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DEVIATIONS OF SOME NUTRIENT CONCENTRATIONS IN DIFFERENT PARTS OF SAFFLOWER CULTIVARS DURING GROWTH STAGES

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Abstract

The objective of this research was to examine the concentrations of P, K, Fe, Zn and Mn during growth and development in different parts of 4 safflower varieties. The nutrient concentrations of safflower showed variations depending on the varieties and plant parts at different stages of growth and development. Both phosphorus and potassium concentrations in all plant parts (except P concentration in head) decreased from shooting to maturity. Phosphorus concentrations in heads were higher than other parts at every stage of the growth and development in all varieties.

Iron concentrations in the roots, stems and leaves showed quite deviations during the periods. Zinc levels in all parts of varieties showed the similar tendency without big deviations until the first blooming. After this stage concentration of Zn showed irregular increases and decreased at harvest again (except root zinc concentration). Mn levels of the root, stem and head in all varieties decreased through the end of the period. But in leaf, Mn concentrations increased through the harvest generally.

Introduction

Nutrient concentration of a plant changes depending on mineral mobility and mineral functions during growing period. The nutrients with high metabolic activity such as potassium, phosphorus or nitrogen moves easily from older tissue to newly growing part of the plant. Therefore, concentrations of highly phloem-mobile elements decrease throughout the leaf development. Import and export of mineral nutrients occur simultaneously during life cycle of a plant. During the growing stage, as a rule, export of mineral nutrients increase and thus decrease in net concentration and decrease in amount per organ such as leaf (Smith, 1996; Beaufils, 1973). During vegetative growth, mineral supply to roots is often either permanently insufficient or temporarily interrupted. Remobilization of mineral nutrients from leaves to growing parts is vitally important for completion of life cycle of plants. Remobilization of mineral nutrients is particularly important during reproductive growth, when seeds, fruits and storage organs are formed. At this growth stage root activity and nutrient uptake generally decrease, therefore the mineral nutrient concentrations of vegetative parts quite often decline sharply at reproductive stage. Remobilization of highly phloem-mobile mineral nutrients can lead to rapid decline in their concentration in the vegetative shoots. From experiments with different vegetables, decrease of mobile mineral nutrient in leaf related to senescence can easily be seen (Wood *et al*., 1986; Mauk & Nooden, 1992).

In a study conducted by Garz (1966), with pea plant, changes of some nutrients concentration were examined from flowering to harvest and it was seen that nitrogen, phosphorus and potassium levels increased first and decreased continuously until ripening time. Similarly, potassium concentration of tomato varieties decreased from full bloom to ripening time and leaves showed severe potassium deficiency.

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The extend of remobilization of micro nutrients strongly depends on their concentrations in the fully developed leaves. During grain development in wheat, for example, leaves containing higher copper, lost more than 20% to 70% of their copper depending on leaf nutrient status (Hill *et al*., 1978). The extent of remobilization of micronutrients, but not manganese is also closely related to leaf senescence (Nable & Loneragan 1984). While Fe, Zn and Cu concentrations of leaf of soybean decreased, Mn and B concentrations increased with plant growth (Wood, 1986).

Safflower (*Carthamus tinctorius* L.) is grown commercially in the world as one of the world's oldest oilseed crops. Safflower seeds are primarily used for edible oil production (rich in linoleic acid over 70%) as a salad and cooking. Its flowers are also a natural dye source due to the including cartharmin (Smith, 1962). Since safflower is more drought and salt tolerant than some other oilseed plants such as sunflower, it is especially suitable for the dry and salty areas where other oilseeds are difficult to grow (Weiss, 1962).

The present study was carried out to determine P, K, Fe, Zn and Mn concentrations in different part of 4 safflower varieties in different growth and development stages. The other aim of this research was to monitor the deviations of some mineral nutrient concentrations during growth stage. Thus, at which growth stage which organ needs which nutrient mostly, will be able to determine, and finally optimum fertilization program for healthy plant growth will be programmed.

Materials and Methods

Characteristics of experimental area: Study was carried out in the experimental field at Süleyman Demirel University in Isparta, Turkey (latitude 37°45' N, longitude 30°33'E, altitude 997 m) during 2001-2002 season. Some physical and chemical characteristics of the experimental area are shown in Table 1. As indicated there, mineral nutrient concentrations of experimental soil is sufficient, organic matter is low, lime content is medium and pH is moderate alkaline.

Plant characteristics: Four safflower varieties which are commonly grown in Turkey were used. Dinçer, Yenice and 5-154 are standard cvs. developed by Eskişehir Anadolu Agricultural Research Institute and Yerli is a local cv. grown in Isparta region. Some botanical characteristics of cvs. are: Dincer with non-spiny capitulum and orange color petals, Yenice with non-spiny capitulum and red color petals, 5-154 with spiny capitulum and yellow color petals and Yerli with spiny capitulum and orange color petals.

Experimental design: There were 3 replications in randomized block design. The seeds of the cultivars were sown on 6th March of 2002 at a recommended spacing of 50 by 20 cm in plots. The plots received common cultural practices for the area where the experiments were conducted. Individual plants in the plots were sampled in the specific seasons.

Sampling and preparation for analysis: The development period of plant was divided into 7 seasons; shooting, first budding, full budding, first blooming, full blooming, seed filling and harvest. Root, shoot and leaf samples were collected at each season. Because there was no heading at first two seasons (shooting and first budding) head samples were not taken. Samples were washed in water, dilute acid (0.2 N HCl) and distilled water and dried at 65°C until stable weight. Dried samples were grinded then 500 mg of samples were wet-digested in HNO_3+$HClO_4$ acid mixture. Digested material was dissolved and filled up to 100 ml with distilled water.

Table 1. Some physical and chemical characteristics of the experimental area.

Soil characteristics							
pH	Organic matter (Walkley-Black method), %	$CaCO_3$ (Calsimetric method), %	Available P (Olsen method), mg kg g^{-1}	Available K (NH_4AcO method), me 100 g^{-1}	DTPA extractable micro nutrients, mg kg^{-1}		
					Fe	Zn	Mn
7.8	1.9	17	8	1.9	5.4	0.6	5.4

Chemical analysis: Phosphorus concentrations of samples were determined with molibdo-vanado phosphoric acid method using spectrophotometer; potassium concentrations were determined using flame photometer and micro nutrient concentrations were determined using atomic absorption spectrophotometer (Kacar, 1986).

Statistical analysis: Deviations of mineral nutrients in plant tissues related to development stages were evaluated statistically with regression analysis.

Results

Phosphorus deviation during growth periods: P deviations depending on root growth periods were polynomially significant and the most significant relation was determined in 5-154 cv. (R^2= 0.98**) but the lowest relation (R^2= 0.86**) was in cv. Yenice (Fig. 1). The highest root P concentration were determined at shooting stage as 0.16%, 0.19%, 0.23% and 0.19% for Dincer, Yenice, 5-154 and Yerli, respectively. These values decreased sharply from shooting to the first blooming periods then did not vary so much until the harvest.

Phosphorus concentration of stem for all varieties were the highest at shooting stage as 0.20%, 0.24%, 0.19% and 0.28% for Dincer, Yenice, 5-154 and Yerli, respectively. At the first budding, phosphorus concentration of stem for all varieties decreased considerably when compared to the shooting stage and phosphorus values determined as 0.13%, 0.14%, 0.16%, 0.22%. But at full budding, phosphorus levels of Dincer, Yenice and 5-154 in stem (except Yerli variety) increased again to 0.20%, 0.23%, and 0.17% respectively. After this stage, stem phosphorus concentrations decreased until the seed filling and harvest. Deviations of stem P concentration were polynomially significant for all cultivars (Fig. 1).

Leaf P concentration in all varieties changed polynomially and these changes were significant in all varieties (Fig. 1). Despite of a small differences among leaf P concentrations of varieties, similar variations were observed during the growth periods. Generally, the highest P concentrations were at shooting stage (except for Yerli) and these values were determined as 0.28%, 0.29% and 0.29% for Dinçer, Yenice and 5-154, respectively. As indicated in Fig. 1, leaf P concentrations were high at early stages, but with progressing periods after full budding, these values decreased continuously and the lowest P concentrations were determined at seed filling and harvest stages.

Head phosphorus deviations during development stages were also polynomial in all varieties and these deviations were significant. Phosphorus concentrations of heads were higher at full budding and harvest than other three stages. At full budding stage, P concentrations were 0.50%, 0.44%, 0.54% and 0.63% in Dincer, Yenice, 5-154 and Yerli were respectively. At first blooming, head phosphorus concentrations decreased to 0.18%, 0.20%, 0.26% and 0.32%, respectively. At full blooming, head phosphorus levels again increased to 0.40%, 0.31%, 0.35% and 0.32% and declined to 0.21%, 0.24%, 0.19% and 0.19% at seed filling. The head phosphorus concentrations reached to the highest level at harvest and the values were determined as 0.63%, 0.53%, 0.58% and 0.66% for Dincer, Yenice, 5-154 and Yerli respectively cultivars (Fig. 1).

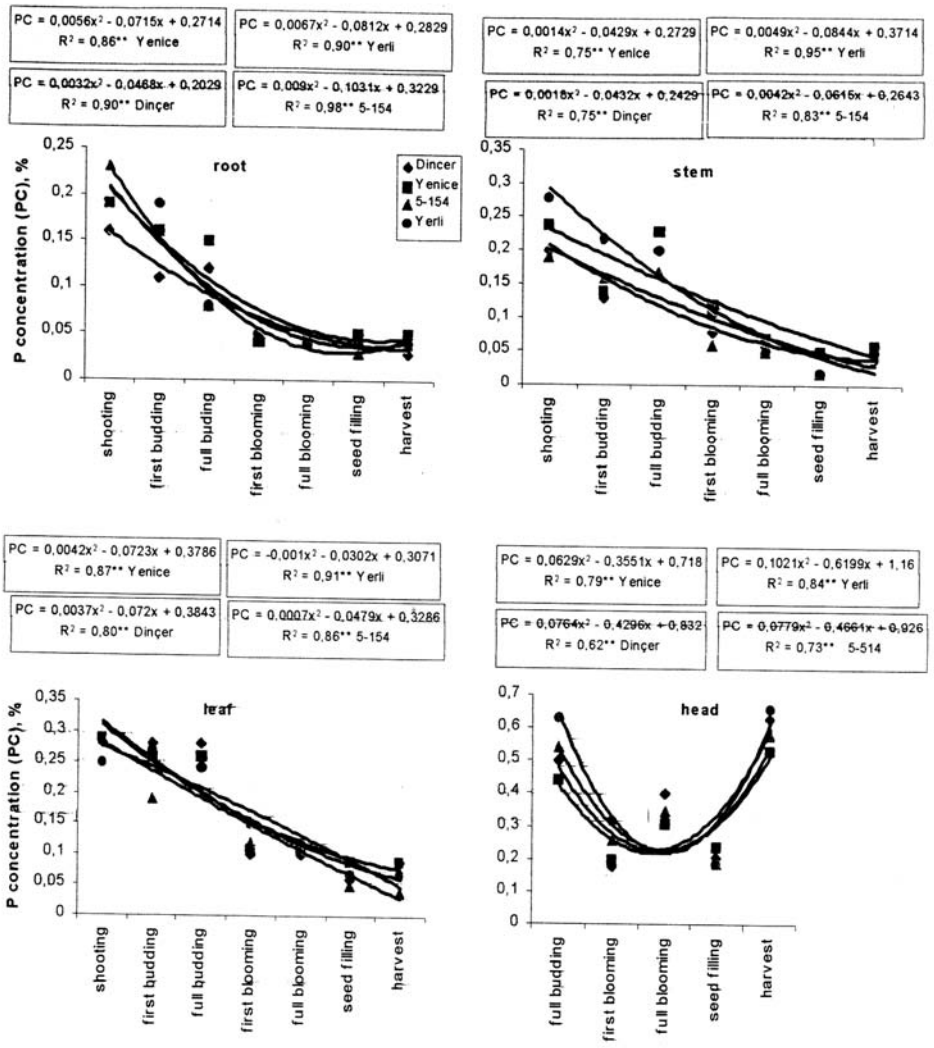

Fig. 1. Phosphorus deviations in different parts of safflower varieties during different growth period.

Potassium deviation during growth periods: Potassium concentration in root of Dincer, Yenice, 5-154 and Yerli varieties decreased until the full budding stage (Fig. 2). After this stage K concentrations of roots followed the same level until the harvest with a small deviations. Variations of root K concentrations were polynomial and these were significant for all varieties.

Potassium concentrations of stem for all varieties changed poliyomially and these were significant for all varieties (Fig. 2). The highest stem potassium levels were determined at shooting, but these values showed a sharp decrease until the full budding. After this stage, K concentrations in all periods (except for 5-154 and Yerli varieties at first blooming') did not change so much until the harvest.

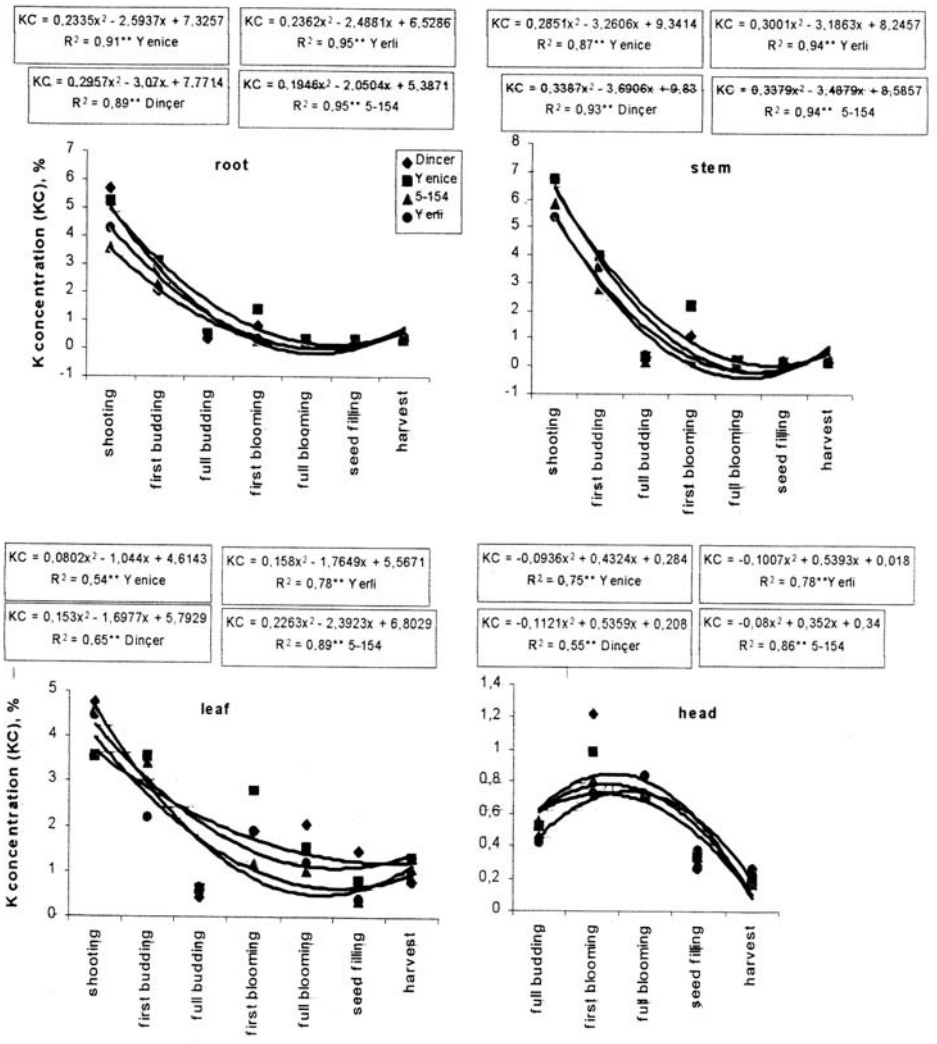

Fig. 2. Potassium deviations in different parts of safflower varieties during different growth period.

Despite of irregular deviations in leaf K concentrations, there were significant polynomial variations. At shooting, the leaf potassium concentrations were the highest for all cultivars and these values were 4.78%, 3.57%, 4.63% and 4.48 % for Dincer, Yenice, 5-154 and Yerli respectively. Potassium concentrations at full budding, seed filling and harvest were lower than others.

Head K concentrations polynomially deviated during growth seasons. Head K concentrations were the highest at first blooming except for Yerli variety. At this stage, head K concentrations increased from 0.45% to 1.22%, 0.52 to 0.99%, and 0.56% to 0.80% in Dincer, Yenice and 5-154, respectively. Throughout the end of the growing period, head K concentrations decreased continuously and the lowest K values were obtained at harvest.

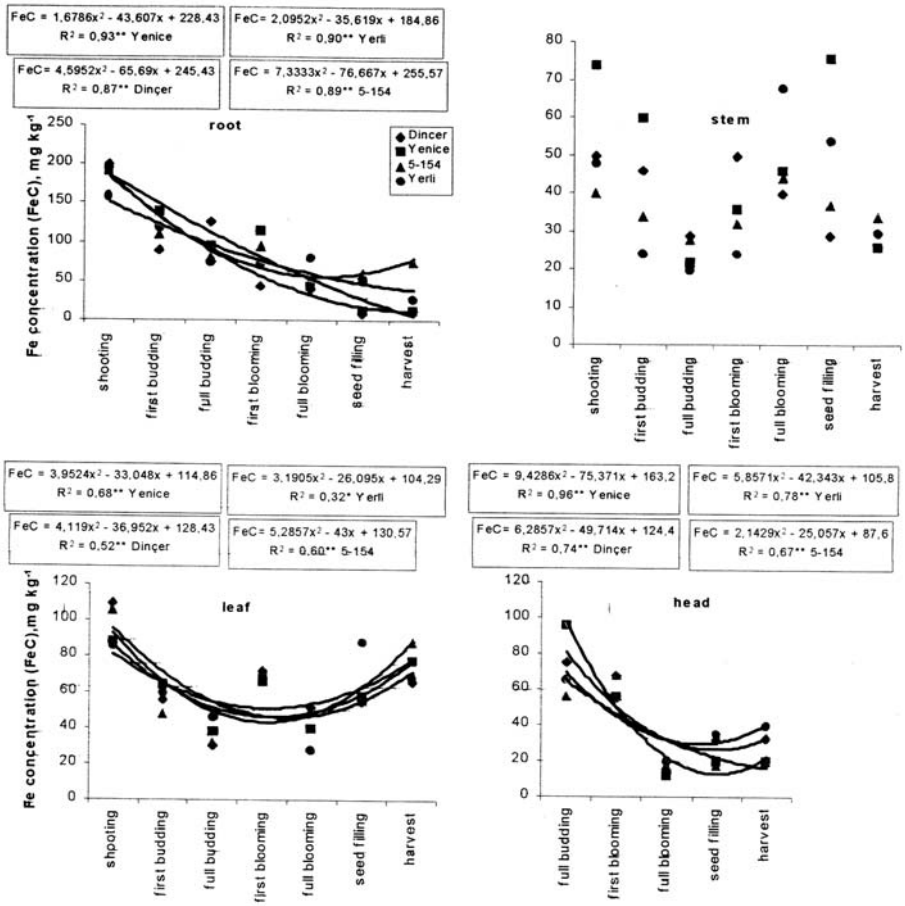

Fig. 3. Iron deviations in different parts of safflower varieties during different growth period.

Iron deviation during growth periods: Root iron concentrations of all cultivars showed significant polynomial decreases towards the late seasons (Fig 3). While the highest Fe concentrations were the highest at shooting stage as 200mg kg^{-1}, 192mg kg^{-1}, 200mg kg^{-1} and 160mg kg^{-1} in Dinçer, Yenice, 5-154 and Yerli respectively, the lowest Fe concentrations were determined at harvest (except 5-154). Stem Fe concentrations showed irregular deviations during growth stages, and there was not any correlative relations for all varieties (Fig. 3). Iron concentrations in leaves varied polynomially, and this polynomial relation was the highest in Yenice (R^2= 0.68**) but the lowest in Yerli (R^2= 0.32*). The highest Fe concentrations were at shooting as 110, 88, 106 and 86 mg kg^{-1} for Dincer, Yenice, 5-154 and Yerli. At full budding and full blooming leaf Fe concentrations were lower than other stages. Head iron concentrations also varied polynomially and these were significant for all varieties. The highest Fe concentrations were at full budding as 75mg kg^{-1}, 96mg kg^{-1}, 56mg kg^{-1} and 66mg kg^{-1} in Dincer, Yenice, 5-154 and Yerli varieties, respectively. At full blooming stage the lowest iron concentrations were obtained as 14mg kg^{-1}, 12mg kg^{-1}, 18mg kg^{-1} and 20mg kg^{-1} in Dincer, Yenice, 5-154 and Yerli, respectively.

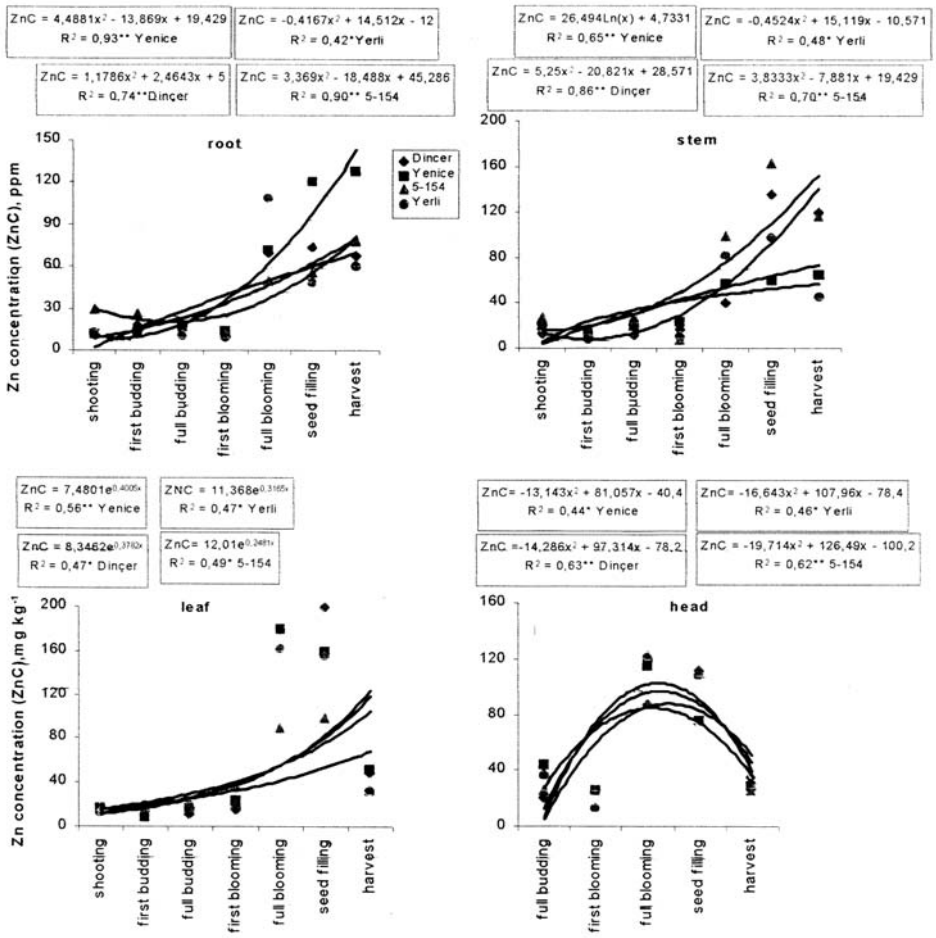

Fig. 4. Zinc deviations in different parts of safflower varieties during different growth period.

Zinc deviation during growth periods: Root, stem, leaf and head Zn concentrations and variations during the growth seasons are given in Fig. 4. As indicated there, root Zn concentrations deviated polinomially and this deviations were significant for all varieties. Root Zn concentrations did not vary until full blooming but after this stage increased generally towards the late seasons.

Stem zinc concentrations showed similar variation with root Zn concentrations. Zinc concentrations from shooting to first blooming were quite lower than that of other stages and did not deviate so much during these periods. After first blooming, Zn concentrations of stem began to increase and the highest Zn concentrations were reached at seed filling (except for Dinçer cv.). Zinc concentrations in steam during growth stages deviated exponentially and these were significant. Leaf Zn concentrations showed a polynomial variations in all varieties. At early growth periods, leaf Zn concentrations were lower. But after first blooming, Zn concentrations in leaves increased considerably and the highest concentrations were reached at full blooming and seed filling. At harvest, leaves Zn concentrations decreased again in all varieties.

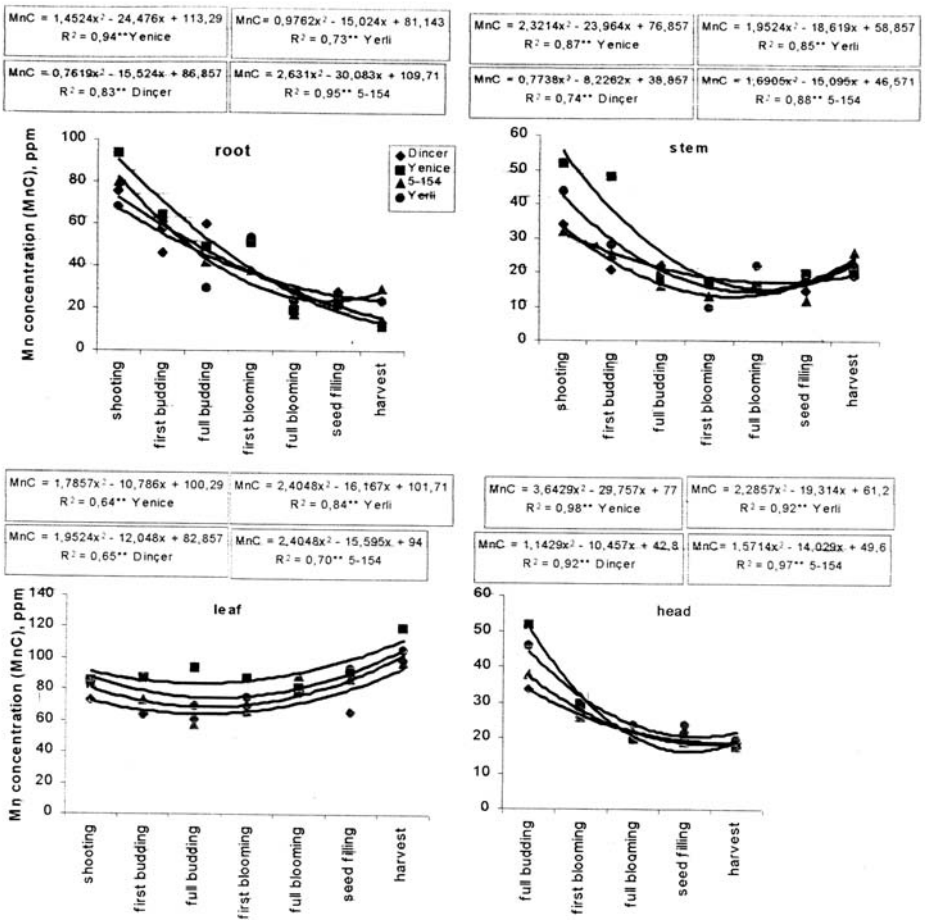

Fig. 5. Manganese deviations in different parts of safflower varieties during different growth period.

Head zinc concentrations showed big alteration during the seasons. Zinc concentrations in head changed polynomially and these were significant. While the highest Zn concentrations were determined at full blooming and seed filling, the lowest Zn concentrations were observed at first blooming stage.

Manganese distribution during growth periods: Manganese distribution in different part of safflower cultivars at different growth periods were presented in Fig. 5. Deviations of Mn in individual tissues at different stages were polynomial and these polynomial correlation were significant in all varieties. Root manganese concentrations were the highest at shooting. At this stage, root manganese concentrations of Dincer, Yenice, 5-154 and Yerli were 76mg kg^{-1}, 94mg kg^{-1}, 80mg kg^{-1} and 68mg kg^{-1}, respectively. Throughout the harvest, root manganese concentrations showed decreasing tendency generally and at harvest, root Mn concentrations declined to 14mg kg^{-1}, 12mg kg^{-1}, 30mg kg^{-1} and24 mg kg^{-1} in the same order.

Stem Mn concentrations were the highest at shooting as 34mg kg^{-1}, 52mg kg^{-1}, 32mg kg^{-1} and 44mg kg^{-1} in Dincer, Yenice, 5-154 and Yerli. Until the first blooming, Mn concentrations decreased but after this stage increased again. Leaf Mn concentrations did not vary much from shooting to seed filling. Among these stages, Mn concentrations in the leaf were between 74 mg kg^{-1} and 80 mg kg^{-1} for Dincer, 86mg kg^{-1} and 82mg kg^{-1} for Yenice, 84mg kg^{-1} and 90mg kg^{-1} for 5-154 and 84mg kg^{-1} and 78mg kg^{-1} for Yerli. But at harvest, the leaf Mn concentrations reached to 100mg kg^{-1}, 120mg kg^{-1}, 98mg kg^{-1} and 106mg kg^{-1} in Dincer, Yenice, 5-154 and Yerli, respectively. Manganese concentrations of heads decreased regularly towards the harvest. Concentrations that were 34mg kg^{-1}, 52mg kg^{-1}, 38mg kg^{-1} and 46mg kg^{-1} at shooting in Dincer, Yenice, 5-154 and Yerli, decreased to 18mg kg^{-1} (in Dincer, Yenice and 5-154 cvs.) and 20mg kg^{-1} (in Yerli cv).

Discussion

Nutrient concentrations of safflower showed a big variation depending on the variety, plant parts and growth stages in our study. Similarly, different authors reported that plant species show a large genotypic variations in mineral concentrations (Kalmbacher, 1983; Römheld & Kramer, 1983; Cakmak *et al*., 1996). If an evaluation is made on the basis of P and K distribution in different parts of safflower during growth periods, concentrations of these nutrients in plant parts (except head P concentration) decreased from shooting to maturity (Smith, 1996; Beaufils, 1973; Leigh *et al*., 1982; Myers, *et al*., 1987). These findings can be expressed mainly as a result of decreasing activity of roots during the reproductive stage (Garz, 1966; Marschner, 1995; Lynch & White, 1987). At the same time senescence of plant might be the reason of decreasing in high mobile P and K (Wood *et al*., 1986; Mauk & Nooden, 1992). Phosphorus concentration in heads in all varieties were higher than that of other parts at every stage (Cabellero *et al*., 1996). This results may be interpreted that P is an essential element to form generative organs and during seed formation, most of P in vegetative parts re-mobilizes to the seed thus, P concentrations of head increase (Batten *et al*., 1986). Zinc, Fe and Mn concentrations of root, stem and leaves showed quite deviation during the periods. Leaf Mn concentration showed an increasing tendency until harvest (Smith, 1996, Beaufils, 1973; Wood *et al*., 1986; Nable & Loneragan, 1984; Kacar, 1972). Despite the micronutrient concentrations of plant parts at different stages varied throughout the harvest, head micronutrient concentrations decreased generally (Caballero *et al*., 1996). This mineral reduction in head is likely to be due to the fact that the absorption rate is high during the early stages of development when minerals were utilized in metabolic pathways. Our findings related to head mineral concentrations is similar to finding of Rahamatalla *et al*., (1998).

As observed from the above findings, mineral concentrations of plants changes with growth periods and also development stages. Determination of these deviations is important to determine at which stage which nutrient should be provided more. For example, head P concentrations at every stages is higher than other organs. This indicates that plant needs more P during head formation. For this reason, for a good head formation, there must be higher amount of plant available P in growth media. In addition, our findings shows that whole plant organs need higher amount of P, K, Fe and Mn at early growth stages. This indicates that good amount of these nutrients should be present at this stage.

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