A Potential Role of Mycorrhizae, Iron and Zinc Combinations on Increasing Peanut Yield (*Arachis hypogea* L.)

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Abstract: The exogenous applications of arbuscular mycorrhizal fungi (AMF), iron (Fe) and zinc (Zn) have the potential to increase yield in peanut. The objective of this study was to evaluate the effects of AMF, Fe and Zn combinations on yield and yield components in peanut. Seed coating with AMF and foliar sprays of Fe and Zn were arranged in split-split plot arrangement in completely randomized block design with four replications under farmer' condition in 2020. The highest values for pod number per plant, pod and kernel yield (kg ha^{-1}) and 100 kernel weight were recorded in parcels where AMF, Fe and Zn were applied together. The combination of AMF, Fe and Zn favorable affected maturity date and harvest index. It was highlighted that AMF, Fe and Zn combinations could be used successfully to improve the yield in peanut cultivation.

Keywords: Arbuscular Mycorrhizae Fungi, Fe, Peanut, Zn, Yield.

Yerfıstığında (*Arachis hypogea* L.) Mikoriza, Demir ve Çinko Uygulamalarının Verim ve Tarımsal Özellikler Üzerine Etkisi

Öz: *Arbüsküler mikorizal fungus, demir ve çinko uygulamaları yerfıstığı verimini artırma potansiyeline sahiptir. Bu çalışmada, AMF, Fe ve Zn'nun birlikte uygulamalarının yerfıstığı verimi ve verim komponentlerine etkisinin belirlenmesi amaçlanmıştır. 2020 yılında ve çiftçi koşullarında AMF'nin tohum kaplaması ile birlikte demir ve çinkonun yapraktan uygulanması konuları 4 yinelemeli tesadüf bloklarında bölünen bölünmüş parseller deneme deseninde değerlendirilmiştir. Bitkide kapsül sayısı, kapsül ve tane verimi ve 100 tohum ağırlığı yönünden en yüksek değerler AMF, Fe ve Zn'nun birlikte kullanıldığı parsellerden elde edilmiştir. Ayrıca AMF, Fe ve Zn kombinasyonunun erken olgunlaşmaya neden olduğu ve hasat indeksini artırdığı belirlenmiştir. Yerfıstığı tarımında verimi artırmak için AMF, Fe ve Zn kombinasyonunun başarı ile kullanılabileceği sonucuna varılmıştır.*

Anahtar Kelimeler: *Arbusküler Mikorizal Fungus, Fe, Verim, Yerfıstığı, Zn.*

INTRODUCTION

Peanut (*Arachis hypogea* L.), which belongs to the family Fabaceae is a legume that originated in South America. Although it is classified as an oil crop, the peanut is most often consumed roasted or as peanut butter in the world and Turkey (Anonymous, 2021). The totally growing area and production of the world were about 21.0 million hectares and 47 million tons, respectively. Major producers are China, India, Nigeria, USA and Myanmar. Turkey's annual production is about 169 thousand tons at 42.0 thousand hectares of growing area (FAO, 2019).

In a mono-cropping system, continuously peanut growing without any crop rotation can adversely affect soil microbial structure (Xiong et al., 2015; She et al., 2017), and peanut yield and marketing value decreased due to these detrimental effects on soil fertility (Maclean et al., 2017). In soil microorganisms, symbiotic mycorrhizal fungi such as Arbuscular mycorrhizal fungi (AMF) enhanced soil fertility, plant growth and uptake of nutrients (Gianinazzi et al., 1994). The AMF application increased the shoot and root length, number of leaves per plant and dry matter weight per plant (Doley and Jite, 2012), number of pods per plant, seed yield and thousand kernel weight (Uko et al., 2019).

Iron and zinc deficiency often occur in areas where peanut production is very intense due to the lack of organic matter (Nakum et al., 2019) in calcareous soils (Patel et al., 1999). Therefore, the effective Fe and Zn content of calcareous soil is very low (Liu et a., 2017). In addition, conditions with alkaline and calcareous negatively affected Zn adsorbtion capacity (Srinivasara et al., 2008). Due to adversely conditions, Zn and Fe deficiency causes considerable reductions in peanut yield (Meena et al., 2007). The highest values for the number of pods per plant, pod weight per plant, thousand kernel weight and pod yield (kg ha^{-1}) were recorded in the combined foliar application of zinc and iron (Arunachalam et al., 2013; El- Metwally et al., 2018; Nakum et al., 2019). In other studies, foliar zinc sprays enhanced pod yield (kg ha^{-1}) in peanut (Irmak et al., 2016; Gowthami and Ananda, 2017). Similarly, the combination of AMF and Ca^{2+} positively affected growth parameters and plant development under mono-cropping conditions (Cui et al., 2019).

The literature review was shown that many previous studies about the effect of AMF were conducted under controlled conditions. Therefore, this study attempt to determine the effects of AMF, Fe and Zn in farmer's field. Also, we hypothesized that the combination of AMF, Fe and Zn could increase the yield in peanut.

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This study is produced from the M.Sc. thesis.
***The submitted date:** November 4, 2021*
***The accepted date:** April 15, 2022*

MATERIALS AND METHODS

The experiment was conducted in a farmer's field where peanut was grown as mono-cropping in Çona/Osmaniye (37°10′ N; 36° 25′ E and 94 m altitudes) during the 2020 summer season. The soil characters of the experimental area were clay loamy, slightly alkali (pH: 7.44), non-saline (0.07%), calcareous (1.82%), low in organic matter (1.69%), sufficient in Zn and Fe (0.56 and 7.23 mg kg^{-1}, respectively).

In accordance with the hypothesis of the study, the field with especially calcareous and low organic matter soil characteristics was selected. According to the climatic characters of Osmaniye, the summers are hot and dry; the winters are cold and wed. Table 1 showed monthly mean temperatures, relative moisture and precipitation for the experimental year and long-term years in the April-September period. The experimental year data compared to long-term indicated a slightly cool, dry but rainy climate during the growing season.

Peanut (*Arachis hypogea* L. cv. NC-7) seeds treated with arbuscular mycorrhizal fungi (17 g L^{-1}) from Shubhodaya™ including *Glomus mossae, Glomus etunicatum* and *Glomus intraradices* (number of live organisms = 1 x 10^5 g^{-1}) 3 hours before sowing. The experiment was arranged in split-split plot arrangement in completely randomized block design with four replications with AMF as main plots, foliar spray of Fe as subplots and foliar spray of Zn as sub-sub plots.

The foliar fertilizers with Fe (2.7 g w/w) Zn (5.4% w/w) were applied by a portable hand-held field plot sprayer using a water carrier volume of 400 L ha^{-1} at the stage of first flowering (02.06.2020).

The experimental unit was 21 m^2 (6 rows x 0.7 m apart x 5.0 m long and 0.2 m of plant to plant). N and P_2O_5 fertilizer as di-ammonium phosphate was added at the rate of 300 kg ha^{-1} during soil preparation and remained N as ammonium nitrate was applied at the rate of 230 kg ha^{-1} before first irrigation at peak flowering stage. All plots were mechanically hoed to weed control and irrigated six times by sprinkler irrigation.

All plots were harvested by hand at 60% pod maturing stage capsule on 25 September 2020. The number of days to maturity was screened by seed-hull maturity index methods (Rowland et al., 2006). Pod $plant^{-1}$, pod yield (kg ha^{-1}) and kernel yield (kg ha^{-1}) were determined in randomly selected 20 plants from each plot. Hundred seed weight (g) and harvest index (%) were measured after harvest.

TOTEMSTAT statistical packet program (Acikgoz et al., 2004) was used to the analysis of variance for observed data in accordance with the split-split plot design. LSD test was used to compare the differences between mean values (Steel and Torrie, 1980).

Table 1. Meteorological data of experimental year (2020), long-term (LT; 1975-2019) and their differences

	Mean Temperature (°C)			**Relative moisture (%)**			**Precipitation (mm)**		
	2020	**LT**	**Diffrence**	**2020**	**LT**	**Diffrence**	**2020**	**LT**	**Difference**
April	17.1	17.5	-0.4	62.8	60.4	2.4	82.8	51.1	31.7
May	23.3	21.7	1.6	64.1	63.8	0.3	74.1	47.1	27.0
June	25.0	25.6	-0.6	66.5	71.4	-4.9	39.9	20.5	14.4
July	27.9	28.2	-0.3	66.9	70.1	-3.2	19.2	6.2	13.0
August	28.5	28.7	-0.2	61.5	68.7	-7.2	10.7	5.5	5.2
September	25.8	26.1	-0.3	61.2	65.1	-3.9	34.4	17.6	19.8
Totally							261.1	148.0	

Meteorological data were obtained from the Turkish State Meteorological Service (Anonymous, 2020).

RESULTS AND DISCUSSION

The number of pods per plant is an important character in terms of yield components in peanut. When AMF, Fe and Zn applications were compared with their controls, the differences were found to be significant for pod number per plant (Table 2). Higher mean values were recorded in the plots where AMF (32.1), Fe (31.1) and Zn (29.3) were applied. It was remarkable that the lowest values (20.0) were determined in the plots where all three applications were not made, whereas the combinations of AMF, Fe and Zn exhibited the highest pod number per plant. This finding indicated that the effects of all applications on pod number per plant were significantly positive.

One of the most important characters for marketing and yield component is pod yield in peanut. Pod yield varied between 2569.5 kg ha^{-1} (non-treatment) and 4260.4 kg ha^{-1} (AMF + Fe +Zn combination) (Table 2). The significant interaction of AMF x Fe indicated that foliar Fe application without AMF gave statistically higher than non-application Fe. Although the differences were non-significant, it was clearly seen that the highest pod yields were recorded in the combinations of AMF, Fe and Zn or AMF +Fe.

The higher kernel yield of peanut increased the marketable value of the product. The result of significant difference between AMF and non-AMF indicated that AMF application gave 145.7 kg ha^{-1} more kernel yield (Table 2). In addition, the higher yields from AMF + Fe + Zn, AMF + Fe and Fe + Zn explained that the contribution of Fe and Zn should be considered to improve the kernel yield in peanut.

Table 2. Pod number per plant (PN/P), pod yield (PY), kernel yield (KY), 100 kernel weight (HKW), number of days to maturity (NDM) and harvest index (HI) of AMF, Fe and Zn interaction

Treatments		PN/P (number)	PY (kg ha^{-1})	KY (kg ha^{-1})	HKW (g)	NDM (days)	HI (%)
AMF+	Fe+						
	Zn+	37.0	4260.4	2273.6	150.5	126.0	35.5
	Zn-	32.0	3926.3	2193.7	142.3	130.8	32.3
	Fe-						
	Zn+	30.3	3892.5	2143.1	148.5	131.5	32.3
	Zn-	29.0	3875.4	2121.7	141.8	133.5	31.5
	Mean Fe+	34.5	4093.3	2233.7	146.5	128.4	33.9
	Mean Fe-	29.6	3870.0	2132.4	145.1	132.5	31.9
	Mean Zn+				149.5 a	128.8	33.9
	Mean Zn-				142.1 b	132.2	31.9
	MeanAMF+	32.1 A	3981.6	2183.0 A	145.8	130.4 A	32.9 A
AMF-	Fe+						
	Zn+	28.5	3683.2	2171.2	145.3	132.3	31.3
	Zn-	27.0	3164.6	2011.5	142.0	134.3	31.0
	Fe-						
	Zn+	21.5	2594.2	2031.7	136.3	138.0	30.3
	Zn-	20.0	2569.9	1935.0	134.0	140.0	30.3
	Mean Fe+	27.8	3423.9 a	2091.4	143.6 a	133.3	31.2
	Mean Fe-	20.8	2581.8 b	1983.4	135.1 b	139.0	30.3
	Mean Zn+				140.8	135.2	30.8
	Mean Zn-				138.0	137.2	30.7
	MeanAMF+	24.3 B	3000.2	2037.3 B	139.4	136.1 B	30.7 B
	Grand Mean Fe+	31.1 a	3758.6	2162.5	145.0	130.8 a	32.6
	Grand Mean Fe-	25.2 b	3225.9	2057.9	140.2	135.8 b	31.1
	Grand Mean Zn+	29.3 a	3607.6	2154.9	145.2	132.0 a	32.4
	Grand Mean Zn-	27.0 b	3376.9	2065.5	140.1	134.6 b	31.3
	AMF	**	**	*	**	**	*
	Fe	**	**	ns	**	**	ns
	Zn	*	ns	ns	**	**	ns
	AMF x Fe	ns	*	ns	**	ns	ns
	AMF x Zn	ns	ns	ns	*	ns	ns
	AMF x Fe x Zn	ns	ns	ns	ns	ns	ns

*, **; significant level 0.05 and 0.01, respectively.

The 100 kernel weight is important for the use of seeds and the classification of the product in peanuts. The interaction of AMF x Fe and AMF x Zn were significant (Table 2).
Foliar Zn spray had a positive and significant effect on 100 kernel weight in AMF applied parcels whereas Fe application without AMF gave a significantly higher 100 kernel weight.
The higher yield in AMF + Zn parcels indicated the significance of the AMF +Zn combination on 100 kernel weight.
The early maturity allows a suitable cropping system. In our study, AMF, Fe and Zn applied plants compared with their control reached statistically physiological maturity at early times (Table 2). Earliness were 5.7 days in AMF, 5 days in Fe and 2.6 days in Zn. In addition, the early maturity obtained from AMF, Fe and Zn combination explained the successful usability of these applications, especially in short-season peanut cultivation.
The proportion of pods/total crop biomass without root is defined as harvest index (%) in peanut (Puttha and Jogloy, 2019). The harvest index values changed from 30.3% to 35.5%, and mean value was 31.8%. The results of harvest index values in our study indicated that the significantly higher harvest index (32.9%) was recorded in AMF application compered with non-AMF treatment (30.7%). Our results are in agreement with Uko et al. (2019) who found a higher harvest index in *G. clarum* inoculation. Although AMF, Fe and Zn interaction was non-significant, the highest harvest index (35.5%) in AMF, Fe and Zn combination clearly revealed that these applications could change the dry matter distribution in the plant.
The presence of only AMF favorable affected the number of pods per plant, pod yield kernel yield, 100 kernel weight, days to maturity and harvest index while AMF with Fe increased the pod yield. He and Nara (2007) emphasized the importance of mycorrhizas in promoting crop productivity. Similarly, many researchers were emphasized that AMF treatment in maize (Sabia et al., 2015), wheat (Pellegrino et al., 2015), potato (Hijri, 2016) and cotton (Gao et al., 2020)

have considerable potential for increasing yield in field conditions.

The foliar application of Fe + Zn treatment with AMF has synergistic effects on yield and yield components in our study. Smith and Read (1997) revealed that AMF enhances the nutrient absorbing surface area and uptake of immobile Zn. In addition it was reported that AMF-colonized peanut can mobilize Fe from calcareous soil (Caris et al., 1998). Also, the Fe + Zn combination increased all yield and yield components and declined the days to maturity. It was clearly demonstrated the positive effect of Fe + Zn on plant height, pods per plant, pods weight, seed weight, shelling, 100 seed weight, seed yield (Arunachalam et al., 2013; Abdel-Motagally et al., 2016; Irmak et al., 2016; El- Metwally et al., 2018; Nakum et al., 2019).

CONCLUSION

This study concluded that seed coating with AMF and foliar application of Fe and Zn, and their combination, improved yield and yield components in peanut. However, more detailed researches should be carried out to support the findings of this preliminary study. Studies in which elements such as manganese and calcium are added to AMF + Fe + Zn should focus on stress conditions.

REFERENCES

Abdel-Motagally FMF, Mahmoud MWSH, Ahmed EM (2016) Response of Two Peanut Varieties to Foliar Spray of Some Micronutrients and Sulphur Application under East of El-Ewinat Conditions. Assiut J. Agric. Sci. 47 (1): 14-30.

Acikgoz N, Ilker E, Gokcol A (2004) TOTEMSTAT Statistical Packet Program. Assessment of Biological Research on the Computer. Ege Uni. ISBN:975-483-607-8 Bornova-Izmir.

Anonymous (2020) Meteorological Data for Osmaniye. Turkish State Meteorological Service https://www.mgm.gov.tr/ (accessed 25 October 2021).

Arunachalam P, Kannan P, Prabhaharan J, Prabukumar G, Kavitha Z (2013) Response of Groundnut (Arachis hypogaea L.) Genotypes to Soil Fertilization of Micronutrients in Alfisol Conditions. Electronic Journal of Plant Breeding 4(1): 1043-1049.

Caris C, Hoerdt W, Hwkins HJ, Roemheld VH (1998) Studies on the Iron Transport by Arbuscular Mycorrhizal Hyphae from Soil to Peanut and Sorghum Plants. Mycorrhiza 8: 35-39.

Cui L, Guo F, Zhang JL, Yang S, Meng JJ, Geng Y, Wang Q, Li XG, Wan SB (2019) Arbuscular Mycorrhizal Fungi Combined with Exogenous Calcium Improves the Growth of Peanut (Arachis hypogaea L.) Seedlings under Continuous Cropping. Journal of Integrative Agriculture 18, 407–416.

Doley K, Jite PK (2012). Response of Groundnut (JL-24) Cultivar to Mycorrhiza Inoculation and Phosphorous Application Sci. Biol. 4(3): 118-125.

El-Metwally IM, Doaa MR, Basha A, Abd El-Aziz ME (2018) Response of Plants to Different Foliar Applications of Nano-iron, Nanganese and Zinc under Sandy Soil Conditions. Middle East Journal of Applied Sciences 474-482.FAO (2019) Food and Agriculture Data. http://www.fao.org

Gao X, Guo H, Zhang Q, Guo H, Zhang L, Zhang C, Zeng F (2020) Arbuscular Mycorrhizal Fungi (AMF) Enhanced the Growth, Yield, Fiber Quality and Phosphorus Regulation in Upland Cotton (Gossypium hirsutum L.). Scientific Reports 10(1): 1-12.

Gianinazzi S, Schuepp H (1994) Impact of Arbuscular Mycorrhizas on Sustainable Agriculture and Natural Ecosystems Birkhauser Verlag, Basel. p. 226.

Gowthami SS, Ananda N (2017) Effect of Zinc and Iron Ferti-fortification on Growth, Pod Yield and Zinc Uptake of Groundnut (Arachis hypogaea L.) Genotypes. International Journal of Agriculture, Environment and Biotechnology 10(5): 575-580.

He X, Nara K (2007) Element Biofortication: Can Mycorrhizas Potantially Offer a More Effective and Sustainable Pathway to Curb Human Malnutrition. Trends in Plant Science 12:331-335.

Hijri M (2016) Analysis of a Large Dataset Form Field Mycorrhizal Inoculation Trials on Potato Showed Highly Significant Increase in Yield. Mycorrhiza 26(3): 209–214.

Irmak S, Cil AN, Yucel H, Kaya Z (2016) Effect of Zinc Application on Yield and Some Yield Components in Peanut (Arachis hypogea L.) in the Eastern Mediterranean Region, Journal of Agricultural Science 22: 109-116.

Liu D, Yang Q, Ge K, Hu X, Qi G, Du B, Liu K, Ding Y (2017) Promotion of iron nutrition and growth on peanut by Paenibacillus illinoisensis and Bacillus sp. strains in calcareous soil. Braz J Microbiol 48(4):656-670.

Maclean AM, Bravo A, Harrison MJ (2017) Plant Signaling and Metabolic Pathways Enabling Arbuscular Mycorrhizal Symbiosis. The Plant Cell 29: 2319–2335.

Meena S, Malarkodi M, Senthilvalavan P (2007) Secondary and Micronutrients for Groundnut - a Review. Agricultural Reviews 28(4): 295-300.

Nakum SD, Sutaria GS, Jadav RD (2019) Effect of Zinc and Iron Fertilization on Yield and Economics of Groundnut (Arachis hypogaea L.) under Dryland Condition. International Journal of Chemical Studies 7(2): 1221-1224.

Patel KP, George V, Patel KC (1999) Micronutrient Research in Gujarat. Journal of Gujarat Society Agronomy & Soil Science 1(1): 27- 32.

Pellegrino E, Opik M, Bonari E, Ercoli L (2015) Responses of Wheat to Arbuscular Mycorrhizal Fungi: a Meta-analysis of Field Studies from 1975 to 2013. Soil Biology & Biochemistry 84: 210–217.

Puttha R, Jogloy S (2019) Evaluation of Advanced Peanut Breeding Lines for Large Seed and Early Maturity in the East, Thailand. Journal of Advanced Agricultural Technologies 6 (2): 128-132.

Rowland DL, Sorensen RB, Butts, CL, Faircloth WH (2006) Determination of Maturity and Degree Day Indices and their Success in Predicting Peanut Maturity. Peanut Science 33: 125-136.

Sabia E, Claps S, Morone G, Bruno A, Sepe L, Aleandri R (2015) Field Inoculation of Arbuscular Mycorrhiza on Maize (Zea mays L.) under Low Inputs: Preliminary Study on Quantitative and Qualitative Aspects. Italian J. Agron. 10: 30–33.

Srinivasara C H, Wani S P, Sahrawat K L, Rego T J, Pardhasaradhi G (2008) Zinc, boron and Sulphur deficiencies are holding back the potential of rain fed crops in semi-arid India: Experiments from participatory watershed management. International Journal of Plant Production 2: 89-99.

She S, Niu J, Zhang C, Xiao Y, Chen W, Dai L, Liu X, Yin H (2017) Significant Relationship between Soil Bacterial Community Structure and Incidence of Bacterial Wilt Disease under Continuous Cropping System. Archives of Microbiology 199: 267–275.

Smith SE Read DJ (1997) Mycorrhizal Symbiosis. London: Akademic Press.

Steel RGD, Torrie JH (1980) Principles and Procedures of Statistics. Second Ed. McGraw-Hill Book Company Inc., New York.

Uko AE, Udo, AI, Effa EB (2019) Growth and Yield Responses of Groundnut (Arachis hypogea L.) to Arbuscular Mycorrhizal Fungi Inoculation in Calabar, Nigeria. Asian Journal of Crop Science 11: 8-16.

Xiong W, Zhao Q, Zhao J, Xun W, Li R, Zhang R, Wu H, Shen Q (2015) Different Continuous Cropping Spans Significantly Affect Microbial Community Membership and Structure in a Vanilla-grown Soil as Revealed by Deep Pyrosequencing. Microbial Ecology 70: 209–218.