EFFECT OF BIOFERTILIZERS AND CHEMICAL FERTILIZERS ON SOIL BIOLOGICAL PROPERTIES AND POTATO YIELD.

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Abstract

Understanding of the interactions between biofertilizers and chemical fertilization in soil is beneficial to soil microbes and plant growth. However, these combinations are not fully comprehended. A field experiment was conducted in a silty clay soil using RCBD design to study the effect of mycorhizal fungi (*Glomus mosseae*), algae (*Ascophyllum Nodosum*), yeast (*Saccharomyces cerevisiae*) and chemical fertilization (0%, 50% and 100%) of the recommended addition on some bio-soil characteristics, and potato yield (*Solanum tuberosum*L.). It was found that the combination of mycorhizal fungi with algae (B3) recorded the highest increase in soil respiration (7.00 mg CO_2 g^{-1}.soil). Furthermore, the application of chemical fertilization at 100% raised soil respiration (6.36 mg CO_2 g^{-1} soil) as compared with control treatments (5.75 mg CO_2 g^{-1} soil). In addition, aggregate stability was largely increased (34.64 %) by the combination of mycorrhizal fungi with yeast (B5). More importantly, the application of the chemical fertilizers at 100% reduced aggregate stability (30.39 %) and bacterial counts (44.67 × 10^6g $^{-1}$**)** as compared with the control treatments (33.25 %) and (51.10× 10^6g $^{-1}$**)** respectively. It's noted also that the highest mycorhizal infection rate was 55.93 % when mycorhizal fungi was combined with yeast (B5). In contrast, the applied chemical fertilization at 100% reduced highly the mycorrhizal infection rate (21.34 %) as compared with the control (51.04 %). Moreover, the combinations of mycorhizal fungi, yeast and algae (B6) proved a significant increase in the total yield (18.91 tons ha^{-1}). This study concluded that chemical fertilization negatively inversely influenced soil aggregate stability, infection rate and microbial community while the combination of mycorhizal fungi, algae and yeast with a higher rate of chemical fertilization was beneficial to microbial respiration and potato yield.

Keywords: NPK,aggregate stability, microbial respiration, potato yield, mycorrhiza, marine algae extract, yeast.

تاثير التسميد الحيوي والكيميائي في بعض صفات التربة الحيوية وحاصل البطاطا

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الخلاصة

التداخل بين التسميد الحيوي والكيميائي في التربة مهم ومفيد لأحياء التربة ونمو النبات الا ان هذا التداخل غير مفهوم بشكل جيد. نفذت تجربة حقلية في تربة طينية غرينية باستعمال تصميم القطاعات تامة التعشية RCBD لدراسة تأثير المايكورايزا(*Glomus mosseae*)،مستخلص الطحالب البحرية **(***Ascophyllum Nodosum***)**،خميرة (*Saccharomyces cerevisiae*)، والتسميد المعدني (بدون اضافة ،50 % و100%) من التوصية السمادية في بعض صفات التربة الحيوية وحاصل البطاطا (*Solanum tuberosum L.*) . وجد ان تداخل المايكورايزا مع الخميرة (B_3) سجل اعلى معدل للتنفس الميكروبي في للتربة (7ملغم كاربون .غم$^{-1}$ تربة) كما نلاحظ ان اضافة الاسمدة الكيميائية عند المستوى 100% سبب انخفاض في ثباتية التجمعات 30.39 % واعداد خلايا البكتريا 44.67 × 10^6 وحدة تكوين مستعمرة.غم$^{-1}$ قياسا بمعاملة المقارنة 33.25 % و 51.10× 10^6 وحدة تكوين مستعمرة.غم$^{-1}$ على الترتيب. كذلك نلاحظ ان اعلى معدل نسبة الاصابة بالمايكورايزا بلغ 55.93 % عند تداخل المايكورايزا مع الخميرة (B_5).على العكس من ذلك ان اضافة الاسمدة الكيميائية عند المستوى 100% سبب انخفاض

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معنوي في معدل نسبة الاصابة بالمايكورايزا 21.34 % قياسا بمعاملة المقارنة 51.04 %. فضلا عن ذلك التداخل بين المايكورايز ،الخميرة والطحالب (B_6) حقق زيادة معنوية في الحاصل الكلي (18.91 طن هكتار$^{-1}$) نستنتج من الدراسة ان التسميد الكيميائي يوثر سلبا على تحسن ثباتية تجمعات التربة ، معدل الاصابة بالمايكورايزا والمجتمع الميكروبي في التربة في حين ان تداخل المايكورايزا ، الطحالب والخميرة مع مستوى عالي من التسميد الكيميائي مفيد للتنفس الميكوبي وحاصل البطاطا.

الكلمات المفتاحية : NPK,ثباتية التجمعات, التنفس الميكروبي , حاصل البطاطا , مايكورايزا , مستخلص الطحالب البحرية , خمائر.

*البحث مستل من رسالة ماجستير للباحث الثاني.

1- Introduction

Potato (*Solanum tuberosum* L.) is a one of the most important vegetable crops for consumption. Potato ranks fourth in terms of the considerable importance after wheat, rice and maize because it is rich in carbohydrates and nutrients and amino acids (17). The higher chemical fertilizer requirements N-P-K for potato plant (1), is considered as one of the growing problems that reduces the quality of crop. An excessive use of chemical fertilizers leads to several environmental problems, including groundwater contamination, soil degradation and its effects on plant growth (39).To minimize these negative effects, alternative methods have to be found such as the inoculation of beneficial microorganisms in soil to increase potato productivity (32). Plant residues and biomass extracts are used to improve soil properties and the growth of plants (4,5,2,3). For instance, marine algae extracts are an able to increase soil fertility due to their contents of nitrogen, phosphorus and iron (16).In addition, yeasts also contain many essential nutrients and growth regulators for plant growth, such as auxins, gibberellins and cytokininsthat promote plant growth and soil fertility (14).Mycorrhizal fungi inoculation is an important biotechnological technique that capable of increasing of the potato productivity due to their role in extending of the root network and its effects on nutrient uptake (31). Mycorrhizal fungi have a concrete role in aggregates formation due to their products of glycoprotein and glomalin substances which provide a full protection for soil structure from the erosion forces (12). Furthermore, the application of algal biomass can increase soil organic matter and nutrients contents causing an enhanced microbial activity (15). The experimental hypothesis is that the applied mycorrhizal fungi, yeast and algal dried biomass have a cementing function to improve potato plant, soil aggregate stability, microbial activity, and mycorrhizal fungal infection.There is no study has ever exploited the importance of mycorrhizal fungi, yeast (*Saccharomyces cerevisiae*) and algae extract (*Ascophyllum Nodosum*) to increase the productivity of potatoes; therefore, this study aimed to use the combinations of biofertilizer with mineral fertilization to determine such effect on the characteristics of the soil biological properties and the yield of potato.

2- Materials and Methods

A field experiment was conducted during the autumn season of 2017 in a silty clay soil in a one of the agricultural fields located in the province of Babil - Abu Gharq locality previously planted with wheat plant. chemical , physical and biological analyses of soil were shown in Table (1).

Table 1: Chemical ,physical and biological properties of soil.

Chemical properties											
Properties	EC_e	pH	Ca^{2+}	Mg^{2+}	Na^{+}	SO_4^{2-}	Cl^{-}	Hco_3^{-}	Available nutrients		
									N	P	K
Units	$dS.m^{-1}$	--	$m.mol.L^{-1}$						$mg.kg^{-1}$		
Value	3.5	7.8	10	11.5	11.8	9.3	21	4.7	85	14	160
Physical properties											
Properties	Bulk density		Moisture content at field capacity				Texture Silty clay				
							Sand	Silt	Clay		
Units	$g.cm^{-3}$		%				$g.kg^{-1}$				
Value	1.34		24.00				120	330	550		
Biological properties											
Properties	bacteria		fungi				Mycorrhizal spore				
Units	$CFU.g^{-1}$ dry soil		$CFU.g^{-1}$ dry soil				$Spore.10^{-1}$ g dry soil				
Value	35×10^{6}		11×10^{3}				^{10}				

1.2 Mineral fertilization

Urea (N 46%), potassium sulfate (K 42%) and diammonium phosphate (**DAP**) (P 23%, N 21% were used. Phosphate fertilizer was added to soil as a one dose before planting. Nitrogen and potassium fertilizers were added as three equal doses; first dose was added two weeks after emergence and the second and third doses were added 25 days after the emergence at a depth of 0.1 m near the plant (Salmany and Mahmoud, 2010).

2.2 Inoculation of Mycorrhiza Fungi AM fungi (*Glomus mosseae*) were obtained from the Agriculture Research Office, Baghdad.The density of spores was 42 spores per 1 g soil.10 g of mycorrhizal fungal inoculums were added under the tuber during agriculture (13).

3.2 Marine Algae Extract (Acadia)

Alges (*Ascophyllum Nodosum***)** is a Canadian-made used as a biofertilizer. Table 2 shows the properties of the extract. The extract was added at a rate of 4 gm. m^{-1} near the roots of the plant. This extract was dissolved in liter of water and added at three stages. The first addition was at planting while the second stage was at theend of the emergence and the third stage was at the beginning of the formation of tubers near the plant.

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Table 2. Properties of the algal extract.

Properties	NPK and Minerals	Alginic Acid	Mannitol	Amino Acids	Moisture	organic matter
%	55 -45	10	4	4	6.5	20

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4.2 Yeast suspension

An active dry yeast French-made brand (Saf-Instant) was dissolved in a distilled water followed by the addition of sugar at a ratio of 1:1 and incubated for 12 hours in order to be activated (8). 10 g. L^{-1} of yeast was added near the roots of the plant at a rate of 1 liter. m^{-2}. Yeast was applied at three stages; the first stage was at the seeding time and the second stage was when the plant was emerged while the third stage was during the formation of tubers.

5.2 Measurements

Soil Respiration was prepared according to the alkali trap method (3). 20 g of soil was added in a flask with a 10 ml beaker consists of 5 ml solution of NaOH (1 M). Beakers then were incubated for 1, 3, and 30 days at 25C°. The NaOH solution was neutralized by 1 M HCl. Furthermore, a solution of $BaCl_2$ (2.0 ml) of a 30% (w/v) was added to the samples before titration to precipitate the CO_3 as $BaCO_3$. The bacterial and fungal communities were counted by a soil dilution plate technique. A serial dilution of 1 g was followed with sterilized water using several dilutions starting from 10^{-1} to 10^{-7} as mentioned by (2). Soil aggregate stability was measured by a Dutch-made wet sieving apparatus, where the soil was passed through a 25 mm diameter sieve and as mentioned in Blake (9). The AM fungal colonization rate was measured according to method described by Phillips and Hyman (34). The roots were situated in a bottle consisted of 10% (w/v) potassium hydroxide (KOH) and kept at 90 C° for 90 min. All roots were laid in 3% hydrochloric acid (v/v) for 5 min, and stained with 0.05% trypan blue in lactophenol solution consisting of 1: 1: 1 glycerol, lactic acid, distilled water) for 15-30 min. A 4X optical microscope was used to indicate the percentage of colonization. Total yield was estimated after the harvesting of tubers on 17/1/2018. Total yield was calculated by dividing of total yield of experimental unit to experimental unit area.

6.2 Statistical Analysis

Two factors (Biofertilizers and chemical fertilization) were analyzed using the Genstat Discovery (2012) program and the differences between means were calculated by testing the least significant difference (LSD) at the probability level of 0.05.

3. Result and Discussion

3.1 Microbial respiration in the soil (mg CO_2. g^{-1} soil)

Data in Table (3) illustratedthat the application of mineral fertilization caused a significant increase in microbial respiration rate in the soil. The highest increases were 6.19 and 6.36 (mg $CO_2.g^{-1}$ soil) in F1 and F2 respectively as compared with the control treatment 5.75 (mg $CO_2.g^{-1}$ soil) F0. There were no significant differences between F1 and F2.It was also observed that the biofertilizer treatments caused an increase in microbial respiration rate in the soil. The highest rate was 7.00 (mg $CO_2.g^{-1}$ soil) in B3 treatment as compared with B0 treatment 5.48 (mg $CO_2.g^{-1}$.soil).The lowest microbial respiration rate was 4.9 in the F0B5 treatment, which differed significantly from these treatments (F2B6, F0B1, F2B4, F2B1, F1B4, F2B2, F1B2, F0B4, and F1B3). The increase in the rate of microbial respiration in the soil may be attributed to the increase in the level of mineral fertilization which considered a very valuable source of energy for microbial community. However, CO_2 releases might depend on how resistant soil aggregate stability is to the environmental fluctuations in the field.

For instance, aggregate stability was decreased by the mineral fertilization Table (3) due to a diminished mycorrhizal infection rate. A deteriorated soil aggregate stability after the application of mineral fertilization can expose the stored organic carbon in soil aggregates to decomposition process and might be used as a source of energy for microorganisms, thus an increase in CO_2 releases was recorded after the chemical fertilizer was applied. These findings are consistent with the results of (41).

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Combination of mycorrhizal fungi with yeast (B4) led to a clear increase in microbial activity and the reason behind that could be ascribed to the yeast products which supported microbial community in soil.

Table 3: Microbial respiration in the soil month of incubation (mg CO_2. g^{-1} soil)

	Biofertilization (B)							Average (F)
Mineral fertilization (F)	B0	B1	B2	B3	B4	B5	B6	
F0	4.90	6.55	6.13	6.14	6.80	4.82	4.92	5.75
F1	5.55	5.40	6.75	7.00	6.68	5.80	6.16	6.19
F2	6.07	6.57	6.72	6.05	6.55	6.10	6.47	6.36
)B (Average	5.51	6.17	6.53	6.40	6.68	5.57	5.85	
L.S.D (B) 0.87		L.S.D (B×F) 1.41				L.S.D (F) 0.23		

controlB_0,mycorrhiza inoculation (*Glomusmosseae*)B_1,marinalga extract(*AscophyllumNodosum*)B_2,bread yeast suspension(*Saccharomyces cerevisiae*) B_3, mycorrhiza inoculations + marine algae extract B_4, mycorrhiza inoculation + bread yeast suspension B_5, and mycorrhiza inoculation + bread yeast suspension + marine algae extract B_6

3.2 Soil stability Aggregate

It's noted from the table (4), there was a significant decrease in the percentage of aggregate stability when mineral fertilization was added at 100 %. The magnitude of reduction was from 33.25% in F0 to 30.39% in F2 treatment. Generally, the main reason for formation of aggregate stability is microbial community. Any obvious changes in their

counts might affect soil aggregate stability. The toxic effect of chemical fertilizers on microorganisms might have limited their effectiveness in forming soil aggregates. Therefore, the decrease in the percentage of aggregate stability in F2 may be attributed to the significant decline in the mycorrhizal infection rate and the total bacteria in the soil. These organisms play an important role in the formation of aggregate stability. Furthermore, these organisms contribute to binding soil particles and create suitable conditions for the formation of aggregates using the external mycorrhizal hyphae (25).In addition, the products of mycorrhizal fungi from the hyphal exudation like glycoprotein and glomalin acting as a biological glue, helping to bind soil particles into different sizes of aggregates (Rillig et al., 2006).Bacteria also play an important role in the formation of soil aggregates through the release of hydrophobic properties substances such as waxes and fats, which connect soil particles leading to an improved aggregate stability.The highest significant increase in aggregate stability was 34.64 % when mycorrhizal fungi combined with yeast (B5).The highest increase rate in aggregate stability was 15.8% when mycorrhizal fungi combined with yeast as compared with control. This increase might

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reflect a friendly relationship between mycorrhizal fungi and yeast in ameliorating soil aggregate stability. Yeast composition is a full of amino acid and nutrients which encourage organisms to be active in the rhizospher leading to more enhancements in aggregate stability. Another indication is that yeast contributed to the increase of the mycorrhizal infection rate and improved roots exudation (19).Such exudation acted as a binding agent of soil aggregates (27).

Table 4: Soil Aggregate stability

	Biofertilizatin (B)							Average (F)
Mineral fertilization (F)	B0	B1	B2	B3	B4	B5	B6	
F0	29.51	30.45	35.02	31.95	39.87	34.47	31.52	33.25
F1	22.70	36.75	31.51	32.12	23.19	42.57	38.74	32.51
F2	37.53	36.25	24.47	26.75	27.30	26.88	33.57	30.39
Average) B(	29.91	34.48	30.33	30.27	30.12	34.64	34.61	
L.S.D (B) 4.03			L.S.D (B×F) 6.76			L.S.D (F) 2.81		

control B_0,mycorrhiza inoculation(*Glomusmosseae*)B_1,marinalgae extract(*Ascophyllum Nodosum*)B_2,bread yeast suspension(*Saccharomyces cerevisiae*) B_3, mycorrhiza inoculations + marine algae extract B_4, mycorrhiza inoculation + bread yeast suspension B_5, and mycorrhiza inoculation + bread yeast suspension + marine algae extract B_6.

3.3 Bacterial and fungal colonies in soil

Data in Table (5) showed that the bacterial colonies varied according to the level of mineral fertilization added. There was a significant increase in bacterial colonies (60.1×10^6) when 50% of the chemical fertilization (F1)was appliedas compared with the control and F2 treatments (51.10×10^6 and 44.67×10^6) respectively.The increase in bacterial community at the low level (F1) may be due to the importance of the low quantity of chemical materials as a source of food and energy for microorganisms. The addition of chemical fertilization (F2) at 100% resulted in a significant decrease in the number of colonies (44.64×10^6) as compared with F0 (51.10×10^6).The decrease in bacterial community at the level of F2 may be due to the fact that the added fertilizers (urea and potassium sulfate)might have created an acidic condition that caused a decrease in PH of the soil. Furthermore, it seems that yeast (B3) recorded the highest rate of bacterial community (70.78×10^6) as compared with B0 treatment (33.11×10^6) and the reason behind that could be associated to the beneficial substances of yeast such as amino acid and nutrients which encourage bacterial community to grow

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rapidly. It's found through the interaction that the F1B6 caused an increase in bacterial colonies of the soil (93.67×10^6) as compared with others. The increase can be caused by several matters; one of them is mycorrhizal products (glycoprotein) in the rhizosphere which might have raised bacterial community in the soil. The second matter is the algal and yeast substances as showing much more aids to bacterial community.

Table 5: Bacterial colonies in soil

	Biofertilization (B)							Average(F)
Mineral fertilization (F)	B0	B1	B2	B3	B4	B5	B6	
F0	43.33	59.67	41.67	50.00	35.67	58.67	68.67	51.10
F1	32.33	42.67	22.67	83.67	88.67	57.00	93.67	60.10
F2	23.67	49.67	76.67	78.67	21.67	33.67	28.67	44.67
Average) B(	33.11	50.67	47.00	70.78	48.67	49.78	63.67	
L.S.D (B) 2.12		L.S.D (B×F) 3.67			L.S.D (F) 1.95			

control B_0,mycorrhiza inoculation(*Glomusmosseae*)B_1,marinalgae extract(*AscophyllumNodosum*)B_2,bread yeast suspension(*Saccharomyces cerevisiae*) B_3, mycorrhiza inoculations + marine algae extract B_4, mycorrhiza inoculation + bread yeast suspension B_5, and mycorrhiza inoculation + bread yeast suspension + marine algae extract B_6.

Table 6 shows that fungal colonies were influenced by the levels of mineral fertilization. Fungal community decreased significantly (47.9×10^{-3}) at the 50 % of the chemical fertilization addition as compared with F0 (54.67×10^{-3}), while F2 treatment caused a non-significant increase in fungal community compared to F0. The biofertilization treatments modified fungal community in the soil. The highest value of fungal community was 71.67×10^{-3} in B6 compared to B0 (44.33×10^{-3}). As for the interaction, the F0B6 treatment had significantly more pronounced counts of fungal community (87.67×10^{-3}).The decrease in fungal community after the application of 50% of the chemical fertilization may be linked to the increase in bacterial community (Table 5) which might have competed fungal community for the source of energy. In addition, it could be that fungal communities are more sensitive to the chemical fertilization and were not tolerated to such events. The increase in fungal community in the B6 treatment may be due to the glomalin which was produced by mycorrhizal fungi which can support soil microbial community.

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Table 6: Fungal colonies in soil

	Biofertilization (B)							Average (F)
Mineral fertilization (F)	B0	B1	B2	B3	B4	B5	B6	
F0	33.67	78.67	52.67	43.67	35.67	50.67	87.67	54.67
F1	35.67	48.67	58.67	48.67	36.33	55.67	51.67	47.90
F2	63.67	83.67	43.67	46.00	38.67	33.67	75.67	55.00
Average) B(	44.33	70.33	51.67	46.11	36.89	46.67	71.67	
L.S.D (B) 0.98			L.S.D (B×F) 1.61			L.S.D (F) 0.48		

control B_0,mycorrhiza inoculation(*Glomus mosseae*)B_1,marinalgae extract(*Ascophyllum Nodosum*)B_2,bread yeast suspension(*Saccharomyces cerevisiae*) B_3, mycorrhiza inoculations + marine algae extract B_4, mycorrhiza inoculation + bread yeast suspension B_5, and mycorrhiza inoculation + bread yeast suspension + marine algae extract B_6.

3.4 Mycorrhizal infection rate

Based on Table (7), there is a significant decrease in the mycorrhizal infection rate after application of the mineral fertilization (F1) 34.97 and (F2) 21.43% as compared with the control 51.04%. Additionally, all biofertilization treatments caused significant increases in the mycorrhizal infection rate except, for B2 which had lower mycorrhizal infection rate as compared with control. The highest significant increase in mycorrhizal infection rate was in B5 (55.93%) as compared to control (17.23%). The explanation of why chemical fertilizer both at low and high rates reduced mycorrhizal infection rate is that mycorrhizal fungi is more sensitive to such events due to probably a change in PH of the soil which might have affected the infection rate or alternatively, to the toxic affect which might lead to more damage to the mycorrhizal infection rate. This study suggests that the indigenous mycorrhizal fungi added to soil is more sensitive to urea and phosphor rate. This study is in agreement with the results of (21) who confirmed that high P supply caused a low root infection. These results are also consistent with Diab, (2012) and Martin et al. (2011), who found that the added mineral fertilization at high levels, especially urea, caused a decrease in infection rate, the number of spores. Furthermore, our outcomes assured that the combination of mycorhizal fungi with yeast contributed greatly to the infection rate and this may be attributed to the cementing role of yeast in increasing the colonization rate (Boby, 2008) due to their contents of natural substances that stimulate the growth of plants such as cytokinein and amino acids and thus increase the roots exudation in the rizosphere

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Table 7: mycorrhizal infection rate

	Biofertilization (B)							Average (F)
Mineral fertilization (F)	B0	B1	B2	B3	B4	B5	B6	
F0	24.46	76.00	16.95	28.31	61.14	84.21	66.22	51.04
F1	16.67	48.21	10.89	22.79	43.51	54.11	48.59	34.97
F2	10.55	29.27	7.97	22.35	22.67	29.48	27.73	21.43
Average) B(	17.23	51.16	11.94	24.49	42.44	55.93	47.51	
L.S.D (B) 4.23			L.S.D (B×F) 6.82			L.S.D (F) 1.07		

control B_0,mycorrhiza inoculation(*Glomusmosseae*)B_1,marinalgae extract(*Ascophyllum Nodosum*)B_2,bread yeast suspension(*Saccharomyces cerevisiae*) B_3, mycorrhiza inoculations + marine algae extract B_4, mycorrhiza inoculation + bread yeast suspension B_5, and mycorrhiza inoculation + bread yeast suspension + marine algae extract B_6.

3.5 Total yield

Table (8) shows that the mineral fertilization treatments (F2) caused an increase in the total yield (19.12 tons.ha^{1}) as compared with control (14.33 tons.ha^{1}). The increased rate was about 33.4%. We also noted that the F1 caused an increase in the total yield but was not significant. Furthermore, the biofertilization treatments increased the total yield and the highest value was 18.91 tons ha^{-1} in B6 treatment. There was a significant interaction plot which confirmed a raise in the total yield (21.23 tons.ha^{-1}) at F2B6 treatment which announced a great combination of mycorihzal fungi, yeast and algal biomass in maximizing the total yield.

The reason of why the total yield in F2 was evidently increased could be due to the mineral fertilizers which provided large amounts of available nutrients (N, P, K) in soil and their roles in improving plant growth as these nutrients play an important role of the plant biological processes and considered as the energy source for plant. Nitrogen is the main unit for the formation of chlorophyll and potassium, which contributes to the regulation of enzymes within the plant. These results are consistent with the results of Sharifi, (2015), who obtained a significant increase in the total yield of potatoes after addition of mineral fertilizer to soil. B6 treatment is considered as an affective combination due to the role of yeast, mycorrhiza and marine algae. Yeast contains nutrients and organic substances that stimulate plant growth and have a clear role in increasing mycorrhizal infection rate (Boby et al., 2008).Mycorrhiza can improve plant growth by increasing the absorption of low-mobility nutrients such as phosphorus, zinc and copper (Neumann and George, 2010), improving water relations and reducing disease (22).The role of marine algae may lead to stimulation in plant growth because of the

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important nutrients such as nitrogen, phosphorus and iron (16).

On the top of that, they contain growth regulators such as alginates, cytokines, oxins and organic acids (20) which have a direct influence on total yield.

Table 8:Total yield(ton.ha^{-1})

	Biofertilization (B)							Average (F)
Mineral fertilization (F)	B0	B1	B2	B3	B4	B5	B6	
F0	14.81	14.81	14.47	13.29	13.32	15.56	15.89	14.33
F1	15.19	15.19	15.86	16.33	19.26	17.44	19.62	16.87
F2	18.89	18.89	20.37	17.41	20.44	18.83	21.23	19.12
Average) B(	16.30	16.30	16.90	15.68	17.67	17.28	18.91	
L.S.D (B) 2.16		L.S.D (B×F) 4.2				L.S.D (F) 3.14		

control B_0,mycorrhiza inoculation(*Glomusmosseae*)B_1,marinalgae extract(*Ascophyllum Nodosum*)B_2,bread yeast suspension(*Saccharomyces cerevisiae*) B_3, mycorrhiza inoculations + marine algae extract B_4, mycorrhiza inoculation + bread yeast suspension B_5, and mycorrhiza inoculation + bread yeast suspension + marine algae extract B_6.

4. Conclusion

This study concluded that the combinations of mycorrhiza, yeast (*Saccharomyces cerevisiae*), and algae contributed to an increase in the proportion of mycorrhizal infection rates and improved soil aggregate stability. Mineral fertilization decreased the mycorrhizal infection rates, microbial community and soil aggregate stability, whiles increases in the soil microbial respiration was observed. Mineral fertilization at higher rate increased the total yield of potato while a lower addition of fertilizer did not lead to a clear increase in the potato yield. This study recommended that the use of 120 kg nitrogen, 60 kg phosphorus and 200 kg potassium per hectare in a combination with the marine algae, yeast and mycorrhizal fungi to be an optimum choice for increasing the potato crop.

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