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Changes in Mineral Composition of Different Peanut Varieties Exposed to Leaf Damage

Mustafa YILMAZ[1*], Cenk Burak ŞAHİN[2], Necmi İŞLER[3]

[1]Düziçi Directorate of Agriculture and Forestry, Osmaniye, Türkiye
[2,3]Hatay Mustafa Kemal University, Faculty of Agriculture, Department of Field Crops, Hatay, Türkiye

[1]https://orcid.org/0000-0002-1816-0729
[2]https://orcid.org/0000-0001-6270-8184
[3]https://orcid.org/0000-0001-5877-7830
*Corresponding author: mustafayilmaz80@hotmail.com

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ABSTRACT

This study was conducted in the Eastern Mediterranean conditions in 2020 and 2021 to determine the effect of different leaf damage (LD) ratios (0, 25%, 50%, and 75%) applied at different developmental stages (flowering, gynophore formation, and pod formation) of two different peanut cultivars (NC 7 and Halisbey) on some macro and micronutrients. In the study, the main plots consisted of cultivars (NC 7 and Halisbey), subplots comprised of application stage (R1, R2, R3) and sub-sub-plots consisted of leaf losses ratios (0, 25%, 50%, and 75%). In the study, the highest content of K, Fe, Cu, Mn, and Na elements was found in 75% LD treatment while the control group was found to be the lowest. At the same time, in 75% LD treatment, it was found that the Cu, Mn, Na and Li element content of the seed was the highest and the control group was the lowest. It was observed that as the leaf damage rate increased in peanuts, the K, Fe, Cu, Mn and Na element values in the leaf and the Mn, Na and Li element values in the seed increased.

Farklı Yerfıstığı Çeşitlerinde Yaprak Zararının Mineral Bileşimindeki Değişimler

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ÖZ

Bu çalışma, iki farklı yerfıstığı çeşidinin (NC 7 ve Halisbey) farklı gelişme dönemlerinde (çiçeklenme zamanı, ginofor oluşum zamanı ve meyve oluşum zamanı) farklı yaprak zararı (YZ) uygulamalarının (%0, %25, %50, %75) bazı makro ve mikro besin elementleri üzerine etkisini belirlemek amacıyla 2020 ve 2021 yıllarında Doğu Akdeniz Geçit uşağı ekolojisinde yürütülmüştür. Çalışmada ana parseller çeşitlerden (NC 7 ve Halisbey), alt parseller uygulama zamanından (R1, R2, R3) ve alt alt parseller ise yaprak kaybı oranlarından (%0, %25, %50 ve %75) oluşmuştur. Çalışmada K, Fe, Cu, Mn, Na element içeriklerinin en yüksek %75 YZ uygulamasında bulunduğu, kontrol grubunun ise en düşük olduğu bulunmuştur. Aynı zamanda %75 YZ uygulamasında tohumun Cu, Mn, Na ve Li element içeriklerinin en yüksek, kontrol grubunun ise en düşük olduğu tespit edilmiştir. Yerfıstığında yaprak zarar oranı artıkça yapraktaki K, Fe, Cu, Mn ve Na element değeri; tohumda ise Mn, Na ve Li element değerlerinin artığı görülmüştür.

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1. Introduction

Peanut (*Arachis hypogaea* L.) originating from South America belongs to the legume family. The peanut plant was cultivated 8500 years ago in the Zana Valley in northern Peru, possibly on the eastern side of the Andes mountains (Hammons et al., 2016; Stalker et al., 2016; Klongová et al., 2023). Peanut, which has been the most valuable food source for thousands of years, especially in China, India, and America has an important role in human and animal nutrition due to their oil, protein, mineral and vitamin contents (List, 2016; Asik and Asik, 2023; Suleman et al., 2023).

Besides its animal and human nutrition, peanut is widely used in the oil industry. Furthermore, peanut is an important oil plant due to its high oil content (42-52%) and is an important protein source for animal nutrition having 25-32% protein content (Shubo et al., 2004; Asibuo et al., 2008; Arioglu et al., 2018).

In 2022, peanut was cultivated on 30.5 million ha with a production of 54.2 million tonnes and the average pod yield was 1770 kg ha^{-1} in the world. In Türkiye, thousands of tons of peanut were produced from 46.0 thousand ha of peanut cultivation. With a pod yield of 4020 kg ha^{-1} in 2023, it had a yield value above the world average (FAO, 2024; TUIK, 2024). The higher average yield of peanut in Türkiye as compared to the world's average yield is due to fertile soils and irrigated agriculture. In Türkiye, 48% of the peanut is produced in Adana, 24% in Osmaniye, and 13% in Şırnak, while the rest is produced in other provinces. Moreover, 95% of the marketing and processing of peanuts in Türkiye is carried out in Osmaniye province (TUIK, 2024).

One of the most significant factors affecting yield and quality in agricultural activities is atmospheric conditions. Agricultural operations are mostly carried out under atmospheric conditions. Meteorological events adversely affect vital life activities as soon as they go beyond their usefulness to living things, and then, with the increase in their severity, they become disasters (Asar et al., 2007; Praveen and Sharma, 2019; Lilianeb and Charles, 2020). Optimum meteorological conditions for agriculture represent themselves in the form of abundant and high-quality agricultural products however, events like severe spring frosts, strong winds, storms, heavy rainfall and floods, drought, hail, etc. significantly reduce or even destroy agricultural production (Gomez, 2005; Asar et al., 2007; Sivakumar, 2020). Hail, which is one of the meteorological natural disasters, causes great damage to agricultural and economic losses when it occurs in the months when agricultural activities are most intense in our country (Asar et al., 2007).

Due to global climate change, abiotic stress factors (like high temperature, hail, storms, frost, flood, and forest fires) negatively affect agricultural production both in Türkiye and in the world. Likewise, biotic stress factors (like diseases and pests) also damage the plants. Besides other factors, leaf losses in peanut occurs due to humans, animals, early (*Cercospora arachidicola*) and late (*Cercosporidium personatum*) leaf spot diseases, cotton leafworm (prodenia) (*Spodoptera littoralis*), green worm (*Heliothis armigera*), beet armyworm (karadrina) (*Spodoptera exigua*), red spider (*Tetranychu* spp.) and natural disasters (flood, frost, storm) (Isler and Gozuyesil, 2016; Sabir et al., 2018; Fahad, 2022).

In recent years, because of global climate change in the world and in our country, disasters such as forest fires, floods, high temperatures, landslides, and hail, along with deadly diseases (COVID-19, etc.) have started to threaten both humanity and nature. In short, the world is now clearly exposed to disasters along with global warming.

In this study, the effect of leaf losses in peanut on both leaf and seed nutrient content was investigated when no measures were taken against biotic (diseases and pests) and abiotic (hail, flood, high temperature, forest fires, etc.) damages caused by climate change.

2. Material and Methods

2.1. Material

The NC 7 cultivar used in this study contributes 95% to peanut cultivation in Türkiye, however, the cultivation of other peanut cultivars (like Halisbey) is also becoming more common. Both varieties were obtained from the Oil Seed Research Institute/Osmaniye seed collection. The experiment was carried out at the agricultural research and examination location (37°07'30.11"N; 36°11'57.35"E 65 m) in Cevdetiye Town belonging to the directorate of Oil Seed Research Institute. The soil analysis of the experimental area showed that the soil was high in pH and iron content, medium in calcium, and insufficient in terms of lime and organic matter. The average climatic values of 2020, 2021 and the long years of Osmaniye, where the experiment was conducted are given in Figure 1.

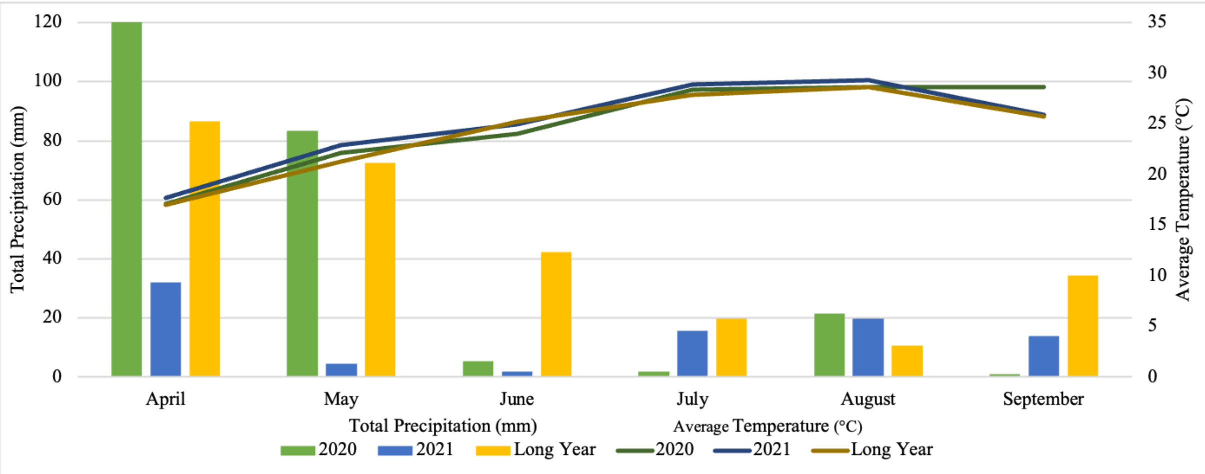

Figure 1. Climate parameters of the research field (2020, 2021 and long-year average)

2.2. Methods

The experiment was carried out for 2 years (2020 and 2021) according to RCBD arranged in a split-split-plot design with 3 replications. Main plots were allocated to cultivars (NC 7 and Halisbey), subplots to application stages ((flowering time (R1), gynophore formation time (R2) and pod formation time (R3)) and sub-subplots to leaf damage (LD) (0, 25%, 50%, and 75%). Each plot comprised of 4 rows of 5 m in length and the planting density was kept as 70 × 15 cm.

In the first year of the experiment, sowing was done manually on April 30, 2020. Leaf damages in the first year of the experiment were done at different stages i.e., at R1, R2 and R3 on June 12, 2020, June 25, 2020, and July 17, 2020, respectively. First year crop was harvested on September 23, 2020. In the second year of experiment, sowing was done manually on April 29, 2021. Leaf damages were done at various stages i.e., at R1, R2 and R3 on June 11, 2021, June 22, 2021, and July 16, 2021, respectively. In the second year, the experiment was harvested on September 27, 2021.

The peanut plant's leaves had an equal number on each branch. All 20 plants in each plot had their branches counted while the leaves were being damaged based on the treatment ratios. The plants in the plot were subjected to leaf reduction (control, 25, 50, and 75%) using scissors after the average number of branches in each plot was established.

The samples to be analyzed for nutrient elements in the leaves were collected in the R4 stage and taken to the laboratory, and the dust on them was removed by passing them through distilled water twice. Afterward, the samples were dried in an oven at 55°C for 72 hours (Sahin and Isler 2022). The dried leaf samples were grounded with the help of a grinder and stored in labeled bags for analysis. Seeds were ground directly without any drying process, then labeled and stored in bags. MP-ASS device was used to read macro and micro nutrients in leaves and seeds (Sahin and Isler, 2022).

2.3. Statistical analysis

The analysis of variance of the obtained data was carried out using R v4 and SPSS 22 statistical programs as appropriate for the RCBD arranged in a split plot design. Means were compared according to Duncan's Multiple Range tests (Steel and Torrie, 1980).

3. Results and Discussion

3.1. Phosphorus (P)

Leaf damage (LD) applications in different stages were found to be significant for variety × stage, variety × damage ratio, stage × damage ratio and variety × stage × damage ratio interactions ($p < 0.01$) (Table 1 and 2). Based on the two-year averages; among the cultivars, leaf P content was 0.96% in NC 7 and 1.09% in Halisbey variety. Regarding stages, the highest leaf P contents (1.07%) were determined in R2 stage and the lowest (0.99%) were found in R3 stage. Leaf P contents were found to be lowest in control and 50% LD (1.02%) treatment, while the highest leaf P contents were found for 25% LD (1.07%) treatment (Table 1). When the two-year averages were examined; among the cultivars, seed P contents were 0.87% in Halisbey and 1.09% in NC 7 variety. There was no difference in terms of seed P contents in stages and applications (Table 2). P is one of the rare elements in the world and is an important element for peanut. P deficiency is more prominent in areas with no P fertilization or high phosphorus costs (Bolonhezi, 2005; Smartt, 2013; Asik and Asik, 2023). It was observed that the applications made in the study did not cause any deficiency in the amount of P.

3.2. Potassium (K)

All possible interactions were found significant ($p < 0.01$) regarding leaf and seed K contents (Table 1 and 2). Based on the two-year averages; Leaf K contents were found to be 6636.16 ppm in NC 7 and

8163.98 ppm in Halisbey variety. Regarding stages, it was found to vary between 7346.81 ppm (R1) and 7446.55 ppm (R2). It was determined that the K contents of the leaves varied between 7047.74 ppm (50% LD) and 7936.41 ppm (75% LD) (Table 1). Among the cultivars, seed K content was found to be 3075.68 ppm (Halisbey) and 4027.84 ppm (NC 7) when the two-year averages were examined. Regarding stages, seed K contents were found to vary between 3180.50 ppm (R1 stage) and 3969.55 ppm (R2 stage). Seed K contents under different applications were found to vary between 3337.56 ppm (25% LD) and 3794.09 ppm (50% LD) (Table 2). The K element in peanut is one of the elements required from the early stages of growth to maturity and is found in sufficient amounts in Türkiye soils (Smartt, 2013; Taiz and Zeiger, 2013). Mupunga et al. (2017) reported the amount of K in peanuts as 7050 ppm. Among the leaf damage treatments in peanut, the highest amount of K in both leaf and seed was determined in the R2 stage, while the lowest amount of K was recorded in the R1 stage. In non-application rates, it was observed that the amount of K increases in both leaves and soil with the increase in damage rate. It is thought that the increase in the amount of K accumulates in the plant to protect itself.

3.3. Iron (Fe)

All interactions were found significant ($p < 0.01$) for leaf and seed Fe contents (Table 1 and 2). Considering the two-year averages; among the cultivars, leaf Fe contents were 43.65 ppm (Halisbey) and 46.22 ppm (NC 7). Regarding stages, the highest Fe contents (49.20 ppm) were recorded in R1 stage while the lowest (40.81 ppm) were recorded in R2 stage. The highest leaf Fe contents were 47.61 ppm for 75% LD treatment while the lowest was 40.79 ppm for 50% LD treatment (Table 1). When the two-year averages were examined; among the cultivars, seed Fe contents were found to be 368.84 ppm (NC 7) and 490.70 ppm (Halisbey). Regarding stages, the highest seed Fe contents (474.09 ppm) were found in R1 stage while the lowest (372.27 ppm) was recorded in R2 stage. In applications, the highest seed Fe contents were found to be (547.49 ppm) 25% LD, while the lowest (342.56 ppm) were found at 50% LD treatment (Table 2). Brar et al. (2008) in their study determined that the leaf Fe contents vary between 127-195 ppm. Iron is one of the most important elements for the growth and survival of almost all living organisms (Valko et al., 2005). Gao and Shi (2007) in their study to determine the peanut genotypes resistant to iron deficiency reported that the leaf Fe content varies between 43.61-195.36 ppm and genetically the iron content varies according to the cultivars.

It has been reported that iron chlorosis causes a decrease in product and pod quality because of a decrease in leaf photosynthetic pigment concentrations, especially chlorophyll (Abadia et al., 2011). In Türkiye, NC 7 peanut varieties account for 95% of peanuts cultivated area. Due to the excessive calcareousness of the area under peanut cultivation, iron uptake by peanut becomes difficult and causes chlorosis, especially in the NC 7 variety (Isler and Gozuyesil, 2016). The present study was not like the research conducted by Brar et al. (2008) however; it was like the study related to the iron conducted by Gao and Shi (2007). Fe element is actively involved in the structure of nitrogenase enzyme, which plays an important role in symbiotic nitrogen fixation in legumes (Chonkar and Chandel, 1991; Terry and Jolley, 1994). Ozcan and Seven (2003) reported that Fe content in peanut seed varies between 1917.86-2311.55 ppm and reported that there were differences between varieties regarding seed Fe content. Additionally, the seed Fe content was higher when the damage was conducted in the R1 stage as compared to other stages (R2 and R3 stages). Among treatments, it was found that 25% LD treatment increased the Fe content in the seed. The differences in the iron content of the seed among the varieties might be due to their genetic factors.

3.4. Calcium (Ca)

All the interactions were found significant for leaf and seed Ca content ($p < 0.01$) (Table 1 and 2). According to two-year data, average leaf Ca content was 115.56 ppm (Halisbey) and 145.79 ppm (NC 7). Regarding stages, the lowest leaf Ca content was 127.97 ppm at R1 stage while the highest and lowest leaf Ca content was 133.46 ppm at R3 stage. The highest leaf Ca content (139.02 ppm) was found in the control while the lowest leaf Ca content (122.01 ppm) was recorded at 25% LD treatment. Calcium is one of the most important elements required for peanut. Peanut plants take about 70% of the calcium they need directly from the soil with their gynophores and pods (Arioglu, 2014; Kolte, 2019). Brar et al. (2008) determined that leaf Ca content varies between 1.7-2.20%. After nitrogen and potassium, the most taken element by peanut from the soil is calcium; therefore, amount of Ca in soil is directly proportional to the amount of Ca in seed and pod (Arioglu, 2014).

Based on the two-year averages; among cultivars, the seed Ca content was found to be 939.79 ppm (Halisbey) and 972.99 ppm (NC 7). Regarding stages, the highest seed Ca content was 1058.76 ppm at R3 stage while the lowest seed Ca content was 872.44 ppm at R2 stage. The highest seed Ca content (1185.31 ppm) was recorded at 25% LD, followed by 936.48 ppm at control, 900.44 ppm at 50% LD, and 803.35 pm at 75% LD. Ca found in the peanut roots cannot be carried to the gynophores and pods, so the seeds in the plant obtain the Ca element with the help of gynophores (Kolte, 2019). Ozcan and Seven (2003) documented that the Ca content in peanut seed varies between 79449.9-89377.9 ppm and there were differences among varieties. The low amount of Ca in the soil reduces the seed emergence and resistance to diseases (Smartt, 2013). In this experiment, the Ca content in the seed of Halisbey cultivar was more due to varietal differences. In both years, the stages also showed a difference. It has been observed that 25% LD treatment increased the seed Ca content in both years. It can be stated that the plant protects itself and accelerates the uptake of nutrients at the 25% LD treatment. But when the damage to the leaves reached more than 50%, it was found that the plant could not withstand the amount of Ca.

3.5. Zinc (Zn)

Leaf Zn content showed a statistically significant difference ($p < 0.01$) between stage x damage ratio, and cultivar x stage x damage ratio interaction (Table 1). All interactions were statistically significant for Zn seed content (Table 2). Based on the two-year averages; among the cultivars, leaf Zn content was 61.45 ppm in Halisbey and 65.59 ppm in NC 7 variety. Regarding stages, the highest leaf Zn content (66.59 ppm) was found in R2 stage while the lowest (58.55 ppm) was recorded in R3 stage. Leaf Zn content was found between 61.49 ppm (25% LD) and 66.09 ppm (Control) (Table 1). Considering the two-year averages; among the cultivars, seed Zn content was found to be 30.21 ppm (NC 7) and 31.74 ppm (Halisbey). Regarding stages, seed Zn content varied between 29.15 ppm (R1 stage) and 34.34 ppm (R2 stage). Seed Zn content was found to vary between 28.26 ppm (control) and 33.59 ppm (25% LD) (Table 2).

Zn deficiency varies in direct proportion to high soil pH and high available P levels (Smartt, 2013). Zn deficiency causes interveinal chlorosis in newly formed leaves. As the deficiency of Zn increases, the leaves turn red brown and then fall off the plant. Moreover, the growth slows down, plants become stunted, and internodes begin to reduce (Smartt, 2013). In this study, there was no difference in leaf Zn content between the stages and LD treatments. On the other hand, it was seen that seed Zn content was most affected in R1 stage while less affected in R2 stage. Here, the flowering started 40-60 days after planting, and it shows the need for Zn during the damage stages (Smartt, 2013). 25% LD treatment increased the seed Zn content while it was observed that the control group was lower among all treatments. It is evident that the little leaf damage that does occur has no detrimental effects on the plant and really works to its advantage. However, the plant suffers when leaf damage losses surpass 50%. According to the results, it was observed that 25% LD and damages at R2 stage were more appropriate to increase Zn content in the seed than other treatments and stages.

3.6. Copper (Cu)

Leaf damage applications at different stages were found to be significant ($p < 0.01$) in terms of cultivar × period, cultivar × damage rate, period × damage rate and cultivar × period × damage rate interactions (Table 1 and 2). Considering the two-year averages; Leaf Cu content was 13.04 ppm (NC 7) and 16.68 ppm (Halisbey) among cultivars. Regarding stages, R3 and R2 stage was found highest (15.05 ppm, 14.89 ppm) whereas R1 stage was recorded to be the lowest (14.64 ppm). In different applications, leaf Cu content was found lowest in the control group (13.99 ppm), while highest 75% LD (16.03 ppm) (Table 1). Considering the two-year averages; among the cultivars, the seed Cu content was found to be 4.22 ppm (Halisbey) and 5.32 ppm (NC 7). Regarding stages, R2 stage was found to be the highest (5.12 ppm) and the R1 stage was recorded to be the lowest (4.42 ppm). In the applications, the seed Cu content was found to be the least in the control group (4.11 ppm), while the highest was found to be 75% LD (5.14 ppm) (Table 2). Peanut provides a significant amount of Cu in terms of nutrition. 100 g of roasted peanuts will meet the daily requirement of Cu. However, the presence of sufficient Cu in the seed reduces the wrinkling of the seeds and increases the number of mature seeds (Smartt, 2013). Mupunga et al. (2017) reported that peanut seeds contain about 11.44 ppm Cu. The cultivars used in our experiment were found to be lower than the literature rate. It is observed that the Cu content of both leaves and seeds increases as the leaf damage rate increases. This can be explained by the fact that the plant increases its Cu content to increase its resistance to increased damage.

3.7. Manganese (Mn)

The results of the study determined that all interactions were significant ($p < 0.01$) in terms of leaf and seed Mn content (Table 1 and 2). When the two-year averages were examined; Leaf Mn content was found to be 20.34 ppm (Halisbey) and 22.91 ppm (NC 7) among cultivars. Regarding stages, the R1 (21.18 ppm) and R2 (21.33 ppm) stages in the same group were found to be the lowest, while the R3 period (22.36 ppm) was the highest. It was determined that the Mn content of the leaves varied between 19.79 ppm (control) and 23.09 ppm (75% LD) in applications (Table 1). Considering the two-year averages; among the cultivars, seed Mn content was found to be 52.81 ppm (Halisbey) and 57.46 ppm (NC 7). Regarding stages, the R3 stage was lowest (52.73 ppm) whereas R2 stage was found to be highest (57.39 ppm). It was determined that seed Mn content varied between 49.85 ppm (25% LD) and 61.33 ppm (75% LD) (Table 2). Deficiency of Mn element is common in extremely calcareous and high pH soils (Smartt, 2013). It varies between 10 and 500 ppm in terms of Mn content in peanut seeds (Mupunga et al., 2017). It was observed that the Mn content in the seed and the leaf increases as the leaf damage rate increases. The increase in this value may be due to the accumulation of more Mn in the plant to reduce the chlorosis that will occur because of Mn deficiency.

3.8. Sodium (Na)

All interactions were found significant ($p < 0.01$) in terms of leaf and seed Na content (Table 1 and 2). Considering the two-year averages; leaf Na content was found to be 258.22 ppm (Halisbey) and 265.26 ppm (NC 7). Regarding stages, R1 stage (262.90 ppm) was found to be highest with lowest R2 and R3 stage (261.06 ppm, 261.26 ppm). In terms of applications, the Na contents were recorded between 256.49 ppm (50% LD) and 269.45 ppm (75% LD) (Table 1). When the two-year averages were examined; Among the cultivars, the seed Na contents were found between 234.65 ppm (NC 7) and 384.43 ppm (Halisbey). Regarding stages, R3 stage (438.81 ppm) was found to be highest while the lowest was R2 stage (241.83 ppm). The seed Na content was maximum i.e. 535.59 ppm with 75% LD application, whereas minimum seed Na content i.e. 233.25 ppm was found under 25% LD application (Table 2). Na, which is beneficial for many plants, is an essential plant nutrient in peanuts. One of the most important benefits of Na is that it resists the wilting of plants in dry periods and plays a positive role in water economy (Smartt, 2013). A decrease was observed in the amount of leaf Na content by the end of applications that were done after the R1 stage, and the amount of leaf Na content was increased with the increase in application rates. With the increased seed Na content in the damage at R3 stage, it is thought that the plant increases the amount of Na for self-protection as the rate of application damage increases in parallel with the amount of leaf Na.

3.9. Lithium (Li)

The interactions of leaf damage applications at different growth stages of peanut, cultivar × period, cultivar × damage rate, period × damage rate and cultivar × period × damage rate were found to be insignificant in terms of leaf Li content whereas they were found significant ($p < 0.01$) in terms of seed Li content (Table 1 and 2). Considering the two-year averages; Among the cultivars, leaf Li content was 4.99 ppm (Halisbey) and 5.01 ppm (NC 7). Regarding stages, the R2 and R3 stages (4.99 ppm) were found to be lowest while highest was R1 stage (5.00 ppm). Under different applications, minimum leaf Li contents were found under 75% LD (4.98 ppm), while the highest was found in the control group (5.02 ppm) (Table 1). When the two-year averages were examined; seed Li contents in the cultivars were recorded between 22.84 ppm (NC 7) and 24.53 ppm (Halisbey). Regarding stages, the R2 stage (24.26 ppm) was highest whereas the lowest was R3 stage (23.09 ppm). Under different applications, seed Li contents were less in the control group (22.50 ppm), whereas high under 75% LD (24.18 ppm) (Table 2). Li contents were found to be increased with the increase in leaf damage rates. According to the different application periods, it is determined that the Li contents increase both in the leaf and the seed by increasing the application’s damage rates.

Table 1. Average values of P, K, Fe, Ca, Zn, Cu, Mn, Na and Li content of peanut leaf for studied years.

	P (%)	K (ppm)	Fe (ppm)	Ca (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Na (ppm)	Li (ppm)
Cultivars	**	**	**	**	ns	ns	**	**	ns
NC 7	0.96±0.02 B	6636.16±31.32 B	46.22±1.45 A	145.79±4.35 A	65.59±4.62	13.04±0.28	22.91±0.34 A	265.26±1.96 A	5.01±0.01
Halisbey	1.09±0.01 A	8163.98±136.04 A	43.65±0.95 B	115.56±3.16 B	61.45±1.04	16.68±0.23	20.34±0.34 B	258.22±2.36 B	4.99±0.01
Stages		**	**	**	ns	**	**	**	ns
R1	1.03±0.03	7346.81±192.09 z	49.20±1.82 x	127.97±4.71 z	65.40±3.25	14.64±0.56 y	21.18±0.38 y	262.90±2.43 x	5.00±0.00
R2	1.07±0.02	7446.55±202.52 x	40.81±1.34 z	130.59±4.90 y	66.59±6.12	14.89±0.51 x	21.33±0.42 y	261.06±3.59 y	4.99±0.01
R3	0.99±0.01	7406.85±206.08 y	44.79±0.65 y	133.46±6.99 x	58.55±1.44	15.05±0.39 x	22.36±0.61 x	261.26±2.05 y	4.99±0.01
Damage	ns	**	**	**	**	**	**	**	**
Control	1.02±0.03	7298.05±189.14 c	45.86±1.62 b	139.02±10.39 a	66.09±8.28	13.99±0.64 d	19.79±0.40 d	261.12±1.93 b	5.02±0.02 a
25%	1.07±0.02	7318.08±186.88 b	45.47±2.26 b	122.01±4.53 d	61.49±1.40	15.05±0.49 b	21.57±0.70 c	259.91±2.27 c	4.99±0.01 ab
50%	1.02±0.02	7047.74±184.76 d	40.79±1.19 c	125.45±4.40 c	64.40±4.51	14.36±0.48 c	22.03±0.45 b	256.49±2.41 d	5.00±0.01 ab
75%	1.03±0.02	7936.41±295.78 a	47.61±1.44 a	136.21±3.59 b	62.08±1.28	16.03±0.54 a	23.09±0.36 a	269.45±4.66 a	4.98±0.01 b
Years	**	**	ns	**	**	**	**	**	**
2020	1.42±0.01	6765.78±202.39	49.73±0.94	109.79±1.54	41.61±4.14	11.79±0.36	11.35±0.18	236.88±3.29	4.98±0.01
2021	0.64±0.02	8034.36±75.50	40.13±1.91	151.55±5.93	85.42±2.58	17.93±0.32	31.89±0.48	286.59±3.00	5.01±0.00
Average	1.03±0.01	7400.07±114.12	44.93±0.87	130.67±3.22	63.52±2.36	14.86±0.28	21.62±0.28	261.74±1.58	5.00±0.01
C × S	**	**	**	**	ns	**	**	**	ns
C × D	**	**	**	**	ns	**	**	**	ns
S × D	**	**	**	**	**	**	**	**	ns
C × S × D	**	**	**	**	**	**	**	**	ns

[a] Letters show different groups in each column. ** $p < 0.01$; ns: Non-significant.

Table 2. Average values of P, K, Fe, Ca, Zn, Cu, Mn, Na and Li content of peanut seed for studied years

	P (%)	K (ppm)	Fe (ppm)	Ca (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Na (ppm)	Li (ppm)
Cultivars	**	**	**	**	**	**	**	**	**
NC 7	1.09±0.01 A	4027.84±172.57 A	368.84±25.89 B	972.99±55.82 A	30.21±0.86 B	5.32±0.16 A	57.46±2.10 A	234.65±3.39 B	22.84±0.41 B
Halisbey	0.87±0.02 B	3075.68±70.36 B	490.70±32.18 A	939.79±28.57 B	31.74±1.08 A	4.22±0.13 B	52.81±3.27 B	384.43±73.77 A	24.53±0.55 A
Stages	ns	**	**	**	**	**	**	**	**
R1	0.97±0.03	3180.50±171.86 z	474.09±32.69 x	937.98±26.22 y	29.15±0.77 z	4.42±0.17 z	55.29±2.84 y	247.97±9.52 y	23.69±0.46 y
R2	0.99±0.03	3969.55±217.61 x	372.27±45.78 z	872.44±30.88 z	34.34±1.36 x	5.12±0.25 x	57.39±3.18 x	241.83±8.60 z	24.26±0.64 x
R3	0.98±0.03	3505.22±135.18 y	442.96±31.26 y	1058.76±81.20 x	29.44±1.11 y	4.77±0.17 y	52.73±4.06 z	438.81±109.19 x	23.09±0.71 z
Damage	ns	**	**	**	**	**	**	**	**
Control	1.02±0.03	3439.91±247.71 c	412.98±31.28 c	936.48±27.67 b	28.26±0.79 d	4.11±0.14 c	56.32±0.81 b	245.32±4.89 b	22.50±0.59 c
25%	0.96±0.03	3337.56±101.86 d	547.49±58.80 a	1185.31±97.34 a	33.59±1.02 a	4.90±0.18 b	49.85±2.50 d	224.00±3.87 d	24.05±0.45 ab
50%	0.93±0.03	3794.09±229.32 a	342.56±31.35 d	900.44±31.43 c	29.38±1.14 c	4.93±0.28 b	53.04±1.98 c	233.25±11.65 c	24.00±0.45 b
75%	1.01±0.05	3635.47±254.38 b	416.08±34.49 b	803.35±18.94 d	32.68±1.96 b	5.14±0.28 a	61.33±6.95 a	535.59±139.92 a	24.18±1.11 a
Years	**	**	**	**	**	**	**	**	**
2020	1.21±0.01	3813.63±139.54	425.86±20.90	1226.07±36.75	26.34±0.86	4.01±0.11	28.69±1.38	166.44±3.87	23.62±0.35
2021	0.75±0.03	3289.89±116.96	433.69±22.85	686.72±46.67	35.61±1.29	5.53±0.18	81.57±3.59	452.64±75.66	23.74±0.36
Average	0.98±0.02	3551.76±108.41	429.77±21.74	956.39±31.19	30.98±0.69	4.77±0.12	55.13±1.95	309.54±37.72	23.68±0.35
C × S	**	**	**	**	**	**	**	**	**
C × D	**	**	**	**	**	**	**	**	**
S × D	**	**	**	**	**	**	**	**	**
C × S × D	**	**	**	**	**	**	**	**	**

[a] Letters show different groups in each column. ** $p < 0.01$; ns: Non-significant.

3.10. Correlation

The Pearson correlation coefficients and significance levels for the characteristics examined in the two-year average data of the trial are shown in Table 3. A significant and negative correlation was observed between leaf Ca, Zn, Cu, Mn, Na elements and leaf P content. A significant and positive correlation was observed between leaf K and Cu content, leaf Zn and Mn content, leaf Cu, Mn and Na contents. In case of seed, a positive and significant correlation was observed between seed P and Ca content, seed Cu and Mn content, seed Zn, Cu and Mn content. A significant and negative correlation was observed between seed Ca and Mn content. Our findings in the trial were like the results obtained by Sahin and Isler (2022).

Table 3. Correlation analysis for the investigated parameters according to average values of peanut for studied years

	P	K	Fe	Ca	Zn	Cu	Mn	Na
Leaf								
P	1							
K	-.334	1						
Fe	.298	.164	1					
Ca	**-.564**	.175	-.088	1				
Zn	**-.558**	.272	-.190	.241	1			
Cu	**-.600**	**.724**	-.195	.183	.458	1		
Mn	**-.908**	.349	-.331	.467	**.610**	**.727**	1	
Na	**-.634**	.454	-.083	.439	.494	**.648**	**.735**	1
Li	-.282	.005	-.096	.352	.135	.079	.227	.231
Seed								
P	1							
K	.317	1						
Fe	-.112	-.370	1					
Ca	**.546**	-.061	.118	1				
Zn	-.137	.036	.186	-.274	1			
Cu	-.078	.228	-.011	-.325	**.671**	1		
Mn	-.424	-.153	.154	**-.542**	**.545**	**.525**	1	
Na	-.366	-.266	-.117	-.090	-.294	.015	-.062	1
Li	-.002	-.218	.142	.030	.318	-.041	.291	-.390

P: Phosphorus, K: Potassium, Fe: Iron, Ca: Calcium, Zn: Zinc, Mn: Manganese, Na: Sodium, Li: lithium.

4. Conclusions

Extreme weather conditions are observed due to global warming and climate change that has accelerated in recent years. Summer plants such as peanuts in their growth and development periods are fully damaged by different biotic and abiotic factors. In this study, the effect of leaf losses occurring at different developmental stages of the plant, on the chemical composition of seeds and leaves of the plant was determined. Because of the evaluation made in terms of developmental periods, it was observed that the amount of nutrients in both the seed and the leaf decreased because of leaf loss, especially at the beginning of the generative period. It was determined that both seed and leaf K, Fe, Cu, Mn, and Na contents increased with the increase in damage rate of leaf damage applications. As a result of the study, it has been observed that the peanut plant will protect itself from possible leaf damage by increasing the amount of nutrients and show resistance against the damage caused by abiotic and biotic leaf damage that occurs because of global climate change.

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Conflict of Interest Statement

No conflict of interest was declared by the authors.

Contribution Rate Statement Summary of Researchers

Concept: M.Y., N.I., Design: M.Y., N.I., Data Collection or Processing: M.Y., C.B.S., Analysis or Interpretation: M.Y., C.B.S., N.I., Literature Search: M.Y., C.B.S., Writing: M.Y., C.B.S., N.I.

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