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Combined Effects of Grafting and Vermicompost on Nutrient Composition in Eggplant under Drought Stress and Its Correlation with Yield

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Abstract

Drought poses an increasing threat to global food production, necessitating sustainable agricultural practices to reduce yield and quality losses. In this study, the synergistic effects of grafted seedlings and vermicompost-V on the nutrient content of eggplant plants and their relationship with yield were investigated. The study was carried out with eggplant seedlings (grafted-G) and non-grafted-NG) in pots containing vermicompost-V (V_0: 0%, V_1: 1%, V_2: 2%, V_3: 3%) under three different drought levels (100% irrigation-, 70% irrigation, mild drought stress - MS) and 30% irrigation, severe drought stress-SS) as irrigation. The findings showed that the interaction of 'grafting x vermicompost x drought' created statistically significant differences in terms of N, P, K, Mg, Fe, Cu and Mn contents. Higher increases were observed in grafted plants under stress compared to the control due to vermicompost application. The most striking increases were 50.56% and 45.67% for N; 110.08% and 96.59% in G x V_3 under SS conditions. In terms of P content, under SS had a 116.50% increase in G x V_3. There was an increase. In terms of K content, 115.69% and 111.16% increases were evident in MS and SS in G x V_2. However, positive correlations were observed between K and N, P and Mg; Mn and Fe and Cu; Fe and Cu. On the other hand, weak and negative correlations were determined between yield and N and K; and high positive correlations were determined between Mn, Fe and Cu. The polar heatmap with dendrogram revealed that macro (N, P, K, Mg) and micro (Fe, Mn, Cu) nutrients were clustered in different groups. While a direct relationship was observed between yield and Fe, Mn and Cu, an indirect relationship was determined with N, P, K and Mg. The findings showed that grafting and vermicompost applications increased nutrient uptake under drought stress conditions and there was a close relationship between yield and nutrient elements. The results are important in terms of revealing the positive effects of sustainable agricultural practices on plant nutrition and yield in drought.

Key Words: *Eggplant, drought, vermicompost, grafted plant, correlation, yield*

Introduction

Drought, as one of the important abiotic stresses, occurs when rainfall is insufficient and evaporation exceeds water intake, and negatively affects plant growth, yield, and quality, eventually leading to plant death. Under drought stress, significant changes occur in leaf area, stomatal density, relative water content, stomatal conductance, and chlorophyll concentration in vegetables (Ors et al., 2021; Hannachi et al., 2022; Kıran and Baysal Furtana, 2023). In addition, drought significantly affects the uptake and utilization of macro (N, P, K, Mg) and micro (Fe, Mn, Cu) nutrients by disrupting water balance, restricting nutrient mobility, and impairing root function, and ultimately causes reduced plant growth and yield (Ors et al., 2021; Hannachi et al., 2022).

Eggplant (Solanum melongena) is the third most important vegetable in the Solanaceae family in terms of production (Sekara et al., 2007). Although eggplant is moderately drought resistant, prolonged drought can negatively affect plant growth and yield by disrupting metabolic activities. The use of cultivars tolerant to drought stress is an important strategy to reduce yield and quality losses. However, since this trait is controlled by many genes, it is difficult to develop drought-tolerance cultivars (Toppino et al., 2022). Grafting in eggplant can control the stomatal regulation system in plant transpiration under drought stress quite well depending on the combination of rootstock and scion and can reduce drought damage (Boyaci and Ellialtıoglu, 2018). Although grafting increases product yield and quality under water-limited conditions, it may not be sufficient alone when drought is severe. Grafting onto drought-resistant rootstocks and the use of vermicompost can increase the adaptation of plants to stress conditions. At this point, vermicompost reduces the water requirement of the plant by increasing the moisture

retention capacity of the soil (Demir, 2019) and strengthens stress tolerance by improving soil fertility (Rehman et al., 2023) (Kıran, 2019).
In this study, the effects of the combined use of grafting and vermicompost on nutrient uptake in eggplant and how these changes are related to each other and yield were investigated. The findings are important for sustainable agricultural practices and contribute to the development of plant nutrition strategies in stress conditions such as drought.

Materyal ve Yöntem

The study was carried out between April and July 2020 in the greenhouse conditions of the Soil, Fertilizer and Water Resources Central Research Institute. Temperature and humidity control were provided automatically in the greenhouse environment. Grafted and ungrafted eggplant seedlings of the Aydın Siyahı variety on the Köksal F1 rootstock constituted the plant material. The grafting process was carried out by Antalya Tarım A.Ş. When the grafted and ungrafted seedlings reached 3-4 true leaves, they were planted in 39x35 cm and 35 L volume polyethylene pots containing clayey soil (1 seedling/pot). 15 days before planting, vermicompost was added to the pots at the rates of 1%, 2% and 3% of the soil weight. Vermicompost (organic matter: 39.2%, total phosphorus: 0.21%, total potassium: 0.94%, EC: 5.62 dS m-1, pH: 6.62) was supplied by Ekosol Tarım ve Hayvancılık A.Ş., Manisa. Stress treatments were started 15 days after seedling planting and continued for 110 days. The study was carried out in randomized plots according to factorial experimental design with 3 replicates. Factors: 1. Grafting (grafted-G, non-grafted-NG plants), 2. Vermicompost application (V0: 0%, V1: 1%, V2: 2%, V3: 3% (w/w)), 3. Drought stress (100% irrigation-well watered,WW), 70% of the water given to control (mild drought stress- MS) and 30% (severe drought stress - SS). The water amount of the pots was determined on the basis of weight. Before applying drought stress, all plants were watered at field capacity level and stress was created by applying limited irrigation with different water amounts. MS and SS subjects were given 70% and 30% of the water amounts given to the control, respectively. Field capacity was taken as the basis for irrigation. The total weight of the pots was determined when the soil moisture content was at field capacity and wilting point levels. Daily pot weighing was done to monitor the amount of water lost and the amount of water lost was completed in accordance with the subject. According to the soil analysis results, the deficient fertilizer need of the plants was met.
N, P, K, Ca, Fe, Zn, Cu analyses were carried out in plant leaf samples. Total N amount was determined in dried and ground leaf samples using the Leco TruSpec-CHN device according to the Dumas method. For P, K, Ca, Fe, Zn, Cu analyses, leaf samples were weighed as 0.25 g and wet-digested with nitric acid (HNO_3) in a microwave device, then these samples were transferred to a 50 ml container and the volume was completed with deionized water and filtered through blue band filter paper. Total K was determined in the plant solution obtained using the wet-digested method using the Jenway PFP 7 Flame photometer (Kacar and İnal, 2008). Total phosphorus in the plant solution obtained using the wet-digested method was determined using the Shimadzu UV-160 Spectrophotometer according to the vanadomolybdenum phosphoric yellow color method (Kacar and İnal, 2008). Ca, Fe, Cu, Zn contents in the filters obtained according to the burning method were determined in Varian 720-ES ICP-OES (Kacar and İnal, 2008).
Total yield (kg plant^{-1}): Fruits collected from the first harvest to the last harvest date of each application subject were weighed. The obtained values were collected cumulatively and total yield per plant (kg plant^{-1}) was calculated.
The numerical data obtained from the experiments were subjected to variance analysis using MSTAT-C software, and differences were expressed with Duncan's multiple comparison test. Correlation analysis was performed to evaluate the relationships between the examined traits and expressed with a heatmap. The clustering between the variables was visualized with a dendrogram polar heatmap. Origin-2024 (Northampton, MA, USA) software was used for both analyses.

Bulgular ve Tartışma

The effects of grafting x vermicompost x drought stress interaction on N, P, K, Mg, Fe, Cu and Mn contents and yield were found to be statistically significant ($p<0.05$) (Table 1). However, there was no significant effect in terms of Ca content ($p>0.05$) (Table 1). Drought stress caused a slight increase in N, P, K and Mg contents of ungrafted and vermicomposted plants. These increases can be attributed to the increase in nutrient concentration with the decrease in water, changes in root morphology and adaptive mechanisms of the plants. However, combined grafting and V applications caused increases in macro and micro element contents compared to control (ungrafted and without vermicompost = without G and without V). Especially as the vermicompost dose increased, higher N, P, K and Mg accumulations were observed in the leaves of grafted plants under stress. Nitrogen content increased by 50.56% and 45.67% under MS and SS at G x V3 dose compared to control. The highest increase in phosphorus content was observed in G x V3 combination with 116.50% in SS, while K content increased by 115.69% and 111.16% with G x V2 application under MS and SS. While Mg concentration decreased significantly in SS medium, a significant increase of 53.80% was obtained with G x V1 application under MS. It was thought that N content might have increased more for the synthesis of special proteins effective in the stress tolerance mechanism of grafted plants under stress (Da Silva et al., 2011). The improved root structure of the grafted plants and the increased mineralization due to the use of vermicompost had a positive effect on the N uptake of the plants. The addition of vermicompost to the growing medium increased P mineralization in the soil and ensured its transformation into a useful form in the soil, allowing the grafted plants to take phosphorus more easily (Uma and Malathi, 2009; Farahani et al., 2020) and supported the stress tolerance of the plant. In addition, the effective root system of the Köksal F1 eggplant rootstock, which is a S. incanum hybrid used in grafting the plants, made a significant contribution to the tolerance to drought stress. Grafting onto a suitable rootstock is effective as a technique that increases drought tolerance, and in a previous study, this rootstock positively affected the drought stress tolerance of the grafted variety (Kıran et al., 2017). Vermicompost applications increase the usefulness of nutrients in the soil due to the activity of microorganisms responsible for the fixation, mineralization or dissolution of the nutrients it contains and the presence of high molecular weight acids that help dissolve some nutrients in the soil, and reduce the leaching of nutrients due to the increase in the negative charges of the soil by OH- in worm compost (Cruz et al., 2024). The emergence of more K and Mg accumulations with the use of vermicompost in eggplant plants grafted onto strong rootstocks can be attributed to the fact that stressed plants accumulate more K and Mg ions in their bodies in order to maintain turgor pressure, ion homeostasis and continue photosynthesis. Rootstocks used in grafted plants provide stress tolerance by increasing stomatal regulation and capacity in leaves by increasing K uptake (Mengel et al., 2001). In fact, there is information in the literature that vermicompost, as an organic material rich in K, has the ability to improve soil properties (Sinha et al., 2010).

Table 1. Variance analysis results of macro and micro elements

Source of Variation	*sd*	N	P	K	Ca	Mg	Mn	Fe	Cu	Yield
Grafting (G)	1	**	**	**	ns	**	**	**	**	**
Vermicompost (V)	3	**	*	ns	*	**	*	**	**	**
Drought stress (DS)	2	**	**	ns	*	ns	*	**	**	**
G × V	3	**	**	**	**	*	**	**	**	**
G × DS	2	**	*	ns	ns	**	ns	ns	**	**
V × DS	6	**	**	ns	*	**	ns	**	*	*
G × V × DS	6	**	**	*	ns	**	*	**	**	*
Error	48	0.04	0.00	0.17	0.05	0.04	45.91	198.41	0.76	0.020
CV(%)		5.99	8.22	9.76	6.22	12.23	9.27	13.31	6.85	11.29

ns: not significant. * p 0.05, **p 0.01.

Table 2. Effect of 'grafting × vermicompost × drought' interaction on macro, micro elements and yield

Grafting	V (%)	DS	N (%)	P (%)	K (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Yield (kg plant^{-1})
Non-grafted	0 (V_0)	WW	2.38 jk	0.120 hı	2.38 kl	1.44 e-g	71.37 n	81.98 h-k	11.37 j	1.22 e
		MS	2.67 ıj	0.127 gh	2.55 ı-l	1.58 c-g	63.43 r	76.16 ı-k	8.95 m	0.93 fh
		SS	2.89 a-c	0.103 ı	2.51 c-g	1.98 bc	57.27 u	66.63 k	9.54 l	0.34 h
	1 (V_1)	WW	3.03 g-ı	0.143 fg	2.9 l	1.66 b-g	73.92 m	101.84 f-ı	12.11hı	1.65 bc
		MS	3.48 d-f	0.197 b-d	4.35 c-ı	1.85 b-e	73.02 m	77.06 h-k	11.53 j	1.21 e
		SS	3.80 b-d	0.180 de	4.37 c-h	1.78 b-e	65.68 p	73.66 jk	11.75 ıj	0.36 h
	2 (V_3)	WW	3.19 f-h	0.150 f	3.89 f-k	1.34 fg	60.60 s	96.55 f-j	15.85 a	1.63 b-d
		MS	3.46 d-f	0.133 f-h	4.01 f-k	1.62 c-g	56.40 w	80.64 h-k	11.43 j	1.38 de
		SS	3.29 e-g	0.190 c-e	4.27 d-j	1.61 c-g	56.75 u	76.67 ı-k	9.55 l	0.54 gh
	3 (V_4)	WW	3.53 c-f	0.120 hı	3.65 h-l	1.27 g	71.40 n	160.91 b	14.43 cd	1.71 b
		MS	3.71 b-d	0.173 e	4.14 d-k	1.67 b-g	64.05 q	135.55 b-d	9.48 l	1.38 de
		SS	4.06 ab	0.20 bc	4.80 a-e	1.64 b-g	59.09 t	85.57 g-k	10.27 k	0.54 gh
Grafted	0 (V_0)	WW	2.23 k	0.19 bc	3.73 g-k	1.64 b-g	85.01e	104.25 f-h	15.77 a	1.63 b-d
		MS	3.32 f-g	0.227 a	4.54 b-f	1.93 b-d	78.00 h	109.33 e-g	13.09 f	1.42 c-e
		SS	3.24 e-g	0.203 bc	4.89 a-d	2.04 b	77.59 ı	82.56 g-k	14.27 cd	0.38 h
	1 (V_1)	WW	2.74 ı	0.180 de	3.82 f-k	1.53 c-g	88.38 b	88.79 g-k	14.37 cd	1.78 b
		MS	3.25 e-g	0.187 c-e	4.82 a-e	2.43 a	74.16 l	90.52 g-k	13.81 e	1.60 b-d
		SS	3.70 b-d	0.200 bc	4.91 a-d	1.81 b-e	80.77 g	68.14 k	12.46 gh	0.41 h
	2 (V_2)	WW	2.88 hı	0.202 bc	3.54 j-k	1.54 d-g	95.36 a	137.19 b-d	14.13 de	2.53 a
		MS	3.60 c-e	0.193 b-d	5.50 a	1.83 b-e	84.70 f	149.87 bc	14.50 c	1.80 b
		SS	3.72 b-d	0.210 ab	5.30 ab	1.70 b-f	65.94 p	118.27 d-f	12.81 fg	0.83 f
	3 (V_3)	WW	2.77 ı	0.173 e	3.59 h-l	1.62 c-g	86.54 d	186.43 a	15.17 b	2.50 a
		MS	4.02 ab	0.180 de	4.07 e-k	1.87 b-d	87.65 c	160.00 b	15.25 b	1.84 b
		SS	4.21 a	0.223 a	5.15 a-c	1.73 b-f	75.62 j	130.99 c-e	13.80 e	0.76 fg

The variance between the means expressed with different letters is significant (p<0.05).

In the study, as in Mn content, increasing losses were also observed in Fe and Cu contents with stress and increases were obtained in the amount of these elements under stress conditions thanks to the interaction of grafting and vermicompost. In terms of Mn content, G x V1 provided 41.36% increase in SS. A similar trend was observed in Fe and Cu concentrations and the highest increase rates were realized in MS and SS conditions with G x V3 (110.08% and 96.59%; 70.89% and 44.84%) (Table 2). Root hydraulic conduction in grafted plants and developed root system of the rootstock provided increases in Mn, Fe and Cu contents. In the study, Fe and Mn uptake by plants remained at low levels in SS and was relatively higher in MS. Vermicompost enriched the soil in terms of Fe and Mn and helped the availability of nutrients in dry conditions by secreting plant growth regulators in the plant rhizosphere thanks to the beneficial microorganisms it contains (Rangarajan et al., 2008). Similar results were reported by Tang (2018) and Kıran et al. (2017).

In the study, it was also examined how the changes in nutrient contents are related to each other and to yield, for this purpose, correlation analysis was performed and the results are given in Figure 1. In the correlation analysis; positive relationships were observed between K and N and P; Mg and K; Mn and Fe and Cu. However, the correlation between nutrient contents and yield was also examined. While it was noted that yield exhibited weak negative relationships with macro elements N and K, it was determined that it showed relatively strong positive relationships with Mn, Fe and Cu. The negative correlation between N and K and yield suggests that excessive N or K accumulation, especially under drought conditions, may have negative effects on plant growth. Although N and K are critical nutrients for plant growth under normal conditions, they may have negative effects under drought stress. N is necessary for protein synthesis, photosynthesis and growth in the plant. However, excessive N intake can promote vegetative growth under drought conditions; this situation can reduce stress tolerance by increasing water loss. In addition, excessive N can cause carbon and nitrogen imbalance, negatively affecting the synthesis of osmoprotectants (proline, sugar, etc.) and thus reducing drought tolerance (Du et al., 2017). As a result, it is possible that the yield will be low and a negative correlation will occur. On the other hand, the relationship between high K levels and reduced yield may be due to antagonistic nutrient interactions. The relatively strong positive correlation between Mn, Fe, and Cu and yield indicates that these microelements play critical roles in stress tolerance and metabolic processes. Mn, Fe, and Cu are micronutrient elements that play an important role in drought tolerance, and high levels of these elements are seen as factors that positively affect yield. Mn deficiency can negatively affect photosynthesis and carbon metabolism; however, high levels of Mn may have increased yield by protecting these processes (Messant et al., 2022). High Fe levels in drought conditions can reduce chlorosis and increase photosynthetic capacity. High Fe can support ATP production by improving photosynthetic electron transport and contribute to yield by providing energy balance under stress conditions (Briat et al., 2015). In addition, Cu is necessary for lignin synthesis and cell wall stability (Li et al., 2023). Under drought stress, plants can contain more Cu against oxidative stress, which can prevent cell damage and help maintain growth (Chen et al., 2022).

The polar heatmap with dendrogram visualizes the relationship between yield and nutrients in grafted/non-grafted plants and vermicompost applications at different drought levels (Figure 2). Temperature differences in the polar heatmap indicate clustering; if high temperatures (red tones) are concentrated in a certain area, this may indicate that the area forms a cluster. Similarly, low temperatures (blue tones) may also show a tendency to cluster. The clustering structure of nutrients reveals that certain elements act together. In this context, macronutrients (N, P, K, Mg) and micronutrients (Fe, Mn, Cu) were located in different groups and exhibited direct relationships among themselves. However, while high nutrient intake represented by dark red came to the fore in control conditions, it was observed that nutrient intake decreased in MS (light red tone) and MS conditions (blue tone). The dendrogram in the heatmap shows that red tones are more dominant in grafted plants grown in vermicomposted environments, meaning that nutrient uptake is better maintained under drought conditions and yield is higher. This is a result of the synergistic interaction between the fact that grafted plants generally have a stronger root system and can increase nutrient uptake under stressful conditions, and the fact that vermicompost improves soil structure and supports plant nutrient uptake. The fact that the color tone does not shift to blue, especially under drought conditions, reveals the power of the synergy of grafting and vermicompost. On the other hand, the fact that blue areas are more common in non-grafted and low vermicompost doses shows that nutrient loss is more pronounced in these groups and yield losses increase due to stress.

In conclusion, our findings suggest that the interaction of grafting, vermicompost and drought stress significantly affects nutrient uptake and yield. Grafted plants grown in vermicompost enriched soil maintained higher nutrient levels and yield under drought stress as expressed by the predominance of red tones in the heatmap. The clustering pattern also revealed strong positive correlations between micronutrients (Fe, Mn, Cu) and their relationship with yield, while excessive N and K accumulation showed a weak negative correlation with yield under drought conditions.

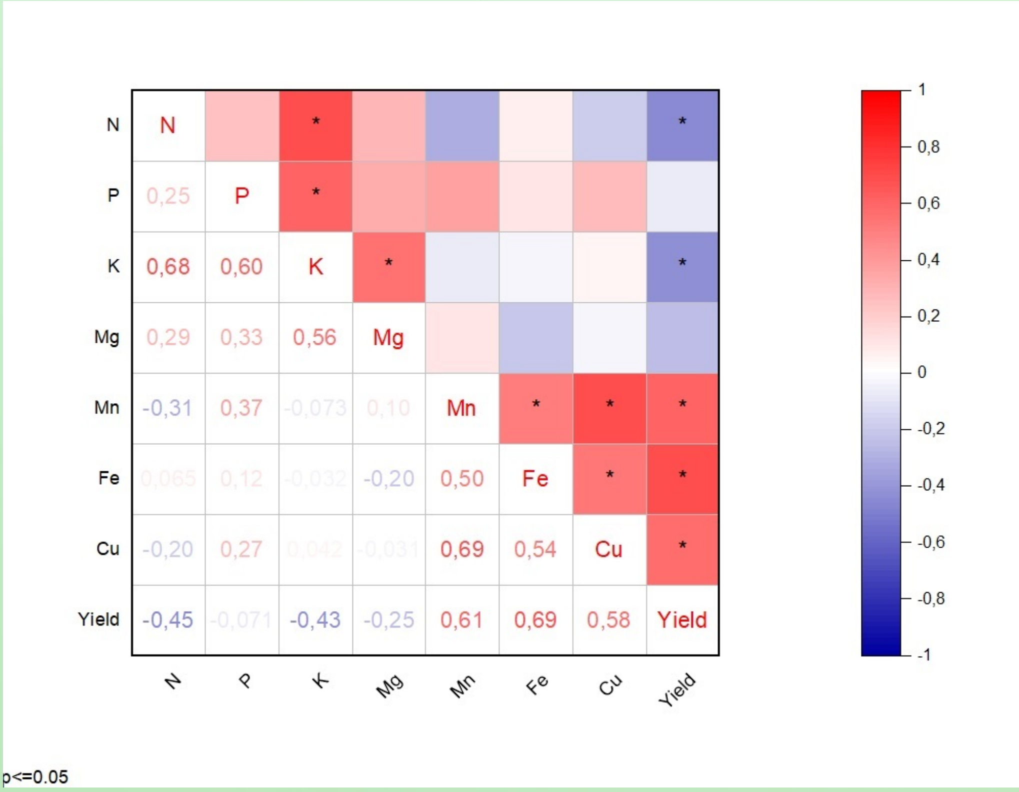

Figure 1. Correlation table between macro and micro element contents and yield.

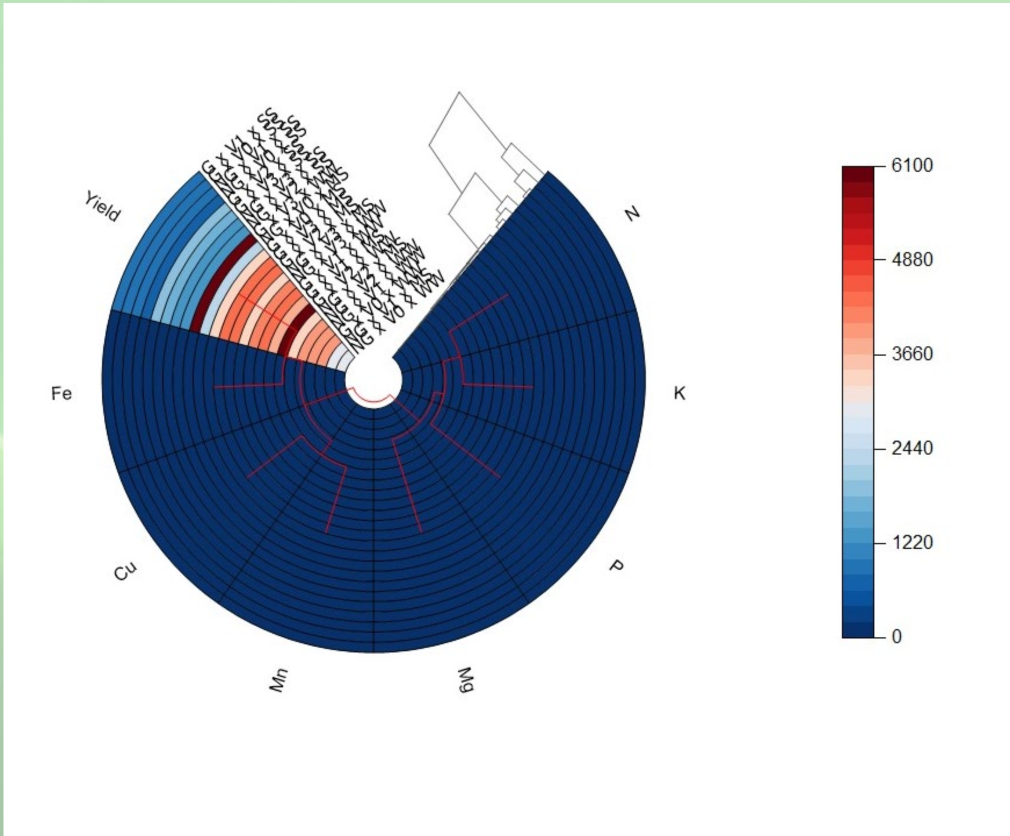

Figure 2. Representation of the relationships between macro and micro element contents and yield with dendrogram polar heatmap

References

Boyacı HF, Ellialtıoğlu ŞŞ. 2018. Rootstock usage in eggplant: Actual situation and recent advances. Acta Horticulturae. 1271:403–410.

Briat JF, Dubos C, Gaymard F. 2015. Iron nutrition, biomass production, and plant product quality. Trends in Plant Science. 20(1):33–40.

Chen H, Song L, Zhang H, Wang J, Wang Y, Zhang H. 2022. Cu ve Zn stresi, alfalfanın (*Medicago sativa*) fotosentetik ve antioksidan sistemlerini etkiler. Journal of Plant Interactions. 17(1):695–704.

Cruz GSJ, Hermes PH, Miriam SV, López AM. 2024. Benefits of vermicompost in agriculture and factors affecting its nutrient content. Journal of Soil Science and Plant Nutrition. 24(3):4898–4917.

Da Silva EC, Nogueira RJMC, Da Silva MA, De Albuquerque MB. 2011. Drought stress and plant nutrition. Plant Stress. 5(1):32–41.

Demir Z. 2019. Effects of vermicompost on soil physicochemical properties and lettuce (*Lactuca sativa* var. *crispa*) yield in greenhouse under different soil water regimes. Communications in Soil Science and Plant Analysis. 50(17):2151–2168. https://doi.org/10.1080/00103624.2019.1665227

Du J, Shu S, An Y, Zhou H, Guo S, Sun J. 2017. Influence of exogenous spermidine on carbon–nitrogen metabolism under $Ca(NO_3)_2$ stress in cucumber root. Plant Growth Regulation. 81:103–115.

Farahani SS, Asoodar MA, Moghadam BK. 2020. Short-term impacts of biochar, tillage practices, and irrigation systems on nitrate and phosphorus concentrations in subsurface drainage water. Environmental Science and Pollution Research. 27(1):761–771.

Hannachi S, Signore A, Adnan M, Mechi L. 2022. Single and associated effects of drought and heat stresses on physiological, biochemical and antioxidant machinery of four eggplant cultivars. Plants. 11(18):2404.

Kaçar B, İnal A. 2008. Bitki Fizyolojisi. Nobel Yayın No:1241-477, Ankara.

Kıran S, Kuşvuran Ş, Çağla A, Ellialtıoğlu ŞŞ. 2017. Some physiological properties and analysis of yield parameters of grafted and non-grafted eggplants under waterless conditions. Soil and Water Journal. 6(2):18–25.

Kıran S. 2019. Effects of vermicompost on some morphological, physiological and biochemical parameters of lettuce (*Lactuca sativa* var. *crispa*) under drought stress. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 47(2):352–358.

Kıran S, Baysal Furtana G. 2023. Responses of eggplant seedlings to combined effects of drought and salinity stress: Effects on photosynthetic pigments and enzymatic and non-enzymatic antioxidants. Gesunde Pflanzen. 75(6):2579–2590.

Li Y, Shi S, Zhang Y, Zhang A, Wang Z, Yang Y. 2023. Buğday fidelerinde fotosentetik özellikler ve lignin metabolizmasıyla ilişkili bakır stres kaynaklı fitotoksisite. Ecotoxicology and Environmental Safety. 254:114739.

Mengel K, Kirkby EA, Kosegarten H, Appel T. 2001. Principles of Plant Nutrition. Springer, Dordrecht.

Messant M, Hennebelle T, Guérard F, Gakière B, Gall A, Thomine S, Krieger-Liszkay A. 2022. Manganese excess and deficiency affects photosynthesis and metabolism in Marchantia polymorpha. bioRxiv. 2022-01.

Ors S, Ekinci M, Yıldırım E, Şahin U, Turan M, Dursun A. 2021. Interactive effects of salinity and drought stress on photosynthetic characteristics and physiology of tomato (*Lycopersicon esculentum* L.) seedlings. South African Journal of Botany. 137:335–339.

Rangarajan A, Leonard B, Jack A. 2008. Cabbage transplant production using organic media on farm. In: Sukumaran N, editor. Proceedings of National Seminar on Sustainable Environment. Bharathiar University, Coimbatore. p. 45–53.

Rehman SU, De Castro F, Aprile A, Benedetti M, Fanizzi FP. 2023. Vermicompost: Enhancing plant growth and combating abiotic and biotic stress. Agronomy. 13(4):1134.

Sekera A, Cebula S, Kunicki E. 2007. Cultivated eggplants–origin, breeding objectives, and genetic resources, a review. Folia Horticulturae. 19(1):97–114.

Sinha RK, Agarwal S, Chaudhan K, Valani D. 2010. The wonders of earthworms and its vermicomposting in farm production: Charles Darwin's 'friends of farmers,' with potential to replace destructive chemical fertilizers from agriculture. Agricultural Sciences. 1(2):76–94.

Tang CV. 2018. Soil microbial community responses to applications of vermicompost, arbuscular mycorrhizal fungi, and grafting under tomatoes [dissertation]. North Carolina State University.

Toppino L, Barchi L, Rotino GL. 2022. Next-generation breeding for abiotic stress resistance in eggplant. In: Kole C, editor. Genomic Designing of Climate-Smart Vegetable Crops. Springer, Cham. p. 363–387. https://doi.org/10.1007/978-3-030-80098-0_14

Uma B, Malathi M. 2009. Vermicompost as a soil supplement to improve growth and yield of Amaranthus species. Research Journal of Agriculture and Biological Sciences. 5(6):1054–1060.