}K_{60}$+2xPervaide 1 l/ha) and v7 (manure 20 t/ha), the 1st stage of culture development 2.15 ppm respectively 1.57 ppm (table 2) and 2nd morphogenesis stage: 1.92 ppm respectively 1.10 ppm, reaching to the plant full maturity that Cu content to be even lower than in the first stages 1.25 ppm (v6) and 1.05 ppm (v7), the normal level of copper in vegetables is up to 5 mg / kg. Plants require small amounts of Cu, an average for normal growth being between 5-20 mg/kg. Over this value copper is considered toxic. Copper accumulates in roots and cell walls, thus transported in the plant and can be eliminated mainly through the leaves [3]. The normal content of Cu (mg/kg) occurred in all vegetation phases of culture, to the variant v5 - $N_{60}P_{60}K_{60}$ + Aqzyme 1 l/ha, to which have determined a content of 6.53 ppm, and 5.57 ppm , in first morphogenesis stages, then to full maturity of the plant to be registered 4.69 ppm (fig. 1). Varying quality of the soil affects copper accumulation in plant roots. It is supposed that some reactions that modify these qualities, respectively the nitrogen content of soil, are important factors for passive transport of copper (Cu).

Copper (Cu) occupies an important place in the reduction of nitrates to nitrites entering in the composition of nitrite reductase reducing enzyme. The absence of copper leads to slow reaction of nitrite reduction to ammonium ion and therefore promotes the accumulation of nitrite in the plant. The Cu concentrations determined in all variants and in all morphogenesis stages are in accordance with the soil supply. The copper (Cu) concentration determined in soil samples from the experimental field 0.25 mg/kg, lower than 0.5 mg/kg noted in literature studies as a medium Cu in soil for growing vegetables.

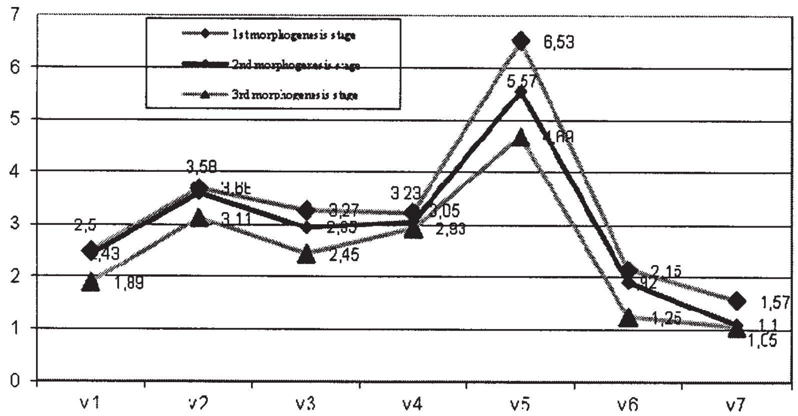

Fig. 1. Evolution of Cu (mg/kg) content in Daucus carrota culture in different morphogenesis stages (results are given as mean of 4 determination)

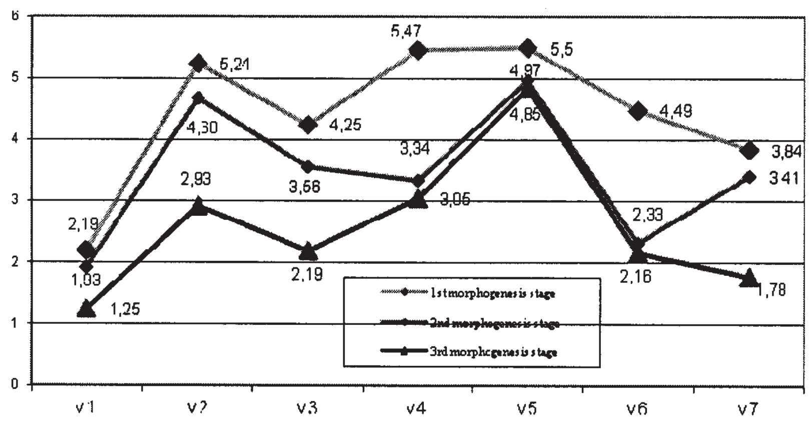

Fig. 2. Evolution of Zn (mg/kg) content in Daucus carrota culture in different morphogenesis stages (results are given as mean of 4 determination)

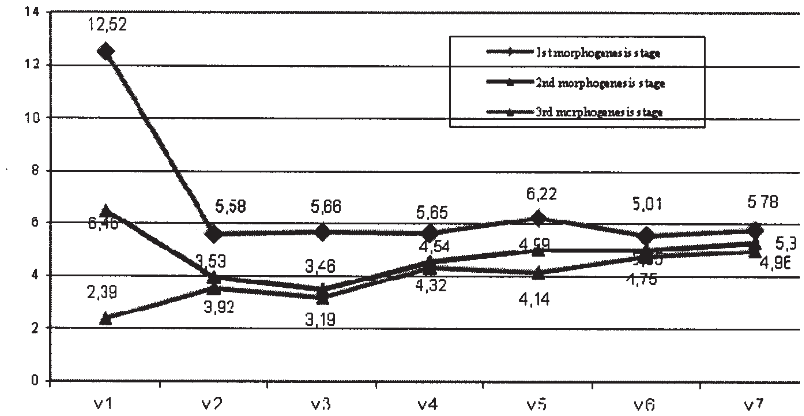

Fig. 3. Evolution of Fe (mg/kg) content in *Daucus carrota* culture in different morphogenesis stages (results are given as mean of 4 determination)

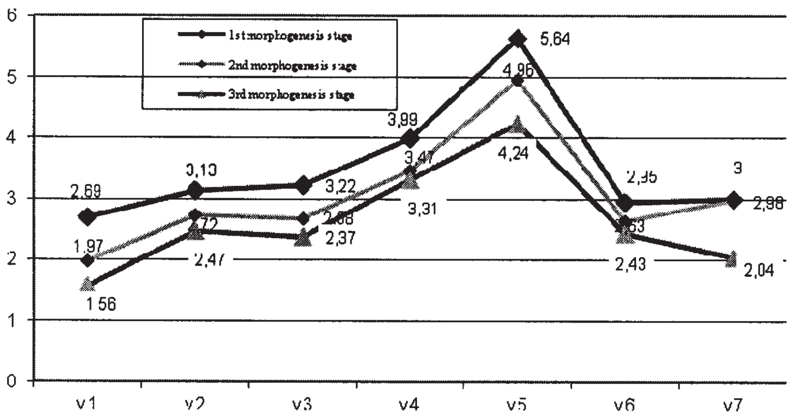

Fig. 4. Evolution of Mn (mg/kg) content in Daucus carrota culture in different morphogenesis stages (results are given as mean of 4 determination)

Zinc (Z) plays an important part in the formation and activity of chlorophyll along with assisting the function of enzymes and the growth of auxin hormone. Figure 2 shows that highest zinc content in carrots was accumulated in variant with low NPK fertilization ($N_{60}P_{60}K_{60}$) and in presence of Aqzyme which contains different micro-elements like zinc. Zinc accumulation in carrots may be inhibited by high phosphorus fertilization rate. Applications of zinc in soil phosphorus decrease its mobility and disrupt its uptake in the plant and translocation to other vegetative organs.

Iron is essential for many plant functions. Some of them are: chlorophyll development and function, it plays a role in energy transfer within the plant it is a constituent of certain enzymes and proteins and participates in plant respiration and plant metabolism. It is involved in nitrogen fixation. The highest iron accumulation takes part in first morphogenesis stage. In all morphogenesis stages, as figure 3 illustrates the iron content of carrots decreases as the NPK fertilizers dose increases. This can be explained by the fact that excessive amounts of soluble P, or high rates of P fertilizer, can inhibit Fe uptake in many crops. Increased NO_3 - N uptake can reduce Fe uptake by causing an anion-cation imbalance in the plant. K appears to play a very specific, but poorly understood role in the utilization of Fe. Some research indicates that low K availability can result in increased Fe uptake. To mature plants, the more the root system is stronger, with a greater capacity of absorption and exploit a larger volume of soil, the lower are requirements for soil nutrients and vice versa.

Manganese is essential for many plant functions. Some of them are: the assimilation of carbon dioxide in photosynthesis, it aids in the synthesis of chlorophyll and in nitrate assimilation, it functions in the formation of riboflavin, ascorbic acid, and carotene. Manganese activates fat forming enzymes. Manganese is preferentially absorbed by plants as the free Mn^{2+} ion from the soil solution. It is readily complexes with plant and microbial organic ligands and with synthetic chelates. However, complexes formed with synthetic chelates are generally considered to be absorbed more slowly by roots than the free cations. There is conflicting research that high soil P can either increase, or decrease Mn uptake by various plants species. Heavy fertilization with nitrogen fertilizer as NO_3^- can enhance Mn uptake in carrots. In variant 5 (fig. 4), where was found the highest manganese content, the lowest NPK fertilizer rate was applied all together with Aqzyme growth regulator, which contains manganese and fungi that can rise manganese mobility in soil and its uptake in carrots.

Conclusions

During the early morphogenesis stages of vegetable species studied, the values of macro elements (K, P and Mg) and microelements (Cu, Zn, Fe, Mn) were higher, plants having higher requirements to the mineral elements, because the root system is less developed and can not explore a large volume of soil.

Total nitrogen content (Nt%) ranged from 0.090% to v1 (unfertilized control) to 0.412% to v4 (120 kg N), in the 1st morphogenesis stage, afterwards during plant development requirements to this macro element to rise, so to full maturity being recorded concentrations between 0.290 % (v1) - 0.592 %(v4).

Phosphorous (P) and potassium (K) content, increased with increasing K and P up to 90kg/ha, variant v3 ($N_{90}P_{90}K_{90}$) and v4 ($N_{120}P_{90}K_{90}$). In the first morphogenesis stages, were registered higher concentrations than to maturity of plant.

Application of high potassium rates diminishes magnesium content in carrots. At highest potassium rate variant $N_{90}P_{90}K_{90}$, magnesium content was ranged between 200.19 ppm in the 3rd morphogenesis stage and 402.39 ppm in 1st morphogenesis stage.

Copper (Cu) content reveals a deficiency compared to the normal level, in variants v6 and v7 in the 1st and 2nd morphogenesis stage, reaching to the plant full maturity that Cu content to be even lower than in the first stages 1.25 ppm (v6) and 1.05 ppm (v7), the normal level of copper in vegetables is up to 5 mg / kg.

Highest Zn content was accumulated in variant with low NPK fertilization ($N_{60}P_{60}K_{60}$) and in presence of Aqzyme which contains different microelements like zinc.

In all morphogenesis stages, the iron content of carrots decreases as the NPK fertilizers dose increases, because excessive amounts of soluble P, or high rates of P fertilizer, can inhibit Fe uptake in many crops.

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