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Intercropping System and Biofertilizers as Complementary Strategies for Increasing the Efficiency of a Sustainable Cabbage, and lettuce Farming System

Eman Bassuny El-Remaly[1*], Khadiga Ibrahim Mohamed ElGabry[2] and Hanan Mohamed Mostafa[3]

[1]Cross-Pollinated Vegetables Research Department, Horticulture Research Institute, Agriculture Research Center (ARC), Giza, 12619, Egypt, emanelrmaly@arc.sci.eg, Orcid ID: 0000-0002-8875-9876

[2]The Agricultural Microbiology Research Department, Soils, Water and Environment Research Institute, Agriculture Research Center (ARC), Giza, 12619, Egypt, khadigagabry@yahoo.com, Orcid ID: 0000-0002-6471-2512

[3]Land and Water Economics Research Department, Agricultural Economic Research institute, Agriculture Research Center (ARC), Giza, 12619, Egypt, hanan_statistic@yahoo.com , Orcid ID: 0000-0002-8847-5785

* Corresponding author: emanelrmaly@arc.sci.

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ABSTRACT

The main objective of this study was to maximize productivity per unit area for cabbage and lettuce crops using the intercropping system and increase its efficiency with biofertilizers. The study compared a monocropping with an intercropping system in combination with bio-fertilization to improve growth, yield, soil efficiency, water efficiency, and reduce chemical residual impacts on the soil. In the two winter, seasons of 2019 and 2020, three fertilizer treatments,100% recommended mineral fertilization (RMF), arbuscular mycorrhizal fungi (AMF), and mixed treatment (AMF and 50% RMF) were conducted in monocropping and intercropping systems for cabbage and lettuce. The experiments were done in a factorial randomized complete block designed. The results revealed no significant differences between mono and intercropped systems for most horticultural traits in two seasons, except for the head length and diameter of cabbage that were affected by the intercropping system. The mixed treatment supported the intercropping system to outperform all treatments. The mixed treatment recorded the highest horticultural parameter values and the most improvement of mineral uptake, potential of hydrogen (pH), total dissolved solids (TDS), and enzyme activities in plants and soil, as well as an economical use efficiency for yield, water, and soil. The results demonstrated the effectiveness of the intercropping system with biofertilizers in producing a high yield of crops while also preserving biological balance of soil, particularly in light of agricultural area fragmentation and climate change challenges.

KEYWORDS: Arbuscular mycorrhiza fungi; Dehydrogenase; Phosphatase; Nitrogenase Peroxidase; Catalase

1. INTRODUCTION

The world faces great challenges in the farming section, coinciding with the water deficit and the attrition of the cultivated soil, with small holdings area. In Egypt, the maximum yield from a unit area should be achieved (Abdrabbo et al. 2015). The total population of Egypt has grown fleetly to further than 100 million, contributing to a drop in the available area for food crops cultivation, water resources declination, accumulation of toxic residues in the soil and deterioration of soil quality and fertility (Pathak et al. 2018). Intercropped systems are one of the key agricultural approaches to increase land and water use efficiency, while achieving good production that minimizes economic risk through effective use of available resources, efficient use of labor, increased crop productivity, erosion control and food security (Addo-Quaye et al. 2011; Brooker et al. 2015). Therefore, it should be optimally used the intercropping system as agricultural practices in small cultivation fields (Pathak et al. 2018; Ronga et al. 2019). It was necessary to think about using some methods to maximize the benefits of the intercropping system and raise its efficiency to achieve the maximum yield that would return economic benefits (Guvenc and Yildirim, 1999). The intercropping strategy is typically preferred by Egyptian peasants because it results in a better total yield per unit area and offers protection against complete crop failure

(Lyocks et al. 2013). Intercropping has the potential to improve land utilization, yield, yield stability, soil quality, and water use efficiency, resulting in more productive and resilient agroecosystems (Abdrabbo et al. 2015).

Crop selection in the inter-cropping system was based on differences in growth rhythm, maturation time, and mor-phological traits with the aim of reducing or displacing intercrop competition due to the complementary effects of intercropped (Homulle et al. 2021). Cabbage, *Brassica oleracea* L. var. *capitata* f., is an important crop of the *Brassicaceae* family, with high levels of mineral nutrients and antioxidants (Homulle et al. 2021). Cabbage is a relatively mid-season crop that grows slowly within the first growth stage, requires high quantities of mineral fertilization, especially nitrogen which gives an opportunity for a short-season crop like lettuce to be intercropped with main-taining yield and quality (Nosek et al. 2011). Lettuce , *Lactuca sativa* L. is a common leaf vegetable belong-ing to the Asteraceae family. Furthermore, lettuce is a short-season crop and its needs for water and minerals do not conflict with the main crop, cabbage. The leafy vegetable crops are considered traditional favorites among Egyptian farmers due to their fast yield and short return income. The chosen crops were suitable for the intercropping system.As a result, the intercrop will maximize the utilization of the quantities of fertilization and irrigation water that will be wasted by loss and leaching. Cabbage is an economically important source of bioactive compounds, antioxidants and anticarcinogens (Šamec et al. 2014).

The improvement of agricultural sustainability could be achieved by using inter-cropping systems with a biofertilizer approach as an efficient soil conservation tool. Furthermore, it is an effective alternative to mineral nutrients, which have harmful effects on population and the environment due to their accumulation in plants and soils, and increase global warming potential. In the research for more sustainable and eco-friendly solutions to improve crop productivity, algae and mycorrhiza are emerging as resources for crop production due to their bio stimulating potential (Pathak et al. 2018; Chiaiese et al. 2018). Intercropping systems upgrade the diversity of crops on a field scale and sustain multiple ecosystem functions such as the coherent use of natural resources soil, water, and light (Win et al. 2018). Use the intercropping in the same row amid to maximize utilization of all added nutrients to the main crop cabbage such as minerals and water. It well known that a huge amount of nutrition elements loses in soil and water causing water pollution, accumulation in soil and consumed yield which harm environment and population (Win et al. 2018). Since the cabbage and lettuce crops have shallow root systems, they require water and minerals available in the surface area. So, the application of mycorrhiza enhances the chemical and physical soil properties and decreases nutrient accumulation in leaves [Chiaiese et al. 2018; Yildirim and Guvenc , 2005). The hyphae of arbuscular mycorrhizal fungi (AMF) play significant roles in increase soil aggregates and boost plant productivity (Saharan et al. 2018). AMF improves the biological activities of the soil include, the dehydrogenase, nitrogen and phosphatase activities and the availability of nitrogen, phosphorus and potassium, resulting in an adjustment of total dissolved solids (TDS) and pH of the soil (Artursson et al. 2005). The overall studies stated that mycorrhiza could be utilized for improving the quality of yield, and the physicochemical properties of soil, releasing growth-promoting compounds and solubilizing the insoluble phosphates. Hence, biofertilizers are economical and environment-friendly and improve soil properties and soil fertility by providing antioxidants enzymes release and the essential macro nutrient elements for plant growth and yield production (Kusvuran and Kusvuran, 2019). Biofertilization and intercropping can be combined to improve plant productivity and soil fertility (Hauggaard-Nielsen and Jensen 2005; Gebru, 2015). Absorption of nutrients (phosphorus and nitrogen) was greatly enhanced by intercropping and their binding via a common mycorrhizal network (Saharan et al. 2018; Artursson et al. 2005). The use of fertilizers is more efficient in an intercropping system due to the different root systems of the crops as well as the different amounts of nutrients absorbed (Kusvuran and Kusvuran, 2019). Previous studies have shown that cabbage intercropping systems maximizes yield and soil nutrient uptake which vary with the combination of treatments (Gebru, 2015). Monoculture cabbage cultivation enhances values for most growth traits, plant height, shoot weight, root weight, root length and yield (Gebru, 2015).

The objectives of the current study are divided into two main objectives: the first aim is optimizing the production of cabbage and lettuce and assessing the sustainability of intercropping systems based on growth, yield, soil, water, and improved net economic income. The other objective is determining the mycorrhiza use efficiency in alternating and reducing the dependence on mineral fertilization, and avoiding its impact on the soil microbial community, soil fertility, chemical properties, soil physics, plant antioxidant enzymes, pH, and TDS.

2. MATERIALS AND METHODS

2.1. Experimental location and design

The experiments were carried out at Kaha Experimental Research Station, Agriculture Research Center, Egypt during two winter consecutive seasons 2019 and 2020. The experimental design was split plot design in RCBD , with four replicates (Das and Giri, 1986). The intercropping treatments were arranged randomly in the main plot, while the fertilizers treatments were set randomly in the subplot. Pre-planting in both seasons, soil samples were taken from the experimental plots at 30 cm depth to determine some physical and chemical properties according to the standard methods of Richards (1954) and presented in Table 1.

Table 1. The physical and chemical properties of the experimental soil sample from Kaha farm in the two seasons.

Parameters	Values
Particle Size of Soil (%)	
Sand	24.23
Silt	33.60
Clay	42.17
Textural class	Clay
Organic matter (%)	0.60
pH	7.95
EC (ppm)	1360
Calcium carbonates (%)	1.88
Soluble Anions ($Cmole.Kg^{-1}$ soil)	
Cl^-	10.8
$SO4^-$	9.60
Soluble Cations ($Cmole.Kg^{-1}$ soil)	
$Mg2+$	4.19
$Na+$	9.33
$K+$	5.26
Available nutrients (ppm)	
N	1.54
P	0.54
K	1.97

2.2. Plant materials and cultivation methods

Monocrop, cabbage (O-S hybrid, TAKI seed company) seedlings were transplanting at 40 cm within plants on ridges 60 cm width and 5 m length. While lettuce, Romain type seedlings were transplanted at 20 cm between seedlings in two sides of ridge 60 cm width and 5 m length. Contrarily, in intercropping system cabbage as a main crop transplanted at 40 cm between plants while the intercropped lettuce was transplanted within row plant spacing 20 cm on the same side ridge with cabbage plants (Fig.1). The area of each plot was 15 m^2 (as each plot contained 5 ridges at 5 m long × 0.6 m width). Both cabbage and lettuce seedlings were transplanted on October 15th 2019 and 2020. Lettuce and cabbage were harvested after 50 and 90 days from transplanting, respectively. The cultivation treatments consisted of monocropping cabbage, monocropping lettuce, intercrop cabbage/lettuce cultivation system. The fertilization treatments included three treatments, 100% mineral fertilization (200, 150 and 120 kg/ha NPK for cabbage; 175, 112.5 and 120 kg/ha NPK for lettuce) according to Egyptian Agricultural Ministry recommendations. The second treatment was 5 kg /ha of mycorrhiza (AMF). In addition, the third treatment was mixed AMF and 50% RMF. The mineral fertilization units were divided into equal batches in mono and intercropped systems. The batches were applied at pre planting, 15, and 30 days from transplanting for lettuce while pre planting, 15, 30, 60 days from transplanting for cabbage. The AMF added with soil preparation and the second dosage inoculated the seedlings. The strain of arbuscular mycorrhizal fungi (AMF) was initially isolated from soil and grown on Zarrouk medium, using an adapted protocol from Gerdemann and Nicolson (1963).

2.3. Assessed parameters

2.3.1. Morphological parameters

At harvest time, the vegetative growth, yield, and quality parameters of cabbage and lettuce in monocrop and intercropped systems were measured. Twenty cabbage and lettuce heads were randomly selected from each experimental unit. Data were recorded for cabbage, total weight/plant (kg), head weight (kg), head length (cm), head diameter (cm), stem length (cm), and net marketable yield (t). As for lettuce crop, head length (cm), head weight (kg), head diameter (cm), number of leaves/plants, net marketable yield(t), and total soluble solid (TSS), which is measured in juice of leaf by using a hand refractometer, according to the methods of AOAC (1980).

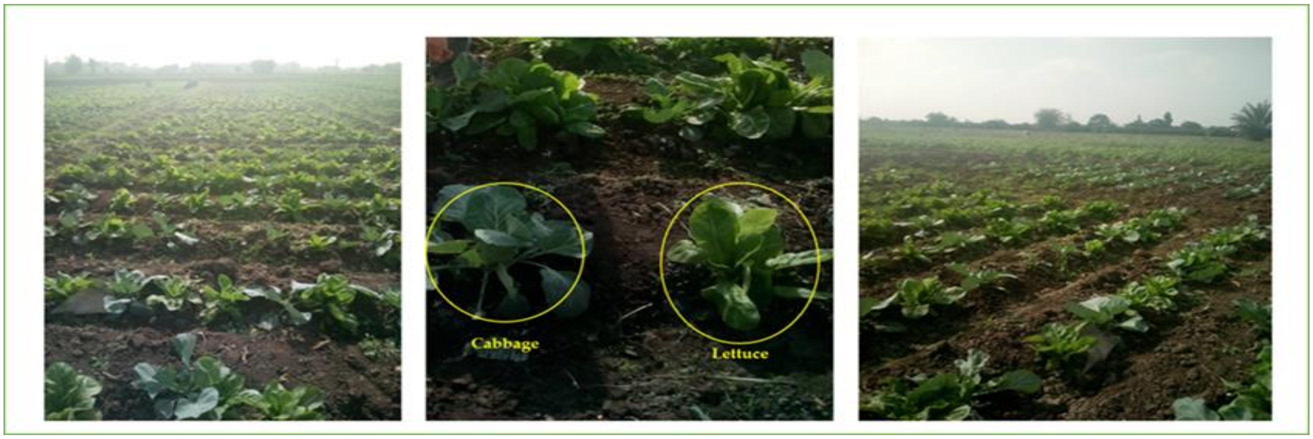

Figure 1. Intercropping cabbage/ lettuce cultivation system

2.3.2. Chemical analysis

Chemical analyzes were conducted after harvest on the inner leaves of cabbage and lettuce plants. In dry samples of inner leaves, the percentages of nitrogen using the micro-kjeldahle method as indicated by Pregl and Roth (1935), phosphorus was assessed using the colorimetric method of Luatanab and Olsen (1965), and potassium was assessed using the flame photometer set as explained by Jackson (1973). The activities of the antioxidant enzymes, peroxidase (POD) and catalase (CAT), determined in leaf samples of 500 g of fresh inner leaves of cabbage and lettuce. The samples homogenized in a mixture consisting of 5 ml of potassium phosphate buffer. 0.5% Triton X-100, 2% N-vinylpyrrolidinone,5 mM disodium salt of dehydrated ethylenediaminetet-raacetic acid and 1 mM ascorbic acid according to Polle et al. (1994). The homogenized mixture was centrifuged at 1000 g for 25 minutes at 4 ° C and the supernatants were used to measure the catalase activity (Aebi, 1984) and peroxidase (Kar and Mishra, 1976).

The pH (1:2.5, w/v), total dissolved solids (TDS) were determined in slusing a Jenway 4310 EC meter and a Beck-man pH meter as described in AOAC [1980]. Dehydrogenase activity (E.C 1.1) was measured according to Thalmann (1968) and modified according to Gong (1997). Phosphatase activity (E.C 3.1.3) was determined in phase with Tabatabai and Bremner (1969). Fresh soil samples of 100 mg were sieved (0.149 mm) and air-dried. After 24 hours at 37 ° C, the phosphatase activity was measured as mg of phenol generated from 1.0 g of dry medium (mg of phenol 1 g of dry medium). Nitrogenase activity (EC1.18.6.1) was meas-ured with an acetylene reduction assay as described by Johnsen and Apsley (1990).

2.3.3. Economic parameters

Economic efficiency indicators were measured including, the total variable cost, total cost, return, net return, return over variable costs, return /cost, and the profitability for cabbage and lettuce crops individually, as well as intercropped, according to El-Akshar et al. (2016). Furthermore, measuring soil and water use efficiency according to Saleh, Enas (2017), irrigation requirements were calculated by CLIMWAT 0.2 and CROPWAT 0.8 software (FAO).

Soil use efficiency= (the productivity of intercropped lettuce)/ (productivity monocrop let-tuce) + (the productivity main crop (intercropped cabbage))/ (productivity monocrop cab-bage)

Water use efficiency= (the productivity of one cubic meter of intercropped lettuce)/ (productivity one cubic meter monocrop lettuce) + (the productivity of one cubic meter main crop (intercropped cabbage))/ (productivity one cubic meter monocrop cabbage).

2.4. Statistical Analysis

The data were statistically analyzed using an analysis of variance (ANOVA) with the Statistix 10 software package of significance among treatments and means were compared using Duncan's multiple range test (Gomez and Gomez, 1984).

3. RESULTS

3.1. Morphological parameters

The data in all figures included the mean of two seasons 2019 and 2020 due to no significant differences between the two seasons. The data in Figure 2 revealed that mono-cropped cabbage outperformed intercropped in total and head weight, which was reflected on the total net marketable yield. The mono cabbage net yield exceeds 56.95 t/feddan for mixed treatment (50% RMF

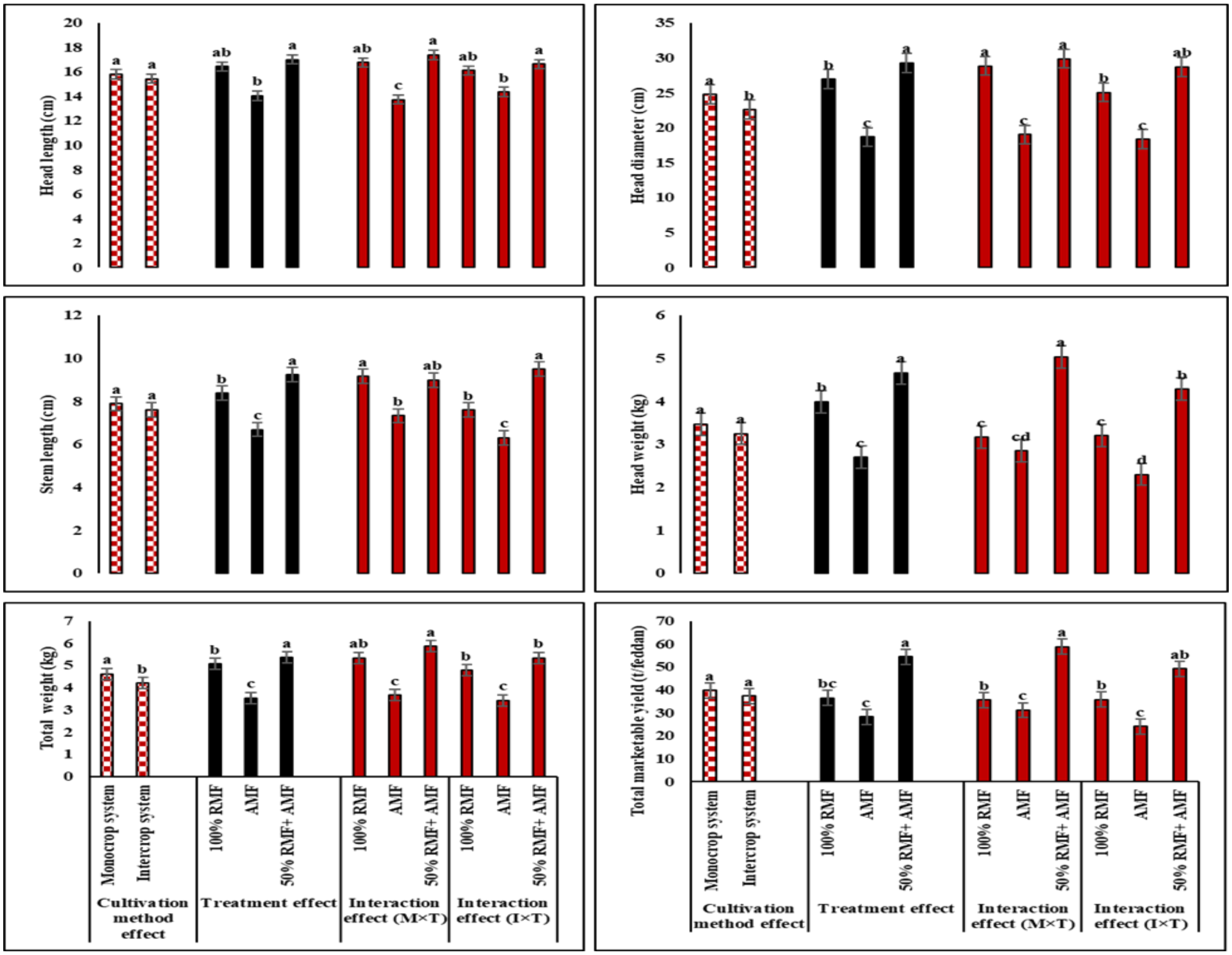

Figure 2. Effect of cultivation system, treatment, and interaction on head length(cm), head diameter(cm), stem length(cm), head weight (kg), total weight (kg), and net marketable yield(t/feddan) in cabbage for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi, Feddan=hectare/2.4

+ AMF). Head cabbage length and diameter were affected by the intercropping system, where the monocrop showed the highest head length and the largest head diameter based on the intercropping effect factor. Regarding the fertilization effect factor, data showed that there were significant differences between all treatments for all assessed traits in cabbage. The notable superiority was recorded for mixed treatment (50% RMF + AMF) followed by recommended mineral fertilization dosage (100 % RMF). As for the interaction effect, significant differences were observed among all six combinations. The treatment monocrop plus mixed fertilizers caused the highest significant values for all traits, followed by intercropped with mixed fertilizers. In contrast, no significant differences were shown in head length, head diameter, or stem length. Furthermore, the monocrop with each of the 100% RMF treatments, mycorrhiza, significantly outperformed the intercropped one in all traits.

The data in Figure 3 did not show any significant differences between the mono and intercropped system in most determinate traits in lettuce except for head length in the first season where the monocrop recorded the highest head length. The net marketable yield for monocrop exactly was the higher than intercrop lettuce due to the population density of each one. Concerning fertilization effect, data were reflected highly significant differences between all

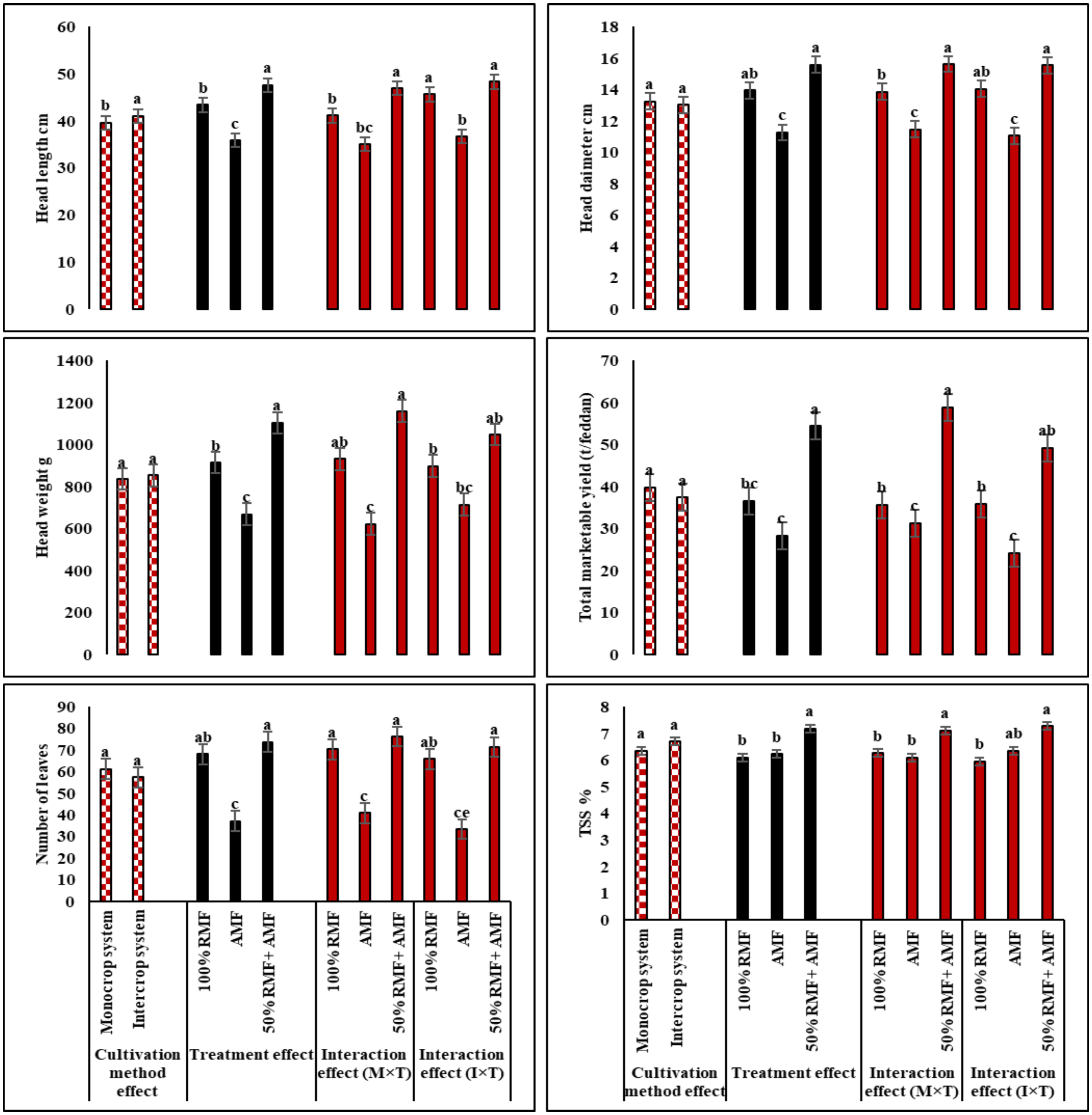

Figure 3. Effect of cultivation system, fertilization, and interaction on head length(cm), head diameter(cm), total soluble solid, head weight (g), number of leaves, and net marketable yield (t) in lettuce for two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi, Feddan=hectare/2.4

treatments in all traits. Moreover, the mixed treatment (AMF+50% RMF) revealed the highest values in all studied traits for two seasons followed by 100% RMF. Concerning, the interaction effect showed that the monocrop + mixed recorded the highest significant values compared with all interactions. Good to mention that there were no significant differences between mixed treatments in mono or intercropped systems except for head length and head weight where the mono culture investigated the higher value than the intercropped. Among the rest of the interactions of treatments monocrop with 100% RMF showed a noticeable superior in leaves numbers and TSS in first season only while inter-crop + 100 % RMF had the highest value in head length and head dimeter. The net yield for mixed treatment gave the highest expected amount of yield which reached to 62 t/feddan.

3.2. Chemical parameters

3.2.1 Nutrient Concentration in plants

The monocrop showed the highest values for NPK uptake in cabbage leaves (Figure 4) compared with intercrop treatment without significant differences in most values. The mixed treatment recorded the highest NPK uptake according to fertilization treatments effects. Furthermore, the AMF application proved the great role on phosphorus uptake.

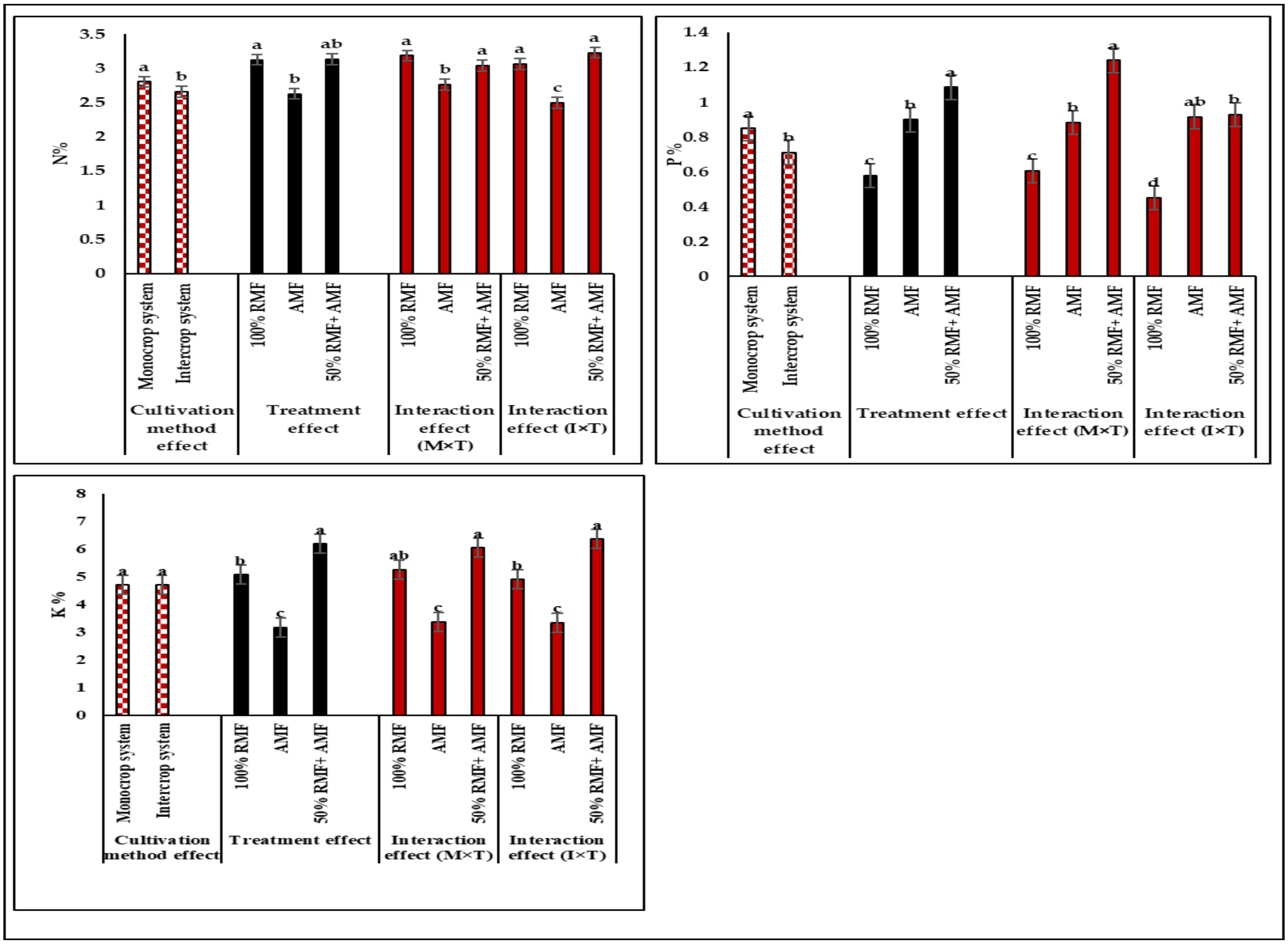

Figure 4. Effect of cultivation system, fertilization, and interaction on nitrogen (N%), phosphor (P%), and potassium(K%) concentrations in cabbage leaves for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

The 100% RMF provides high N uptake in cabbage leaves compared with all treatments. Regarding interaction effects, the combination treatments with monocropping had the highest NPK values, followed by the combination treatments with Intercrop and 100% RMF with monocropping. Concerning, the intercropping effects on N, P, and K concentrations of lettuce leaves (Figure 5) have significant differences. The monocrop system outperformed the intercropped one in most treatments in both seasons. Regarding the fertilization effects, highly significant differences on minerals uptake between treatments were observed. The mixed treatment (AMF+ 50% RMF) revealed the highest totally NPK uptake without significant difference with AMF in P uptake. The interaction effects proved highly significant differences for the mixed treatment with mono crop which caused the highest NPK uptake followed by the mixed treatment with intercrop without significant differences.

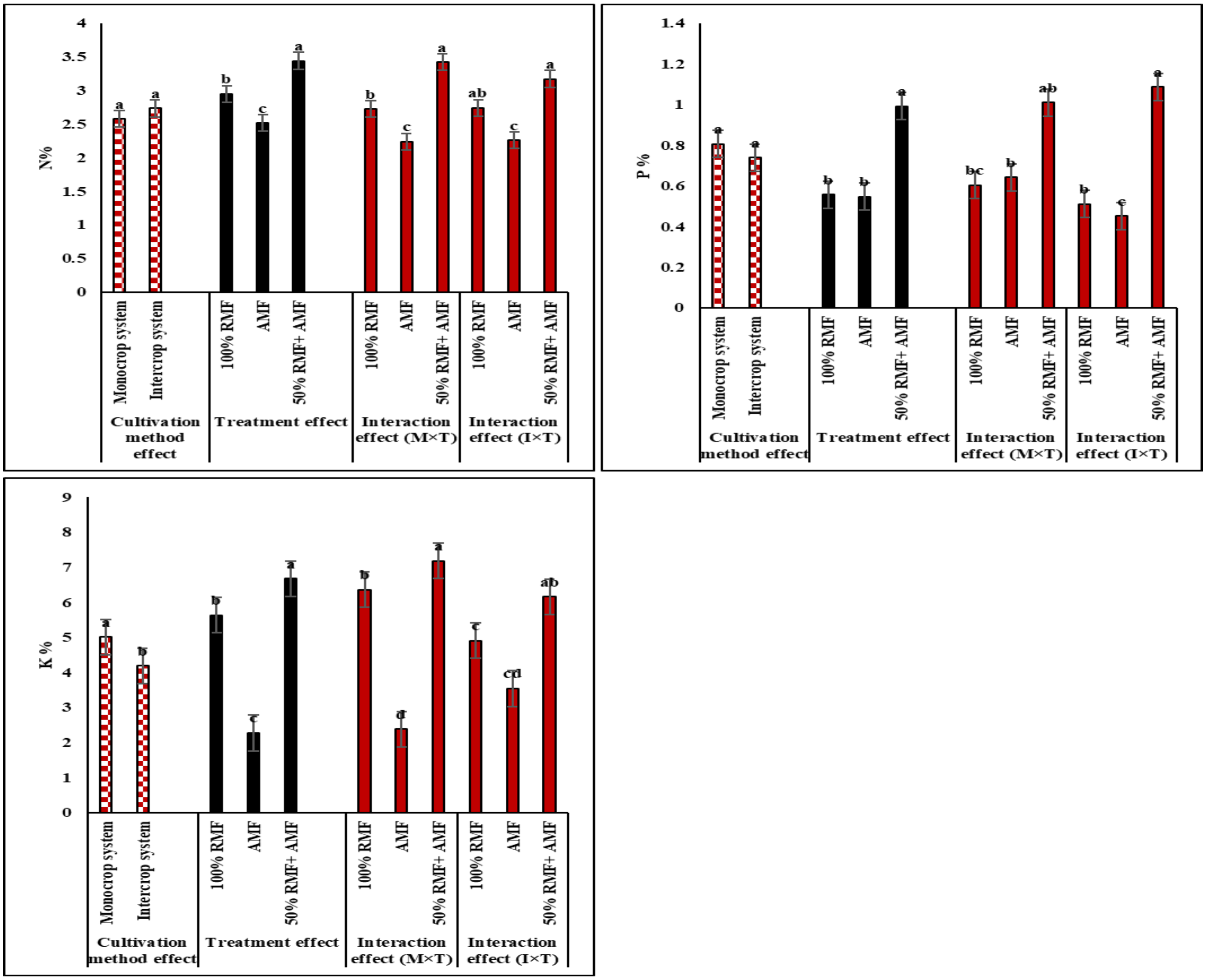

Figure 5. Effect of cultivation system, fertilization, and interaction on nitrogen(N%), phosphor(P%), and potassium(K%) concentrations in lettuce leaves for means of two seasons 2019 and 2020. where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

3.2.2 Antioxidant enzymes activities in plants

The data in Figures 6 and 7 showed that the antioxidant enzymes peroxidase (POD) and catalase (CAT) activities in cabbage and lettuce leaves were significantly affected by the intercropping system and the fertilization treatments. The activity of the antioxidant enzymes CAT and POD increased in intercropped systems compared with monocrop one. Concerning, the fertilizations treatments the mixed treatment had a positive effect on the activity of CAT and POD in the leaves cabbage and lettuce plants, the lowest values of the antioxidant enzymes CAT and POD were found in monocrop with the 100% RMF treat-ment followed by intercrop treated with 100 RMF. CAT and POD activities were was elevated in plants treated with AMF. The result shows that the mixed treatment was effective in regulating catalase and peroxidase activity in cabbage and lettuce plants in monoculture and intercropped systems.

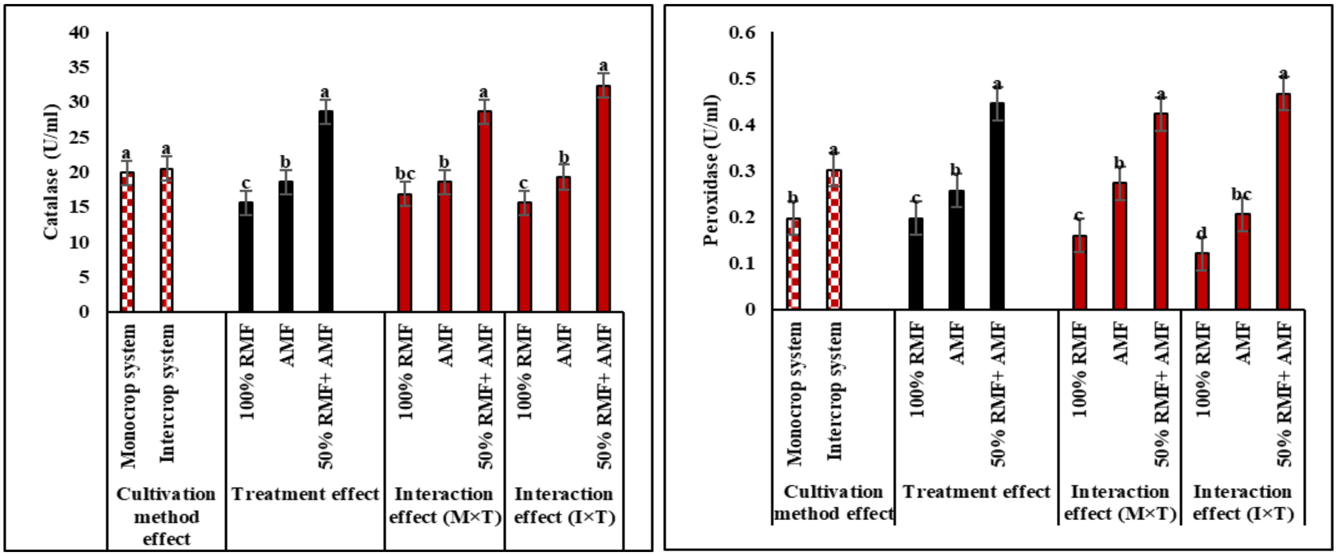

Figure 6. Effect of cultivation system, fertilization, and interaction on antioxidant enzymes catalase (CAT) and peroxidase (POD) in cabbage leaves for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

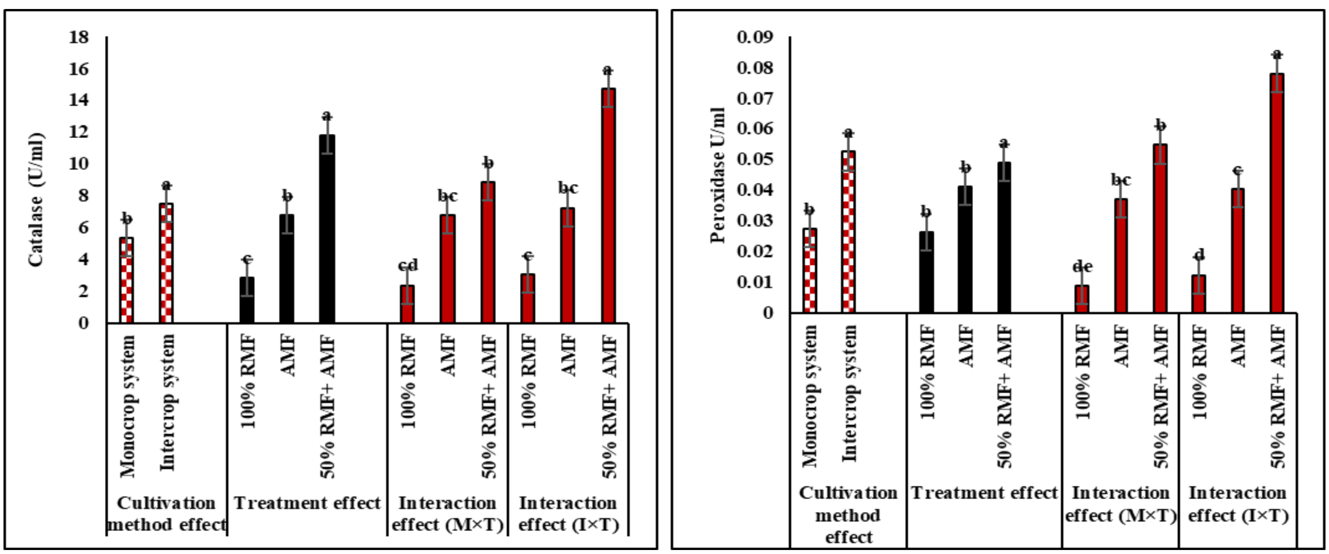

Figure.7 Effect of cultivation system, fertilization, and interaction on antioxidant enzymes, catalase and peroxidase in lettuce leaves for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

3.2.3 Chemical analysis in soil

The intercropping system had not effect on pH or TDS of cabbage soil (Figure 8) while there were significant differences observed between intercropping and monocropping in lettuce soil (Figure 9). According the fertilization treatments effect, the mixed treatment showed the lowest values for pH and TDS in cabbage and lettuce soils. By highlighting the interaction impact it was found that the mixed treatment with monocrop and intercrop systems significantly reduced the values of pH and TDS compared with the values after 100% RMF. It is worth noting that biofertilizers with single or mixed treatment modified the values of pH and TDS.

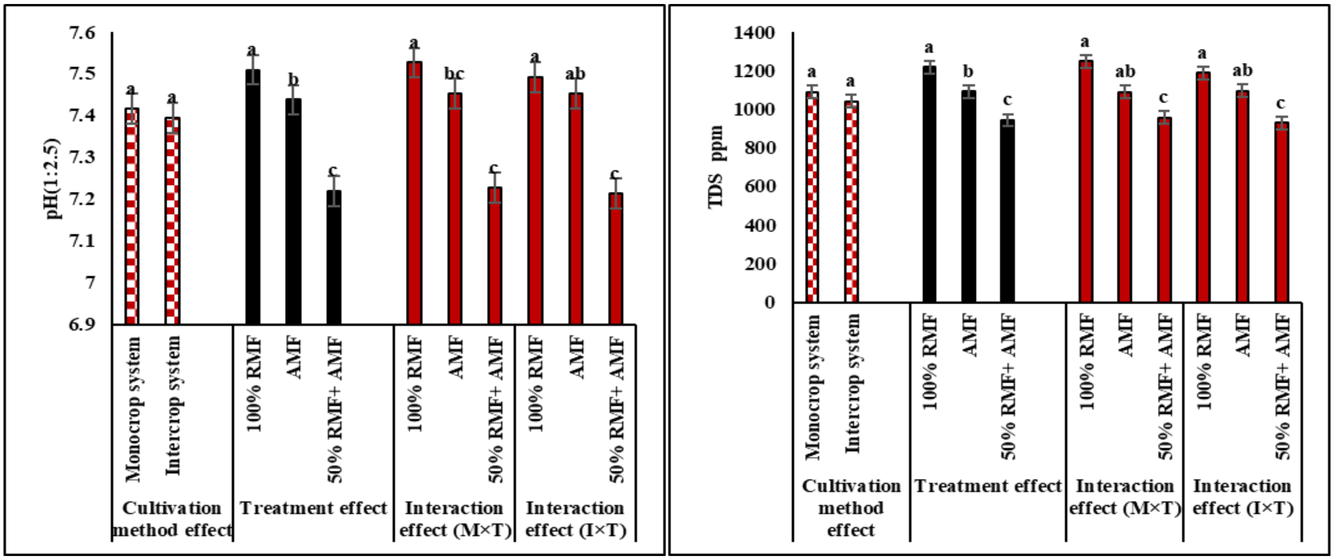

Figure 8. Effect of cultivation system, fertilization, and interaction on pH and TDS in cabbage soil for means of two seasons 2019 and 2020, where RMF: recommended mineral ferti-lization, AMF: arbuscular mycorrhizal fungi.

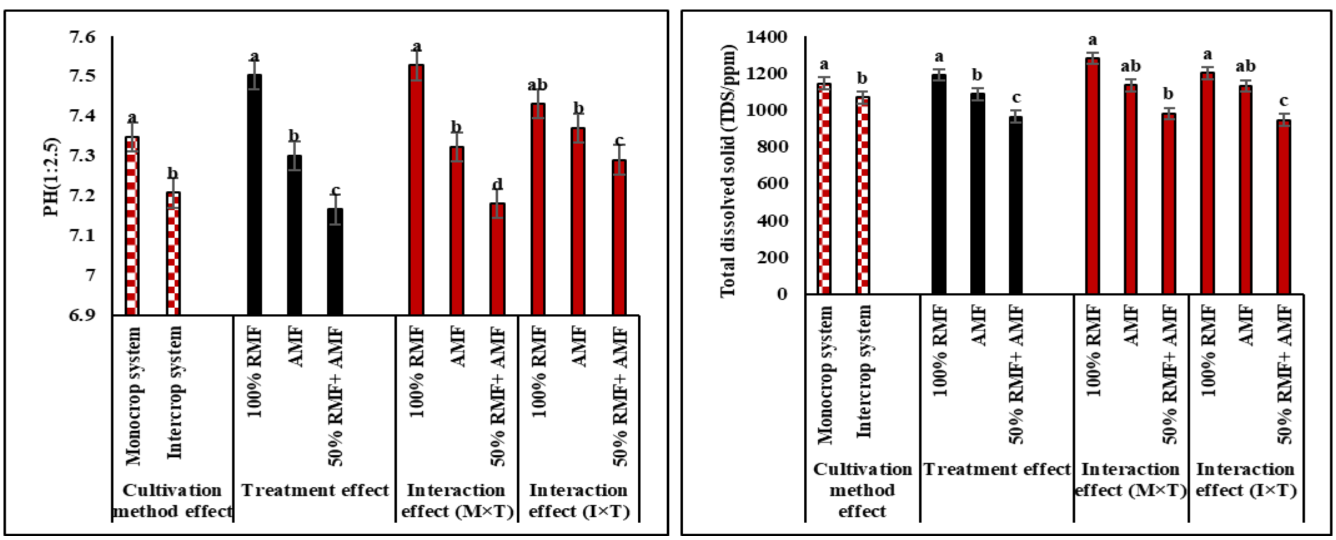

Figure 9. Effect of cultivation system, fertilization, and interaction on pH and TDS in lettuce soil for mean of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

The data in Figures 10 and 11 revealed that dehydrogenase (DHA) in the mixed treated soils was significantly ($P < 0.05$) higher than in the 100% RMF treatment. This was probably caused by the positive side effects of AMF being applied. The results revealed that DHA activity was the highest in intercropping systems compared to the monocrop system. In the same direction the fertilization effect showed that the mixed treatment recorded the highest enzymes activities in comparison with other treatments in both crops. Moreover, the mixed treatments with intercropping system significantly exceeded the other treatments in all parameters in cabbage crop however in lettuce crop equated with the mixed with monocrop treatment.

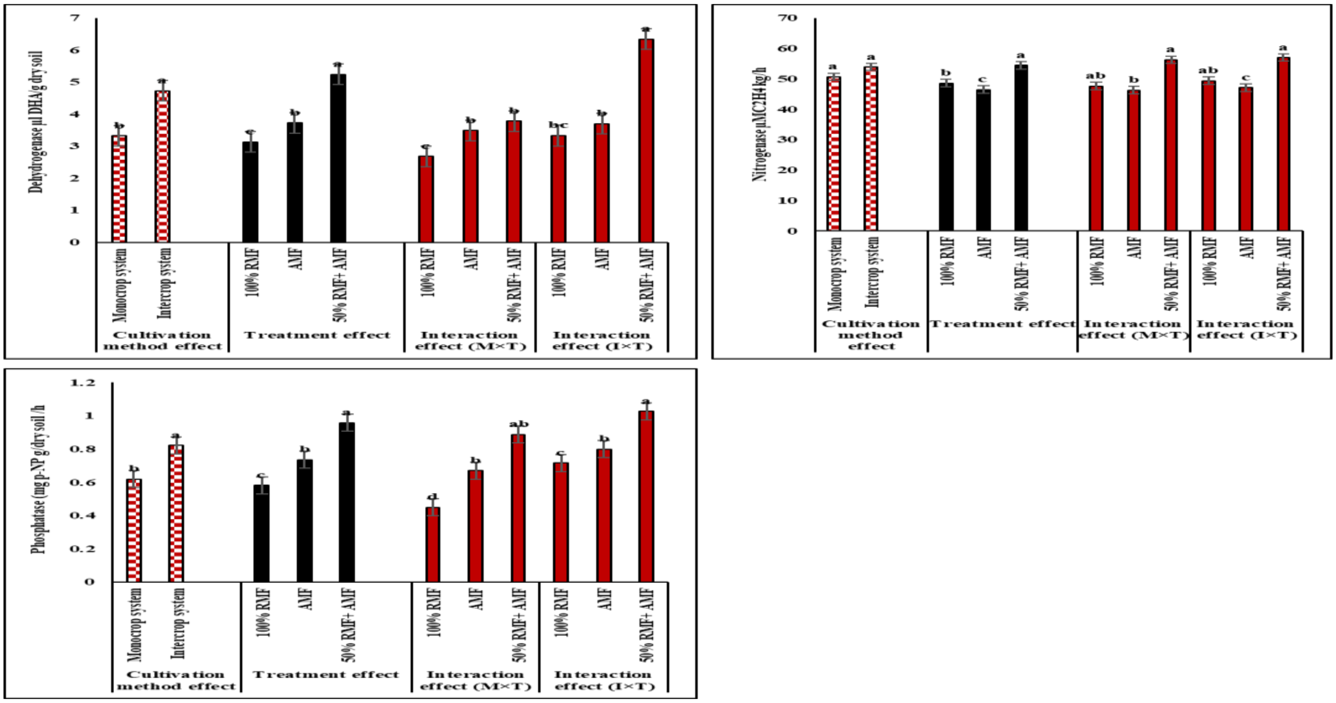

Figure 10. Effect of cultivation system, fertilization, and interaction on soil enzymes dehydrogenase, nitrogenase, and phosphatase in cabbage soil for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

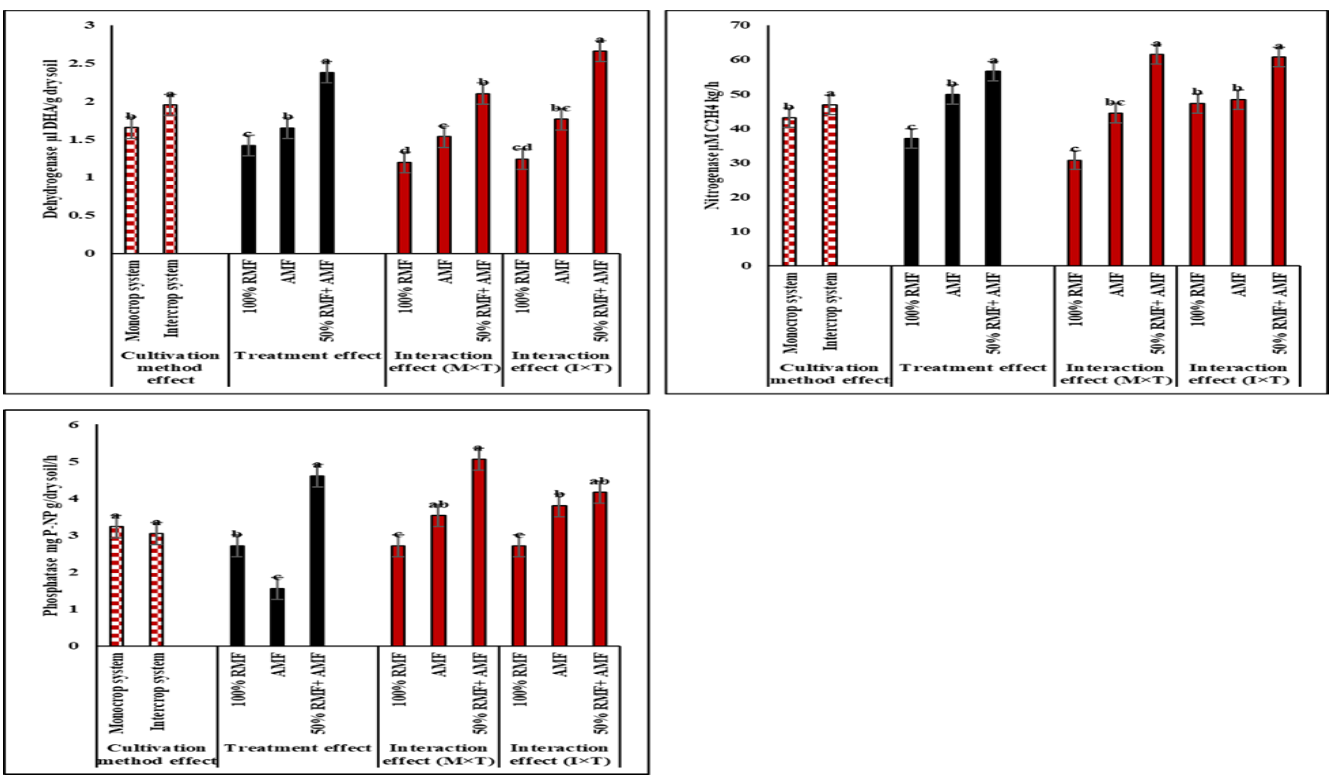

Figure 11. Effect of cultivation system, fertilization, and interaction on soil enzymes dehydrogenase, nitrogenase, and phosphatase in lettuce soil for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

3.3. Economic parameter

3.3.1. Economic Efficiency

The data in Figure 12 A-H showed that the productivity (net marketable yield) of cabbage crop increased to 11700 and 11500 heads, which is the maximum productivity by using mixed fertilization treatment in mono and intercropped cultivation systems, respectively. Concerning the costs, the total costs of mono cabbage cultivation reached to its maximum by applied 100% RMF treatment. Furthermore, the variable cost has reached to maximum value with 100% RMF treatment. In contrast, it was decreased until it reached its lowest value with mixed treatment application. Regarding cabbage cost in intercropping cultivation system, the total costs have reached a maximum in the 100% RMF treatment while the total cost reached the lowest when using mycorrhiz fertilization treatment. The variable costs have reached a maximum in the 100% RMF treatment. The return, net return, and the return over variable costs for mono and intercropping cabbage cultivation were reached to the maximum with mixed fertilization treatment, while the lowest return was recorded with mycorrhiza application. As it turns out calculates the yield / cost the highest return on costs in the cultivation of intercropping cabbage and mono cabbage were 2.09 and 2.05 respectively, in using mixed fertilization. Profitability indicated that the intercropping system is 1.09 greater than the profitability of mono cultivating cabbage.

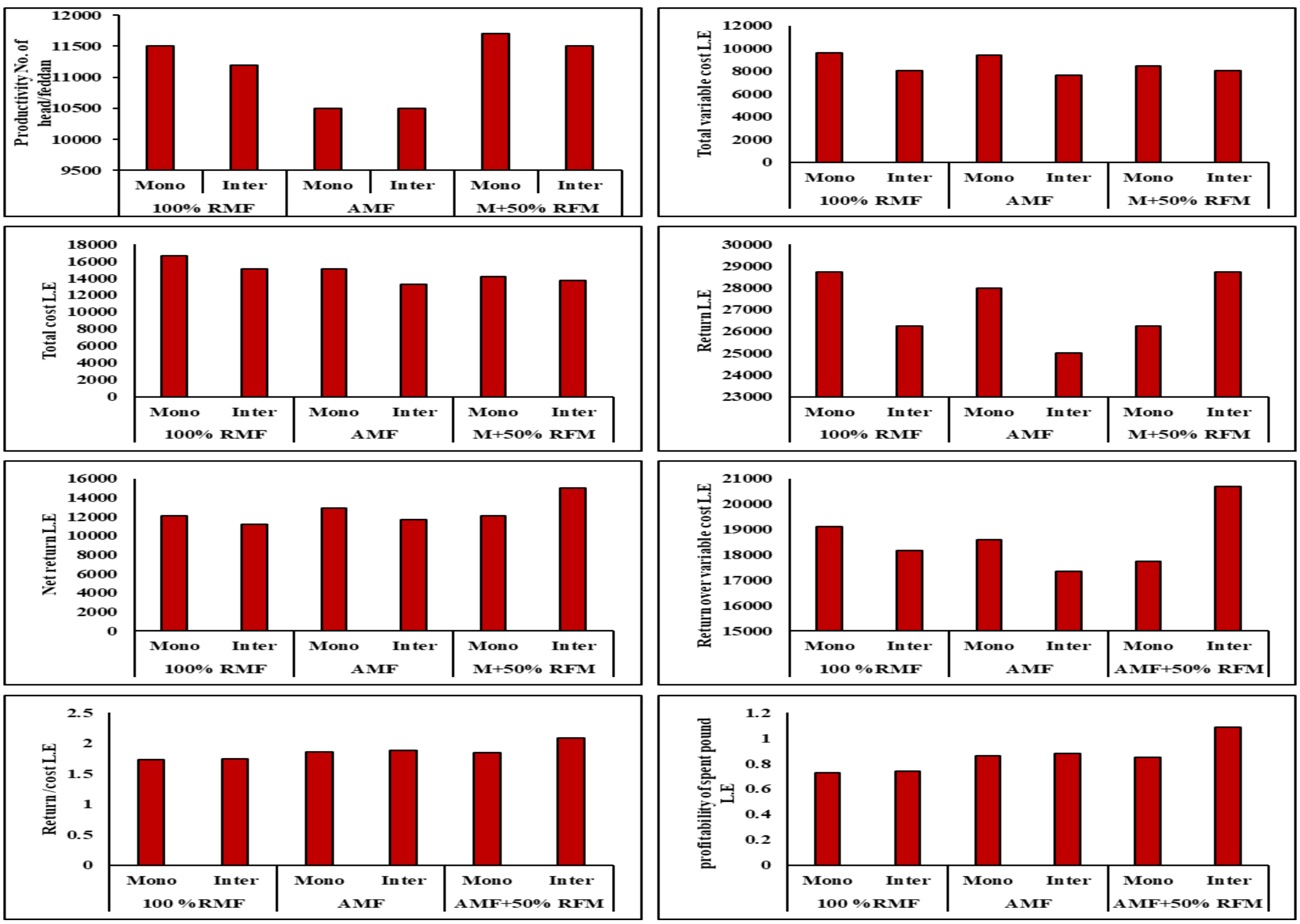

Figure 12. Economic Efficiency Indicators, A, productivity (no. of heads/feddan), B, total variable cost (L.E), C, total costs, D, return (L.E), E, net return (L.E), F, return over variable cost (L.E), G, return/cost (L.E), and H, profitability of spent pound based on cultivation system and fertilization type in cabbage for mean of two seasons 2019 and 2020. where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

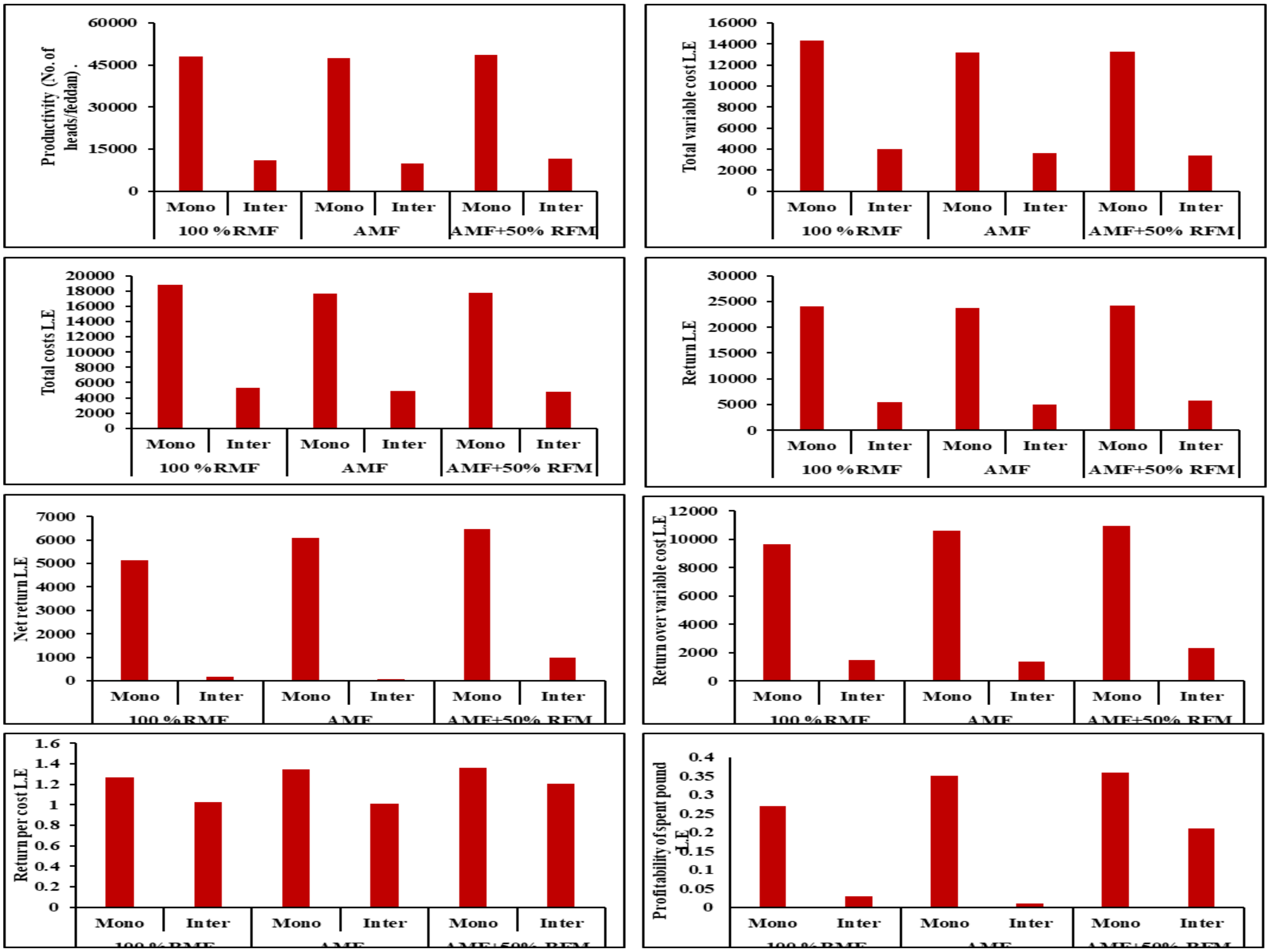

Figure 13. Economic Efficiency Indicators, A, productivity (no. of heads/feddan), B, total variable cost (L.E), C, total costs, D, return (L.E), E, net return (L.E), F, return over variable cost (L.E), G, return/cost (L.E), and H, profitability of spent pound based on cultivation system and fertilization type in lettuce for means of two seasons 2019 and 2020, where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi.

Concerning, the productivity (net marketable yield as heads numbers) of lettuce crop also increased to 48500 and 11500 head, which is the maximum productivity by using mixed fertilization treatment in mono and intercropping cultivation system (Figure. 13A-H). The total cost and the maximum variable cost of mono lettuce cultivation reached to its maximum in the 100% RMF treatment while it reached to the lowest cost by using mycorrhiza fertilization treatment. In a related the total costs and variable costs of lettuce in the intercropping cultivation were a maximum with the mineral fertilization treatment, while it reached to the lowest when using mycorrhiza fertilization treatment followed by mixed treatment. The return and net return, and the return over variable costs for mono and intercropping lettuce cultivation was the maximum with mixed fertilization treatment application, while it was the lowest return with applying mycorrhiza fertilization treatment, and the lowest net return observed with AMF application. In the cultivation of mono and intercropping lettuce, its achieved 1.36 and 1.21 respectively with applied mixed fertilization treatment. While the ratio of return to costs for growing intercropping lettuce cultivation is 1.21 that means that the profitable for the pound amounted to about 0.21 although it is less than the profitability of cultivation of the lettuce alone, but it is giving the farmer more additive return from the same cultivated area due to the number of plants which considered the quarter of standers lettuce plant numbers.

3.3.2 Soil and water use efficiency

The efficiency of using soil and using irrigation water resources presented in Table 2. The efficiency of use soil was increased to 1.22 in the intercropping system with using mixed fertilization treatment. In addition, data showed an increase in the productivity of the water unit in the intercropping of cabbage, with lettuce. While the maximum productivity of water unit in cultivating intercropping cabbage was 7.55 heads/m3 while the maximum in mono cultivation system was 5.32 heads/m3. Regarding the efficiency of using water was reached to maximum value 2.19 in mixed fertilization treatment compared with other treatments.

Table 2. The efficiency of use soil and irrigation water resource.

Treatments	Cabbage production (No. of heads/ feddan)		lettuce production (No. of heads/ feddan)		efficiency of using land	cabbage water productivity		lettuce water productivity		efficiency of using water m^3
	M	I	M	I		M	I	M	I	
100 % RMF	11500	11200	48000	11000	1.20	5.23	7.35	21.82	16.25	2.15
AMF	11000	10500	47500	10000	1.17	5.0	6.89	21.59	14.77	2.06
AMF+50 % RMF	11700	11500	48500	11500	1.22	5.32	7.55	22.05	16.99	2.19

where RMF: recommended mineral fertilization, AMF: arbuscular mycorrhizal fungi, I: Intercropping, M: Monocrop

4. DISCUSIONS

Use of the intercropped cultivation system as an alternative to monoculture became necessity worldwide, depending on the holding area, local climate, soil conditions, and economic situation (Lithourgidis et al 2011). The results indicated that no significant differences between mono and inter-cropped cultivation system for cabbage and lettuce in most horticultural traits that was agreed with Guvenc and Yildirim (2006). Some physical traits such as head weight, head length, and head diameter revealed superiorty in mono culture that mean the intercropped cultivation system has a significantly effect on both crops (Gianinazzi et al. 2010). The obtained results proved that the intercropped cultivation system had not negative effects on growth and yield traits while some physical characteristics were affected (Guvenc and Yildirim, 2006). Although all cover crop systems provide crop, soil and water improvement, certain approaches are necessary to improve the quality and quantity of yields. Biofertilization is considered one of the amplifiers of the cropping system, improving growth and yield. The results demonstrate the effectiveness of biofertilization in combination with the intercropping of cabbage and lettuce (Saharan et al. 2018, Gianinazzi et al. 2010). In this section the study compared four fertilization treatments to get the best fertilizers alternative. All results revealed that the mineral fertilizers showed the highest values compared with AMF application. In contrast, the mixed treatment which mixed two beneficial strategies of fertilization (AMF and 50% RMF) gave the highest significant values for all studied traits on horticultural, minerals uptake, soil improvement, and economical levels. The positive effect of each approach was discussed as follow, AMF application provides nitrogen fixation , many beneficial effects on phosphor solubility and makes it available for roots in short period (Smith et al. 2011). The presence of AMF with RMF contributes as soil enhancers, play important roles for root efficacy for mineral fertilization uptake in short time and make it available in root zone or rhizosphere. It is well known that the vegetable crops have a short life period so the intercropping method will maximize fertilizers and water use efficiency and decrease the loss amount beside the bioagents which make all elements easier to absorb in rhizosphere (Dimkpa et al. 2009). Improved growth and yield of cabbage and lettuce was observed with the use of biofertilizers which improved the chemical, physical and biological properties of the soil. The application of AMF as a part of fertilization treatments, due to its role in increasing the production and quality of cabbage and lettuce, sequesters soil microbial and mineral levels, increasing soil fertility and adjusted soil pH and TDS [Bender et al. 2016].

The results showed that the nutrient concentrations of leaves in intercropped systems were comparable to those of monocultures, illustrating the efficient use of available resources per unit area for different crops (Varghese, 2000). The intercropping system has been found to have a higher nutrient uptake per area than monocultures because the root growth of constituent species with different root characteristics explores a larger soil mass (Santos et al. 2002). Intercropping systems may have higher nutrient use efficiency due to possible differences in peak demand time for different nutrients due to the mix components and residence time of each crop (Santos et al. 2002). In this study, intercropping systems with different root properties of the constituent crops could increase nutrient utilization efficiency and utilize more nutrients. The study revealed that the possibility of depending on biofertilization in the cultivation of cabbage and lettuce as an alternative to mineral fertilization without negative effects on yield and soil fertility. The results indicated a significant increase in total soil nitrogen, phosphorus and potassium levels and yield compared to mineral fertilizers (Górka et al. 2018). Dehydrogenase (DHA) recorded the highest activity in the mixed treatment. This activity may reflect the full range of oxidative activity of the soil microflora (Watts et al. 2010). The activity of DHA in the soil of intercropping with the mixed treatment was higher than in the other treatment (Scherer et al. 2011). The decrease in DHA activity had a negative effect on soil fauna by the decreasing number of total bacteria according to Scherer et al. (2011) and Wolinska and Stepniewska (2012), DHA is directly related to the microbial biomass. In this experiment, the increase in soil DHA with the mixed treatment in the intercropped system could be due to AMF in the soil improving the enzymatic activity of the microbes (Tian et al. 2019). Dehydrogenase (DHA) activity provides the total range of oxidative activity of the soil microflora (El-Komy, 2005). Also, Dehydrogenase activity (DHA) considered - an indicator of overall microbes' activity in the soil (Wang et al. 2008). The data represented showed that mineral fertilizers without the application of biofertilizer recorded lower DHA activity values compared to biofer-tilization treatments. This may be because mycorrhiza has played an important role in promoting plant growth through nitrogen fixation. This can lead to the accumulation of available nutrients and stimulate microorganisms in the soil rhizosphere. Many investigators have demonstrated the positive effect of bio fertilization on nitrogenase activity with intercropping system complementary to biofertilizers as a nitrogen fixer (Goiris et al. 2012). Use of the biofertilizers modulated the pH value of soil which indirectly effected on enzymatic activity (Wang et al. 2008). In addition, after the addition of biofertilizers, the soil environ-ment of the rhizosphere improved and the number and type of microorganisms and root exudates increased, thereby increasing phosphatase activity. However, with mineral fertilization, a decrease in phosphatase activity can be observed due to its effects on pH and TDS values, which could significantly change the soil environment and destroy the living conditions of enzymes., causing a decrease in phosphatase activity (Köksal et al. 2012). Numerous studies have proven that in addition to pollution, excessive fertilization also has a bad impact on the quality of plant phytonutrients and a decrease in antioxidant content (Bursal, 2013). Antioxidant enzymes play an important role in scavenging reactive oxygen species (ROS) generated by environmental stress which is believed to lead to increased cell death, stunted plant growth and reduced crop productivity (Simova-Stoilova et al. 2008). PODs (E.C. 1.11.1.7) are involved in a variety of biochemical and physiological functions. Wound healing, hormonal regulation, general stress response, synthesis of cell wall components, protection of tissues from physical damage, and control of defense mechanisms against pathogens are some of the functions offered (Bursal, 2013). Additionally, PODs play a role in maintaining crop quality, including unwanted flavor and color changes (Simova-Stoilova et al. 2008). Catalase (CAT) and peroxidase (POD) enzymes are important antioxidants that play a major role in defense against ROS. Nutrient management practices play a main role in the antioxidant and enzyme de-fense activity of cabbage and lettuce (Simova-Stoilova et al. 2008). The results showed that the activity of POD and CAT was positively affected by the application of the mixed treatment (AMF and 50% RMF). The positive relationship between biofertilization and antioxidant enzyme activity has been recorded in cabbage (Bursal, 2013). Moreover, Abdel-Fattah and Al-Amri (2012) reported that POD activity increased with biofertilization in cabbage and lettuce. The results showed that the improvement in growth and yield due to the use of a mixed fertilizer had a positive impact on the activity of antioxidant enzymes. These results proved that the bio-fertilization make the balance conditions between the reactive oxygen (ROS) and antioxidant enzymes (Cong et al. 2015). The economics of traditional farming systems, high input systems using chemical fertilizers, simplified crop diversity, leading to potential problems of soil degradation, pollution and low resilience risk. Therefore, use biofertilizers, with a system of intercropped studied with high economic performance (Hauggaard-Nielsen and Jensen , 2005; Guvenc and Yildirim , 2006). All results showed that the values of land use efficiency in intercropping systems were always greater than 1, indicating gains in productivity and efficiency of land and resource use of these systems. systems compared to the monoculture system (Guvenc and Yildirim , 2006). The highest values were obtained in the cabbage and let-tuce intercropping system with mixed fertilization treatment (1.22). These findings are supported by Varghese (2000), and Santos et al. (2002), who examined the effectiveness of mixed crops against monocultures in different combinations of crops. This efficiency might be attributed to the more efficient use of available resources per unit area, especially when nutrients and water were provided in sufficient quantities (Abdrabbo et al. 2015). Furthermore, it has been reported that the efficiency of intercropping systems is very efficient when the constituent crops differ significantly in growth times, so that their greatest need for growth sources occurs at different times (Brooker et al. 2015).

The results obtained in this study indicated that mixed cropping systems could increase total yield, productivity and profitability. The cabbage inter cropping system varied in growth, yield, quality, sustainable soil health, and nutrient uptake depending on the com-bination of fertilizer treatments (Guvenc and Yildirim, 2006). All results indicated the efficacy of biofertilization in combination with the intercropping system (Gebru, 2015). The previous result proved that the ef-ficiency of intercropping cultivation system in economic and applied side. In addition to, the use of non-mineral fertilization, not only did not affect negatively on productivity but also increase the production of cabbage and lettuce in mono and intercropped system (Raseduzzaman and Jensen, 2017). The importance of reducing mineral fertilization and the environmental benefits in reducing its negative effect on the soils and maintaining the sustainability of the farming re-sources as well as preserving the health of population by reducing the use of mineral fertilization. In the intercropping of a lettuce crop with a cabbage crop, about 25% of the lettuce area is saved for the cultivation of other crops in addition to achieving an additional re-turn for the farmer while maintaining the return of the main crop, which is cabbage. The two indicators of efficiency of land and water utilization and use in intercropping also showed a rise, and this shows the extent of the intercropping efficiency of cabbage and lettuce crops. Therefore, we recommend intercropping cabbage and lettuce by using AMF in the fertilization, because of its economic benefits for the farmer and its benefits at the level of the economy by providing 25% of the lettuce area for cultivat-ing other crops. In addition, it is achieving an efficient using for land and water resources, and because of its positive environmental impact on maintaining the sustainability of land and water suppliers in particular (Smith et al. 2011). The sustainability of the farming system is influenced by the economic returns, which determine the commercial profitability of the numerous systems of association. It has been recorded that intercropping approach could lead to enhancement in horticultural productivity per farm area and an increase in profit-ability (Corre-Hellou et al. 2006).

5. CONCLUSION

This study presented the unique sustainable ways for small farmers with limited re-sources, especially irrigation water, to achieve greater yield efficiency and higher net income and to use their own manpower and inputs more efficiently. Also use biofertilization as an alternative to mitigate adverse impacts on the environmental balance, climate, economic pressures and soil degradation. The present study showed that cabbage-based mixed cropping systems were more productive, more profitable, and had higher soil and resource use efficiency than cabbage monoculture. The study showed that growing intercropped did not negatively impact cabbage yield, but instead increased intercrop lettuce yield. The intercropped cultivation system has explored a great overrun due to crop growth, lettuce considered the short-season vegetable crop planted among the full-season vegetables for the complementary depth and spread of root systems, a serious competition to exclude light, water and nutrients. The study was an attempt to maximize the utility of the territory and of all resources. Cabbage has also been reported to be sustain than lettuce. Cabbages can take full advantage of all available resources to complete their growth after the intercropped harvest. Additionally, the long-season crop can grow slowly in the first half of the growing season and only form a full canopy after several weeks, providing the oppor-tunity for intercropped between rows. In this study, differences in growth rate, maturation time, morphological traits, or resource use of main and intercropped may have reduced or displaced intercrop competition due to the complementary effects of inter cropped. It is explained that this occurs by an increase in the activity rate of microorganisms in the soil, as shown by the increase in the activity of soil enzymes. In addition to the significant economic implications for the efficient use of water, soil and material yield from doubling the harvest in unit area. The study revealed that the activity of the antioxidant enzyme showed significant differences between the mono and intercropped systems on the side of the intercropped systems. The recorded results showed that the use of biofertilizers can improve the uptake of N, P and K and improve soil properties, reflecting economic efficiency. The mycrohiza improved the biological activity of the soil, dehydrogenase and the formation of nitrogen and the available nitrogen, phosphorus and potassium, resulting in an increase in total dissolved solids (TDS) and a decrease in soil pH. The companion system not only improves soil use efficiency but can also improve soil quality, increase yield stability and reduce dependence on mineral fertilizers and the risk of leaching of nitrates compared to monoculture.

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Abbreviations

AMF, arbuscular mycorrhizal fungi
RMF, recommended mineral fertilization
pH, potential of hydrogen
TDS, Total dissolved solids
DHA, Dehydrogenase
POD, peroxidase
CAT, catalase
ROS, reactive oxygen

6. REFERENCES

Abdel-Fattah G.M., Al-Amri S.M. (2012). Induced systemic resistance in tomato plants against Fusarium oxysporum f. sp. lycopersici by different kinds of compost. Afr. J. Biotechnol. 11, 12454–12463. DOI: 10.17584/rcch.2021v15i3.12822.

Abdrabbo M.A., Hashem F.A., Abul-Soud M.A., Abd-Elrahman S.H. (2015). Sustainable production of cabbage using different irrigation levels and fertilizer types affecting some soil chemical characteristics. Int. J. Pl. Soil Sci., 8: 1-13. https://doi.org/10.9734/IJPSS/2015/17590 .

Addo-Quaye A.A., Darkwa A.A., Ampiah M.K. (2011). Performance of Three Cowpea (Vigna unguiculata (L.) Walp) Varieties in Two Agro-Ecological Zones of the Central Region of Ghana II: Grain yield and Its Components. ARPN Journal of Agricultural and Biological Science, 6, 34-42.

Aebi H. (1984). Catalase in vitro. Methods Enzymol., 105, 121–126. https://doi.org/10.1016/s0076-6879 .

AOAC (1980). Official Methods of Analysis of the Association of Official Analytical Chemist. 12th ed. Washington, D.C., USA.

Artursson V., Finlay R.D., Jansson J.K. (2005). Interactions between arbuscular mycorrhizal fungi and bacteria and their potential for stimulating plant growth. Environ Microbiol. 2006 Jan;8(1):1-10.. 10.1111/j.1462-2920.2005.00942.x .

Bender S.F., Wagg C., van der Heijden M.G.A. (2016). An underground revolution: biodiversity and soil ecological engineering for agricultural sustainability. Trends Ecol. Evol. 31, 440–452. https://doi.org/10.1016/j.tree.2016.02.016 .

Brooker R.W., Bennett A.E., Cong W., Daniell T.J., George T.S., Hallett P.D., Hawes C., Iannetta P.M., Jones H.G., Karley A.J., Li L., Mckenzie B.M., Pakeman R.J., Paterson E., Schöb C., Shen J., Squire G., Watson C.A., Zhang C., Zhang F., Zhang J., White P.J. (2015). Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. New Phytologist 206, 107–117. doi:10.1111/nph.13132 DOI: 10.1111/nph.13132.

Bursal E. (2013). Kinetic properties of peroxidase enzyme from chard (Beta vulgaris Subspecies cicla) leaves. International Journal of Food Properties, 16, 1293–1303. DOI: 10.1080/10942912.2011.585729

Chiaiese P., Corrado G., Colla G., Kyriacou M.C., Rouphael Y. (2018). Renewable Sources of Plant Biostimulation: Microalgae as a Sustainable Means to Improve Crop Performance. Front. Plant Sci., 9, 1782. https://doi.org/10.3389/fpls.2018.01782 .

Cong W.F., Hoffland E., Li L., Janssen B.H., Van Der Werf W. (2015). Intercropping affects the rate of decomposition of soil organic matter and root litter. Plant and Soil 391, 399–411. DOI: 10.1007/s11104-015-2433-5.

Corre-Hellou G., Fustec J., Crozat Y. (2006). Interspecific competition for soil N and its interaction with N2 fixation, leaf expansion and crop growth in pea-barley intercrops. Plant Soil 282:195–208. doi:10. 1007/s11104-005-5777-4. DOI: 10.1007/s11104-005-5777-4.

Das M.N., Giri N.C. (1986). Design and analysis of experiments. Wiley Eastern Limited, New Delhi, India.

Dimkpa C., Weinand T., Asch F. (2009). Plant-rhizobacteria interactions alleviate abiotic stress conditions. Plant, Cell & Environment 32, 1682–1694. doi.org/10.1111/j.1365-3040.02028.x .

El-Akshar Y.S., Mervat S., Hasanin Mahmoud Y.I., Mohamed A.A., Afifi M.M.I., Fatma S.H.I. (2016). Determine improve nutrient digestibility by in- vitro rumen method of germination barley seeds on rice straw as agriculture media after additive different levels of potassium humate, compost tea and Plant growth promoting (PGPR). African Journal of Agricultural Science and Technology (AJAST) 4, (1): 549-562.

El-Komy H.M.A. (2005). Coimmobilization of Azospirillum lipoferum and Bacillus megaterium for successful phosphorus and nitrogen nutrition of wheat plants. Food Technol. Biotechnol.,43 (1): 19-27. UDC 661.632:579.835.11:633.11

FAO ( ). http://www.fao.org/land-water/databases-and-software/crop information/cabbage/en/.

Gebru H. (2015). A Review on the Comparative Advantages of Intercropping to Mono-Cropping System. Journal of Bi-ology, Agriculture and Healthcare.Vol.5, No.9,1-13.

Gerdemann J.W., Nicolson T.H. (1963). Spores of Mycorrhizal Endogone Species Extracted from Soil by Wet Sieving and Decanting. Transactions of the British Mycological Society, 46, 235-244. http://dx.doi.org/10.1016/S0007-1536(63)80079-0 .

Gianinazzi S., Gollotte A., Binet M.N., van Tuinen D., Redecker D., Wipf D. (2010). Agroecology: the key role of arbuscular mycorrhizas in ecosystem services. Mycorrhiza 20, 519–530. https://doi.org/10.1007/s00572-010-0333-3.

Goiris K., Muylaert K., Fraeye I., Foubert I., De Brabanter J., De Cooman L. (2012). Antioxidant potential of microalgae in relation to their phenolic and carotenoid content. Environ. Boil. Fishes 24, 1477–1486. DOI: 10.1007/s10811-012-9804-6

Gomez K.A., Gomez A.A. (1984). Statistical procedures for agricultural research (2st Ed.). John Wiley and sons, NewYork, 680.

Gong P. (1997). Dehydrogenase activity in soil: a comparison between the TTC and INT assay under their optimum con-ditions. Soil Bio. Biochem., 29(2): 211-21.

Górka B., Korzeniowska K., Lipok J., Wieczorek P.P. (2018). The Biomass of Algae and Algal Extracts in Agricultural Production. In Algae Biomass: Characteristics and Applications; Springer Science and Business Media LLC: Berlin, Germany; pp. 103–114. DOI:10.1007/978-3-319-74703-3_9.

Guvenc I., Yildirim E. (1999). Multiple cropping systems in vegetable production. Turkey I. Organic Agriculture Symposium, 288-296, 21-23 June, Izmir-Turkey.

Guvenc I., Yildirim E. (2006). Increasing Productivity with Intercropping Systems in Cabbage Production, Journal of Sustainable Agriculture, 28:4, 29-44, DOI: 10.1300/J064v28n04_04.

Hauggaard-Nielsen H., Jensen E.S. (2005). Facilitative root interactions in intercrops. Plant Soil 274:237–250. doi:10.1007/1-4020-4099-7_13

Homulle Z., George T.S., Karley A.J. (2021). Root traits with team benefits: understanding belowground interactions in intercropping systems. Plant and Soil. doi:10.1007/s11104-021-05165-8.

Jackson M.L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.

Johnsen K.H., Apsley D.K. (1990). A simple method for measuring acetylene reduction of intact, nodulated black locust seedlings. Tree Physiol., 9(4): 501-506.

Kar M., Mishra D. (1976). Catalase, Peroxidase, and Polyphenoloxidase Activities during Rice Leaf Senescence. Plant Physiol., 57(2): 315-319. PMID: 16659474.

Köksal E., Bursal E., Aggul A.G., Gulcin I. (2012). Purification and characterization of peroxidase from sweet gourd (Cucurbita moschata Lam. Poiret). International Journal of Food Properties, 15, 1110–1119. DOI: 10.1080/10942912.2010.513216

Kusvuran A., Kusvuran S. (2019). Using of microbial fertilizer as biostimulant alleviates damage from drought stress in guar (Cyamopsis Tetragonoloba (L.) Taub.) seedlings. Int. Lett. Nat. Sci.76, 147–157. [CrossRef]. https://doi.org/10.18052/www.scipress.com/ILNS.76.147

Lithourgidis A.S., Vasilakoglou I.B., Dhima K.V., Dordas C.A., Yiakoulaki M.D. (2011). Annual intercrops: an alternative pathway for sustainable agriculture. Review article. AJCS 5(4):396-410.

Luatanab F.S., Olsen S.R. (1965). Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil. Soil Sci. Soc. Amer. Proc., 29: 677-678. https://doi.org/10.2136/sssaj1965.03615995002900060025x

Lyocks S.W.J., Tanimu J., Dauji L.Z. (2013). Growth and yield parameters of ginger as influenced by varying populations of maize intercrop Journal of Agricultural and Crop Research Vol. 1(2), pp. 24-29.

Nosek M., Surowka E., Cebula S., Libik A., Goraj S., Miszalski A.K.Z. (2011). Distribution pattern of antioxidants in white cabbage heads (*Brassica oleracea* L. var. *capitata* f. alba). Acta Physiologiae Plantarum, 33, 2125–2134.

Pathak J., Rajneesh., Maurya P.K., Singh S.P., Häder D.P., Sinha R.P. (2018). Cyanobacterial Farming for Environment Friendly Sustainable Agriculture Practices: Innovations and Perspectives. Front. Environ. Sci., 6, 7–19. https://doi.org/10.3389/fenvs.2018.00007

Polle A., Otter T., Mehne-Jakobs B. (1994). Effect of magnesium deficiency on antioxidative systems in needles of Norway spruce [Picea abies (L.) Karst.] grown with different ratios of nitrate and ammonium as nitrogen sources. New Phytol. 128, 621–628. https://doi.org/10.1111/j.1469-8137.1994.tb04026.x .

Pregl F., Roth H. (1935). Die quantitive organische Mikroanalyse Berlin, 4th edition, 105.

Raseduzzaman M., Jensen E.S. (2017). Does intercropping enhance yield stability in arable crop production? A meta-analysis. European Journal of Agronomy 2017 Vol. 91 Pages 25-33 DOI: https://doi.org/10.1016/j.eja.2017.09.009.

Richards L.A. (1954). Diagnosis and Improvement of Saline Alkali Soils, Agriculture, 160, Handbook 60. US Department of Agriculture, Washington DC.

Ronga D., Biazzi E., Parati K., Carminati D., Carminati E., Tava A. (2019). Microalgal Biostimulants and Biofertilisers in Crop Productions. Agronomy, 9, 192 https://doi.org/10.3390/agronomy9040192.

Saharan K., Schütz L., Kahmen A.,Wiemken A., Boller T., Mathimaran N. (2018). Finger Millet Growth and Nutrient Uptake Is Improved in Intercropping With Pigeon Pea Through “Biofertilization” and “Bioirrigation” Mediated by Arbuscular Mycorrhizal Fungi and Plant Growth Promoting Rhizobacteria. Front. Environ. Sci. 6:46. Agronomy 10, 121. https://doi.org/10.3389/fenvs.2018.00046

Saleh E.M.A. (2017). The economic impact of wheat intercropping systems in the old lands on the use of land and water resources. Egyptian Journal of Agricultural Economics 27(2)1099-1108.

Šamec D., Bogovi´c M., Vincek D., Martinˇci´c J., Salopek-Sondi B. (2014). Assessing the authenticity of the white cabbage (Brassica oleracea var. capitata f. alba) cv. ‘Varaždinski’ by molecular and phytochemical markers. Food Research International, 60, 266–272. 10.1016/j.foodres.2013.07.015.

Santos R.H.S., Gliessman S.R., Cecon P.R. (2002). Crop interactions in broccoli intercropping. Biological Agriculture and Horticulture 20: 51-75. https://doi.org/10.1080/01448765.2002.9754948

Scherer H.W., Metker D.J., Welp G. (2011). Effect of long-term organic amendments on chemical and microbial properties of a luvisol. Plant, Soil and Environment, 57: 513–518. DOI: 10.17221/3283-PSE.

Simova-Stoilova L., Demirevska K., Petrova T., Tsenov N., Feller U. (2008). Antioxidative protection in wheat varieties under severe recoverable drought at seedling stage. Plant Soil Environ. 54, 529–536. DOI: 10.17221/427-PSE

Smith S.E., Jakobsen I., Grønlund M., Smith F.A. (2011). Roles of arbuscular mycorrhizas in plant phosphorus nutrition: in-teractions between pathways of phosphorus uptake in arbuscular mycorrhizal roots have important implications for understanding and manipulating plant phosphorus acquisition. Plant Physiol 156:1050–1057. https://doi.org/10.1104/pp.111.174581 .

Tabatabai M.A., Bremner J.M. (1969). Use of p-nitro- phenyl phosphate for assay of soil phosphatase activity. Soil Biol. Bi-ochem.,1(4): 301-307.

Thalmann A. (1968). Dehydrogenase activity. In: Methods in Applied Soil Microbiology and Biochemistry (Eds. Alef, K. and Nannipieri, P.). Academic Press Ltd, pp. 228–230.

Tian X.L., Wang C.B., Bao X.G., Wang P., Li X.F., Yang S.C., Ding G.C., Christie P., Li L. (2019). Crop diversity facilitates soil aggregation in relation to soil microbial community composition driven by intercropping. Plant and Soil 436, 173–192. DOI: 10.1007/s11104-018-03924-8

Varghese L. (2000). Indicators of production sustainability in intercropped vegetable farming on montmorillonitic soils in India. Journal of Sustainable Agriculture 16 (4): 5-17. https://doi.org/10.1300/J064v16n04_03 .

Wang H., Wang G., Huang Y.Y., Chen J., Chen M.M. (2008). The effects of pH change on the activities of enzymes in an acid soil. Ecol Environ. 17(6):2401–2406.

Watts D.B., Torbert H.A., Feng Y., Prior S.A. (2010). Soil microbial community dynamics as influenced by composted dairy manure, soil properties, and landscape position. Soil Science, 175: 474–486. DOI: 10.1097/SS.0b013e3181f7964f.

Win T.T., Barone G.D., Secundo F., Fu P. (2018). Algal Biofertilizers and Plant Growth Stimulants for Sustainable Agriculture. Ind. Biotechnol. 14, 203–211. https://doi.org/10.1089/ind.2018.0010 .

Wolinska A., Stepniewsk Z., (2012). Dehydrogenase Activity in the Soil Environment, in: DOI: 10.5772/48294

Yildirim E., Guvenc I. (2005). Intercropping based on cauliflower: More productive, profitable and highly sustainable. European Journal of Agronomy.; 22(1):11–18. 10.1016/j.eja.2003.11.003.

الملخص العربي

استخدام التحميل والتسميد الحيوي كإستراتيجيات متكاملة لرفع كفاءة نظام الزراعة المستدامة لمحصولي الكرنب والخس

إيمان بسيوني الرميلي[١]، خديجة ابراهيم محمد الجابري[٢] و حنان محمد مصطفي[٣]

[١]قسم بحوث الخضر خلطية التلقيح – معهد بحوث البساتين– مركز البحوث الزراعية
[٢]قسم بحوث الميكروبيولوجيا– معهد بحوث الاراضي والمياه والبيئة – مركز البحوث الزراعية
[٣]قسم بحوث اقتصاديات الاراضي والمياه – معهد بحوث الاقتصاد الزراعي– مركز البحوث الزراعية

الهدف الرئيس لهذه الدراسة هو تعظيم الانتاجية من وحدة المساحة لمحصولي الكرنب والخس مستخدما نظام الزراعة المحملة وزيادة كفاءتها بإستخدام التسميد الحيوي. قارنت الدراسة بين نظامي الزراعة المفردة والمحملة بالتكامل مع التسميد الحيوي وتأثيرها علي النمو ،المحصول، كفاءة استخدام التربة، كفاءة استخدام الماء،وتقليل تأثير متبقيات الكيماويات علي التربة. في شتاء ٢٠١٩ و٢٠٢٠ تم استخدام ثلاث معاملات من التسميد، ١٠٠% تسميد معدني كامل، تسميد بفطريات الميكروهيزا، معاملة مختلطة بين التسميد بالميكروهيزا ونصف كمية التسميد المعدني الموصي به وذلك في أنظمة الزراعة المفردة والمحملة لمحصولي الكرنب والخس. نفذت الدراسة في تجارب عاملية في قطاعات كاملة العشوائية. أظهرت النتائج عدم وجود فروق معنوية بين نظامي الزراعة في معظم الصفات البستانية فيماعدا طول وقطر رأس محصول الكرنب والتي تأثرت بالتحميل. أدي استخدام المعاملة المختلطة الي تحسين نظام التحميل وتفوقت علي كل المعاملات. لقد سجلت المعاملة المختلطة افضل قيم للصفات البستانية،كما حسنت من امتصاص النباتات للعناصر الغذائية ، كماساهمت في تحسين الرقم الهيدروجيني، المواد الصلبة الكلية الذائبة، أنشطة انزيمات التربة وانزيمات مضادات الاكسدة بالنبات وكذلك تفوقت هذه المعاملة علي اساس الكفاءة الاقتصادية للمحصول والماء والتربة . لقد أثبتت النتائج كفاءة استخدام نظام التحميل بالتكامل مع التسميد الحيوي في انتاج محصول عالي الي جانب المحافظة علي التوازن البيولوجي في التربة في ضوء تفتت الرقعة الزراعية وتحدي تغيرالمناخ.

الكلمات المفتاحية: فطر الميكروهيزا، ديهيدروجينيز ، فوسفاتيز ، نيتروجينيز ، بيروكسيديز ، كتاليز