

Manuscript Details

Manuscript number	APSOIL_2019_1084
Title	Soil cultivable microorganisms as affected by different soil managements in a two years wheat-faba bean rotation
Article type	Short Communication

Abstract

Agricultural practices greatly influence soil chemical and microbiological parameters, which affect the soil fertility. The aim of the study was to investigate the effects of different tillage (conventional (CT), minimum (MT) and no tillage (NT)), fertilization (fertilization versus no fertilization), soil depth (0-30, 30-60, and 60-90 cm) and crops (wheat versus faba bean) on the abundance of selected microorganisms. Positive and significant correlations were found between soil cultivable microorganisms (SCM) and both the total cultivable bacteria (TCB) and total fungi (TF) suggesting a predominance of those microorganisms in the microbial community composition, compared to the total yeasts (TY). The SCM were positively correlated to the content of soil organic carbon, total nitrogen and available phosphorus. The minimum tillage increased significantly the microbial populations, representing a good compromise between soil aeration and available nutrients as well as the faba bean. In particular, the unfertilized legume resulted in a higher TY with respect to the fertilized one, meaning that somehow those microorganisms lose their low ecological competition in presence of inorganic phosphorus. Finally, the differences among the three soil depth were ascribed mainly to the chemical parameters and, secondarily, to the microbiological ones.

Keywords	soil cultivable bacteria; total yeasts; total fungi; tillage; fertilization; PCA
Taxonomy	Soil Microbial Populations, Soil Chemistry, Farming Systems
Manuscript category	Microorganism-related Submissions
Corresponding Author	Gennaro Brunetti
Corresponding Author's Institution	Università degli Studi di Bari "Aldo Moro"
Order of Authors	Francesco De Mastro, Andreina Traversa, Gennaro Brunetti, Giambattista Debiase, Claudio Coccozza, Franco Nigro
Suggested reviewers	Karam Farrag, Giovanni Garau, Carlos Garcia

Submission Files Included in this PDF

File Name [File Type]

Cover letter.doc [Cover Letter]

Highlights.docx [Highlights]

Manuscript.docx [Manuscript File]

Figure 1.docx [Figure]

Table 1.docx [Table]

Table 2.docx [Table]

Table 3.docx [Table]

To view all the submission files, including those not included in the PDF, click on the manuscript title on your EVISE Homepage, then click 'Download zip file'.

Bari, September 10, 2019

Dr. Judith Ascher-Jenuß
Editor in Chief
Applied Soil Ecology

Dear Editor,

On behalf of all Authors, I like to re-submit to your kind attention the manuscript entitled: “**Soil cultivable microorganisms as affected by different soil managements in a two years wheat-faba bean rotation**”, by Francesco De Mastro, Andreina Traversa, Gennaro Brunetti, Giambattista Debiase, Claudio Coccozza, Franco Nigro.

As requested, we report your decision and a point by point response of your observations in this cover letter.

Decision

Ref: **APSOIL_2019_907**

Title: Dynamic of soil cultivable microorganisms as affected by different soil managements in a two years wheat-faba bean rotation

Dear Professor Brunetti,

Thank you for your interest and submission to Applied Soil Ecology. Unfortunately, after an initial evaluation, I feel your manuscript is not yet appropriate for Applied Soil Ecology. The reasons for this decision are explained below in the Editor’s comments.

However, resubmission of a thoroughly revised and condensed manuscript into a short communication may be considered if you feel the raised concerns can be addressed adequately. If



you choose to submit a revision, you should include the manuscript number of this current submission and a point by point response to reviews in your resubmission cover letter.

Thank you for giving us the opportunity to consider your work.

Kind regards,

Dr. Ascher-Jenull
Editor-in-Chief
Applied Soil Ecology

Comments from the editor: option to resubmit as short communication

According to your comments, the manuscript has been modified as follows:

Comment	Response
The cross-check facility used by the Journal detected a very high similarity, 48%, to existing literature resources, jeopardizing the novelty of your presented work	The paper has been almost entirely rewritten.
The English of your manuscript (starting with the highlights 1 and 2) does not yet meet the Journal's desired criteria. Please accurately proof read/English Edit your manuscript, taking advantage of the help by a native speaking colleague or an English Editing Service with basic field-knowledge, so as to improve the read-flow, and thus, the overall comprehensiveness of your performed research.	Highlights and the entire paper have been revised also for the quality of English.
The performed analyses/resulting data do not provide sufficient data for publication as regular	The Editor suggestion has been accepted and the paper has been rewritten as Short



<p>full length research paper in Applied Soil Ecology: to be in this Journal, the research must focus on some aspect of the ecology of soil microbial or faunal organisms (e.g. must include a suite of measurements on the activity, community structure/diversity, or functions of these organisms) relative to practical applications in managing ecosystems. In fact, based on the amount of performed analyses/resulting data, the article type short communication would be better fitting than a full length research paper. Accordingly, and given the importance of your topic addressed, I would like to offer you the opportunity to resubmit a condensed version of your manuscript (new submission) for reconsideration as *SHORT COMMUNICATION.</p>	<p>Communication.</p>
<p>The conclusion drawn (also last sentence in the abstract) is not supported by your data since you have “only” assessed the cultivable fraction of the soil microbiota, known to present only 2-10% of the overall microbiota!</p>	<p>The Editor is right but, although the percentage of microorganisms considered is low in soils, they represent the active part of the soil microbial community. They are involved in the ongoing processes and, therefore, all processes should be related to the population of active microorganisms driving biogeochemical elements cycling in soil.</p>
<p>References: Besides the papers by De Mastro et al. (2019), most of the cited literature is outdated; please make an effort in up-dating the</p>	<p>The references have been updated, according to the Editor suggestion.</p>



UNIVERSITÀ
DEGLI STUDI DI BARI
ALDO MORO

Dipartimento di Scienze del Suolo, della
Pianta e degli Alimenti - Di.S.S.P.A.

reference section and implementing the discussion of your findings with most recent ones.	
---	--

I look forward to hearing from you about this matter at your nearest convenience.

With my best regards

Sincerely yours

Gennaro Brunetti

Corresponding Author

Dipartimento di Scienze del Suolo, della Pianta e degli Alimenti

Università degli Studi di Bari "Aldo Moro"

Via Amendola, 165/A - 70126 Bari (Italy)

- Soil cultivable microorganisms are more abundant after faba-bean
- Minimum tillage results in the highest population of soil cultivable microorganisms
- Phosphorous fertilization has a negative effect on yeasts population after faba bean
- Soil cultivable microorganisms population decreases with soil depth

1 **Soil cultivable microorganisms as affected by different soil managements in a two years**
2 **wheat-faba bean rotation**

3

4 De Mastro Francesco¹, Traversa Andreina¹, Brunetti Gennaro^{1*}, Debiase Giambattista², Coccozza
5 Claudio¹, Nigro Franco¹

6

7 ¹ Dipartimento di Scienze del Suolo, della Pianta e degli Alimenti, Università degli Studi di Bari,
8 Via Amendola, 165/A, 70126 Bari, Italy

9 ² Council for Agricultural Research and Economics – Research Centre for Viticulture and Enology,
10 Via Casamassima 148, 70010 Turi (BA), Italy

11

12 **ABSTRACT**

13 Agricultural practices greatly influence soil chemical and microbiological parameters, which affect
14 the soil fertility. The aim of the study was to investigate the effects of different tillage (conventional
15 (CT), minimum (MT) and no tillage (NT)), fertilization (fertilization versus no fertilization), soil
16 depth (0-30, 30-60, and 60-90 cm) and crops (wheat versus faba bean) on the abundance of selected
17 microorganisms. Positive and significant correlations were found between soil cultivable
18 microorganisms (SCM) and both the total cultivable bacteria (TCB) and total fungi (TF) suggesting
19 a predominance of those microorganisms in the microbial community composition, compared to the
20 total yeasts (TY). The SCM were positively correlated to the content of soil organic carbon, total
21 nitrogen and available phosphorus. The minimum tillage increased significantly the microbial
22 populations, representing a good compromise between soil aeration and available nutrients as well
23 as the faba bean. In particular, the unfertilized legume resulted in a higher TY with respect to the
24 fertilized one, meaning that somehow those microorganisms lose their low ecological competition
25 in presence of inorganic phosphorus. Finally, the differences among the three soil depth were
26 ascribed mainly to the chemical parameters and, secondarily, to the microbiological ones.

* Corresponding Author

27 **Keywords:** soil cultivable bacteria, total yeasts, total fungi, tillage, fertilization, PCA

28

29 **1 INTRODUCTION**

30 Agricultural practices influence greatly the soil chemical properties and the microbial
31 population, both playing a fundamental role in soil fertility. Some polysaccharides and proteins (i.e.,
32 glomalin, mucilages and hydrophobins) produced by bacteria and fungi can affect the soil structure
33 through the formation of stable soil aggregates (Rashid et al., 2016), while the composition and
34 abundance of the microbial community are influenced by chemical parameters such as pH, organic
35 carbon (OC), total nitrogen (TN) and available phosphorus (P_{ava}) (Banning et al., 2011). Soil depth
36 influences the microbial community due to the reduction of oxygen concentration and quantity and
37 quality of nutrients from the upper to the lower layers, although the soil moisture and temperature
38 become less variable with depth and can be more suitable for microorganisms (Fierer et al., 2003).

39 Previous studies have demonstrated that the soil management based on no tillage (NT) and crop
40 residues incorporation enhances the microbial population, while frequent and deep tillage
41 (conventional tillage, CT) increases the microbial activity (Balota et al., 2004) but not its biomass
42 (Das et al., 2014). The CT enhances also the depletion of living and not living soil organic matter
43 (SOM) through the physical disruption of aggregates and the higher oxygenation that increase its
44 mineralization (Alam et al., 2014). In contrast, minimum (MT) or NT (conservation tillage) reduce
45 the physical disturbance, increase the soil moisture and alter the distribution of SOM in the profile,
46 avoiding an excess of oxygen in soil (Zhang et al., 2015). Fertilization influences the microbial
47 community too: Fierer et al. (2012) found a shift of microbial composition from oligotrophic to
48 copiotrophic microorganisms when a N fertilization is adopted. Finally, different plant species and
49 their root exudates can considerably affect the microbial community (Steinauer et al., 2016), also by
50 means of their association with several symbionts (Aschi et al., 2017).

51 The aim of this study was to investigate the impact of different soil managements (fertilized vs
52 unfertilized plots; CT, MT or NT) on selected soil microorganisms isolated from three soil layers
53 during a 2-year crop rotation of faba bean–wheat.

54

55 **2 MATERIALS AND METHODS**

56 **2.1 Field trials and soil sampling**

57 Details about the experimental site, crop rotation and tillage practices can be found in De Mastro
58 et al. (2019 a), while the fertilizations adopted and the soil chemical characterization are reported in
59 De Mastro et al. (2019 b). The treatments were: i) NT and no fertilization; ii) NT and crops
60 fertilization; iii) MT and no fertilization; (iv) MT and crops fertilization; (v) CT and no fertilization;
61 (vi) CT and crops fertilization, in a split-block experimental design with three replications. At the
62 end of each crop cycle, the aerial residues were removed from the experimental plots. After a
63 decade of the aforementioned managements, soil samples were taken at the end of each crop cycle
64 from each elementary plot at three different depths (0-30, 30-60 and 60-90 cm).

65

66 **2.2 Soil cultivable microorganisms**

67 The population of the soil cultivable microorganisms (SCM: total fungi (TF), total yeasts (TY)
68 and total cultivable bacteria (TCB)) was determined suspending 10 g of each soil sample in 90 mL
69 of sterile phosphate buffer (0.1 M, pH 6.8) and shaking vigorously at 270 rpm for 1h. Then, 100 μ L
70 from several 10-fold serial dilutions (10^{-1} - 10^{-6}) of each sample were spread onto 5 plates of two
71 nutrient yeast dextrose agar substrates, one amended with 150 mg L⁻¹ of cycloheximide to favor the
72 growth of bacteria, and the second amended with ampicillin 250 mg L⁻¹ and streptomycin sulfate
73 250 mg L⁻¹ for fungi and yeasts detection. Seeded plates were incubated in the dark, at 24 °C, and
74 colonies of TF, TY and TCB were counted after 4-5 days, 6-7 days and 2-3 days incubation,
75 respectively, and expressed as log (CFU+1) g⁻¹ of dry soil (CFU=Colony Forming Unit).

76

77 2.3 Statistical analysis

78 The effects of different tillage and fertilization management were studied for each year. All data
79 were analyzed by STATGRAPHICS® Centurion XVI software package. Specifically, after testing
80 their normal distribution by Shapiro-Wilk's test together with their homoscedasticity by means of
81 the Levene test, it was performed the Analysis of Variance (ANOVA) followed by a Tukey HSD or
82 *t* test. Correlation matrix was achieved. Principal component analysis (PCA) was performed using
83 PAST: Paleontological Statistics, version 1.34, software in order to summarize the variability
84 measured through the variables considered.

85

86 **3 RESULTS AND DISCUSSION**

87 Positive and significant correlations were found between SCM and both TCB and TF meaning
88 that bacteria and fungi predominated among the microorganisms studied (Table 1). The SCM, TF
89 and TCB were positively correlated to the content of soil OC, TN and P_{ava} since these elements
90 represent microbial nutrients. The P_{ava} appeared positively correlated to OC and TN contents,
91 because the higher the content of OC and TN available for microorganisms, the greater their
92 activity, with the consequent increase of P_{ava} (Guppy et al., 2005).

93 Total fungi, TCB and SCM were higher after faba bean in comparison to wheat (Table 2)
94 possibly because of the greater enzymatic activity and metabolic diversity induced by legumes with
95 respect to cereal cultivation (Siczek et al., 2018). No tillage reduced all microbial populations
96 studied, while they showed the highest values after MT (Table 2). This result could be related to the
97 higher dissolved organic carbon and total dissolved nitrogen content found in MT (23.6 and 2.5 mg
98 L^{-1} , respectively) with respect to NT and CT reported by De Mastro et al. (2019 b), since those
99 parameters are more responsible for microbial abundance with respect to the total organic carbon
100 and nitrogen contents in soils (Hill et al., 2008). In accordance to results of Li et al. (2015), the
101 microbial community was positively affected by fertilization due to the greater availability of

102 nutrients but, in the present study, TY showed an opposite trend (Table 2) possibly because of their
103 lower competitiveness for nutrients and the predation by bacteria (Botha, 2011). Finally, all microbial
104 populations decreased with soil depth, but differently: TCB decreased only about 3% from the
105 upper layer to the lower one, demonstrating a major adaptability of bacteria, while TF and TY
106 decreased about 35 and 38%, respectively. That was possibly due to the lower quantity and
107 availability of nutrients with depth, as well as to a reduction of oxygen (Fierer et al., 2003).

108 The detailed effects of each crop on chemical and microbiological soil parameters are presented
109 in Table 3. In this context, the fertilized parcels were not considered for avoiding the interferences
110 of the two different fertilization (De Mastro et al., 2019 b). The faba bean confirmed its positive
111 effects on all chemical and microbiological parameters: in particular, the TY population was greater
112 after faba bean in comparison to wheat (Table 3), in contrast to what found when the statistical
113 analysis involved also the fertilized treatments (Table 2). Possibly, the legume fertilization, based
114 on P fertilizer (De Mastro et al., 2019 b), significantly inhibited the development of TY since their
115 phytase expression is usually induced by phosphate deficiency (Menezes-Blackburn et al., 2013).

116 The PCA analysis related to the soil depth isolated eight principal components, but only the first
117 three were considered because they explained the 78.7% of the variability. Along the PC1 (Figure
118 1A) there was a complete segregation between the points belonging to the 0-30 cm layer (red
119 points) and those belonging to the 60-90 cm layer (purple points), while the points attributable to
120 the 30-60 cm layer (blue points) partially overlapped the other two clusters. This distribution, that
121 explained 48% of variance, was supported mainly by chemical variables, as OC and TN contents
122 (loads 0.4395 and 0.4297, respectively). Along the PC2 there was a partial differentiation between
123 the points attributable to the upper and the lower layers, and this distribution (19% of variance) was
124 more supported by microbiological variables, as TCB and SCM (loads 0.5366 and 0.4976,
125 respectively). In Figure 1B, along the PC3 most of the points were in the third and fourth quadrant,
126 and this distribution (11.7% of variance) was mainly supported by the TY variable (load 0.9270)
127 explaining how the concentration of these microorganisms along the soil profile was not

128 particularly influenced by the different depths, but differed in a point-like manner from the average
129 values recorded in the entire layer 0-90 cm.

130 In conclusion, the results of the present study demonstrate that the population of TF, TY, TCB
131 and SCM are sensitive to different soil management, even if they represent only 2% of the soil
132 microorganisms (Blagodatskaya and Kuzyakov, 2013). Minimum tillage and faba bean result in the
133 highest microbial population possibly because the former represents a good compromise between
134 soil aeration and nutrients availability, while the latter creates better conditions for the development
135 of soil microorganisms. Among the microorganisms studied, yeasts do not enhance their population
136 with the fertilization apparently because they lose competition for nutrients with the other
137 microorganisms in relatively richer environments. Finally, the chemical variables have a greater
138 influence on the variability of soil with depth than microbiological variables.

139

140 **4 REFERENCES**

- 141 Alam, M.K., Islam, M.M., Salahin, N., Hasanuzzaman, M, 2014. Effect of tillage practices on soil
142 properties and crop productivity in Wheat-Mungbean-Rice cropping system under subtropical
143 climatic conditions. *Sci. World J.*, 1-10. <http://dx.doi.org/10.1155/2014/437283>.
- 144 Aschi, A., Aubert, M., Riah-Anglet, W., Néliu, S., Dubois, C., Akpa-Vinceslas, M., Trinsoutrot-
145 Gattin, I., 2017. Introduction of Faba bean in crop rotation: Impacts on soil chemical and
146 biological characteristics. *Appl. Soil Ecol.* 120, 219–228.
147 <http://dx.doi.org/10.1016/j.apsoil.2017.08.003>.
- 148 Balota, E.L., Colozzi Filho, A., Andrade, D.S., Dick, R.P., 2004. Long-term tillage and crop
149 rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. *Soil Till.*
150 *Res.* 77, 137–145. <https://doi.org/10.1016/j.still.2003.12.003>.
- 151 Banning, N.C., Gleeson, D.B., Grigg, A.H., Grant, C.D., Andersen, G.L., Brodie, E.L., Murphy,
152 D.V., 2011. Soil microbial community successional patterns during forest ecosystem restoration.
153 *Appl. Environ. Microb.* 77, 6158–6164. <https://doi.org/10.1128/AEM.00764-11>.

154 Blagodatskaya, E., Kuzyakov, Y., 2013. Active microorganisms in soil: Critical review of
155 estimation criteria and approaches. *Soil Biol. Biochem.* 67, 192–211.
156 <http://dx.doi.org/10.1016/j.soilbio.2013.08.024>.

157 Botha, A., 2011. The importance and ecology of yeasts in soil. *Soil Biol. Biochem.* 43, 1–8.
158 [10.1016/j.soilbio.2010.10.001](http://dx.doi.org/10.1016/j.soilbio.2010.10.001).

159 Das, A., Lal, R., Patel, D., Idapuganti, R., Layek, J., Ngachan, S., Ghosh, P., Bordoloi, J., Kumar,
160 M., 2014. Effects of tillage and biomass on soil quality and productivity of lowland rice
161 cultivation by small scale farmers in North Eastern India. *Soil Till. Res.*, 143, 50–58.
162 <https://doi.org/10.1016/j.still.2014.05.012>.

163 De Mastro, F., Coccozza, C., Traversa, A., Savy, D., Abdelrahman, H.M., Brunetti, G., 2019 a.
164 Influence of crop rotation, tillage and fertilization on chemical and spectroscopic characteristics
165 of humic acids. *Plos One*. <https://doi.org/10.1371/journal.pone.0219099>.

166 De Mastro, F., Brunetti, G., Traversa, A., Coccozza, C., 2019 b. Effect of crop rotation, fertilization
167 and tillage on main soil properties and its water extractable organic matter. *Soil Res.*
168 <https://doi.org/10.1071/SR18297>.

169 Fierer, N., Lef, J.W., Adams, B.J., Nielsen, U.N., Bates, S. T., Lauber, C.L., Owense, S., Gilberte,
170 J.A., Wall D.H., Caporaso, J.G., 2012. Cross- biome metagenomic analyses of soil microbial
171 communities and their functional attributes. *Proc. Nat. Acad. Sci.* 109, 21390–21395.
172 <https://doi.org/10.1073/pnas.1215210110>.

173 Fierer, N., Schimel, J.P., Holden, P.A., 2003. Variations in microbial community composition
174 through two soil depth profiles. *Soil Biol. Biochem.* 35, 167–176. [https://doi.org/10.1016/S0038-](https://doi.org/10.1016/S0038-0717(02)00251-1)
175 [0717\(02\)00251-1](https://doi.org/10.1016/S0038-0717(02)00251-1).

176 Guppy, C.N., Menzies, N.W., Moody, P.W., Blamey, F.P.C., 2005. Competitive sorption reactions
177 between phosphorus and organic matter in soil: a review. *Aust. J. Soil Res.* 43, 189–202.
178 <https://doi.org/10.1071/SR04049>.

- 179 Hill, P.W., Farrar, J.F., Jones, D.L., 2008. Decoupling of microbial glucose uptake and
180 mineralization in soil. *Soil Biol. Biochem.* 40, 616–624.
181 <https://doi.org/10.1016/j.soilbio.2007.09.008>.
- 182 Li, J., Li, Y.-t., Yang, X.-d., Zhang, J.-j., Lin, Z.-a., Zhao B.-q., 2015. Microbial community
183 structure and functional metabolic diversity are associated with organic carbon availability in an
184 agricultural soil. *Journal of Integr. Agr.* 14, 2500–2511. [https://doi.org/10.1016/S2095-](https://doi.org/10.1016/S2095-3119(15)61229-1)
185 [3119\(15\)61229-1](https://doi.org/10.1016/S2095-3119(15)61229-1).
- 186 Menezes-Blackburn, D., Jorquera, M.A., Greiner, R., Gianfreda, L., de la Luz Mora M., 2013.
187 Phytases and Phytase-Labile Organic Phosphorus in Manures and Soils. *Crit. Rev. Env. Sci. Tec.*
188 43:9, 916-954. <https://doi.org/10.1080/10643389.2011.627019>.
- 189 Rashid, M.I., Mujawar, L.H., Shahzad, T., Almeelbi, T., Ismail, I.M.I., Oves, M., 2016. Bacteria
190 and fungi can contribute to nutrients bioavailability and aggregate formation in degraded soils.
191 *Microbiol. Res.* 183, 26–41. <https://doi.org/10.1016/j.micres.2015.11.007>.
- 192 Siczek, A., Fraç M., Kalembasa S., Kalembasa D., 2018. Soil microbial activity of faba bean (*Vicia*
193 *faba* L.) and wheat (*Triticum aestivum* L.) rhizosphere during growing season. *Appl. soil Ecol.*
194 130, 34-39. <https://doi.org/10.1016/j.apsoil.2018.05.012>.
- 195 Steinauer, K., Chatzinotas, A., Eisenhauer, N., 2016. Root exudate cocktails: the link between plant
196 diversity and soil microorganisms? *Ecol. Evol.* 6, 7387–7396. <https://doi.org/10.1002/ece3.2454>.
- 197 Zhang, S., Li, Q., Lü, Y., Sun, X., Jia, S., Zhang, X., Liang, W., 2015. Conservation tillage
198 positively influences the microflora and microfauna in the black soil of Northeast China. *Soil*
199 *Till. Res.* 149, 46–52. <https://doi.org/10.1016/j.still.2015.01.001>.

200

201 **FIGURE CAPTIONS**

202 **Figure 1.** Scatter plot of the first three principal components for soil depth arranged as PC1/PC2
203 (1A) and PC1/PC3 (1B).

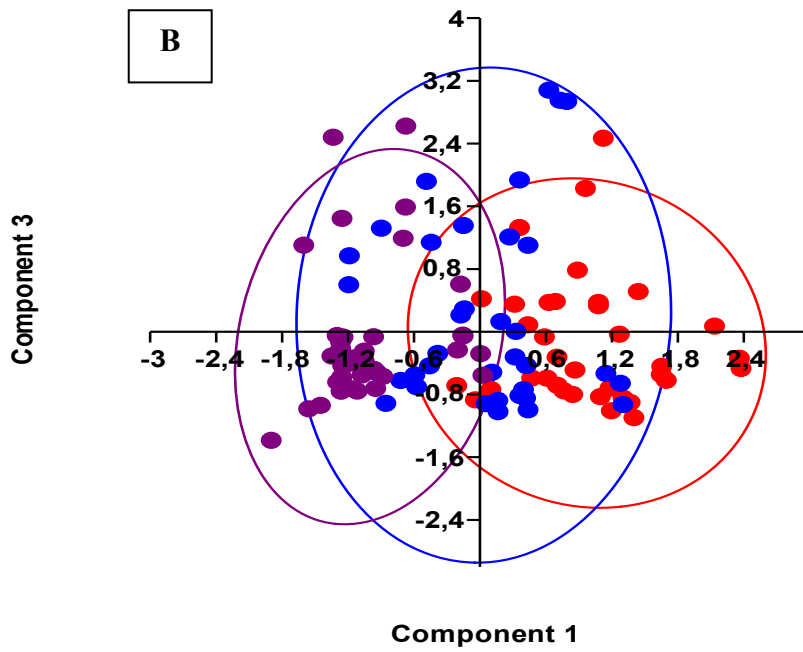
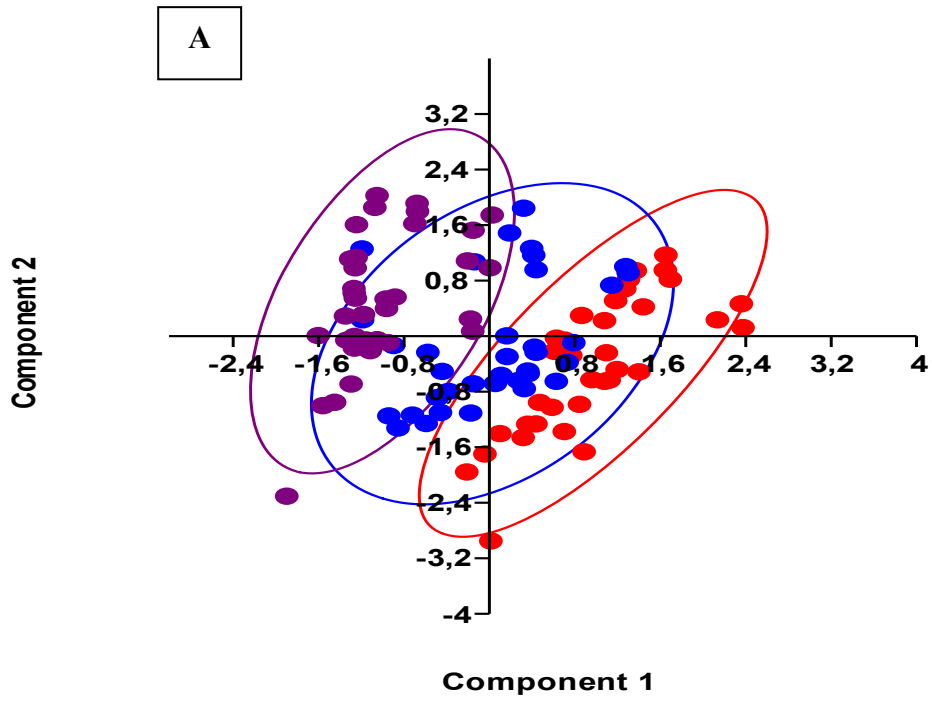


Figure 1

Table 1. Pearson's moment correlation among population level of different microorganisms and chemical soil properties.

	TF	TY	TCB	SCM	OC	TN	P _{ava}
TF		-0.1339 n.s.	0.3554 ***	0.5194 ***	0.4349 ***	0.4171 ***	0.4147 ***
TY			-0.0647 n.s.	0.0736 n.s.	0.0448 n.s.	0.0450 n.s.	-0.0332 n.s.
TCB				0.8698 ***	0.2958 **	0.3758 ***	0.5146 ***
SCM					0.3787 ***	0.4505 ***	0.5763 ***
OC						0.9427 ***	0.6441 ***
TN							0.6431 ***
P _{ava}							

TF: total fungi; TY: total yeasts; TCB: total cultivable bacteria; SCM; soil cultivable microorganisms; OC: organic carbon; TN: total nitrogen; P_{ava}: available phosphorus. n.s.: not significant; significant at *P ≤ 0.05, **P ≤ 0.01 and ***P ≤ 0.001, respectively.

Table 2. Effect of crop, tillage, fertilization and soil depth on total fungi (TF), total yeasts (TY), total cultivable bacteria (TCB) and soil cultivable microorganisms (SCM)

	TF	TY	TCB	SCM
	[Log₁₀(UFC+1)] g⁻¹			
Crop				
Fababean (2015)	3.62 a	0.85 a	6.30 a	6.41 a
Wheat (2016)	1.71 b	1.00 a	5.78 b	5.89 b
Tillage				
No tillage	1.92 b	0.80 b	5.89 b	5.99 c
Minimum tillage	3.01 a	1.61 a	6.14 a	6.29 a
Conventional tillage	3.08 a	0.37 b	6.10 a	6.16 b
Fertilization				
Yes	3.10 a	0.69 b	6.23 a	6.31 a
No	2.23 b	1.16 a	5.85 b	5.99 b
Soil Depth				
0-30 cm	3.38 a	0.90 ab	6.14 a	6.26 a
30-60 cm	2.44 b	1.32 a	6.03 ab	6.12 b
60-90 cm	2.19 b	0.56 b	5.96 b	6.06 b

The values in each column followed by a different letter are significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 3. Effects of the crops on the investigated variables.

	Faba bean (2015)	Wheat (2016)
Total fungi	2.78 a	1.69 b
Total yeasts	1.71 a	0.63 b
Total cultivable bacteria	6.16 a	5.55 b
Soil cultivable microorganisms	6.26 a	5.72 b
Organic carbon	12.76 a	10.40 b
Total nitrogen	1.72 a	1.26 b
P_{ava}	2.64 a	0.79 b

The values in each column followed by a different letter are significantly different according to Tukey's HSD test ($P \leq 0.05$).