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Effect of olive mill wastewater spreading on the rhizosphere potassium and the growth of an intercropping system triticale-forage pea

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ABSTRACT/RESUME

Abstract: *In order of olive mill wastewater (OMW) valorization, a greenhouse study was conducted to investigate the OMW effects on potassium content in the rhizosphere and on the growth of an intercropping system triticale-forage pea. The used soil is a calcaric cambisol with a silt-clay texture. Despite high EC* ($10.8\ dS.m^{-1}$) *of OMW, bulk and rhizospheric soil of two species in monocropping and intercropping systems did not show a salinization after 45 days of cropping. The bulk soil and rhizosphere of monocropping and intercropping systems has been enriched in* KNH_4^+ *after OMW spreading. However, intercropping induced a higher* KNH_4^+*depletion in the rhizosphere compared to monocropping systems. No negative effects of OMW application were observed on the seeds emergence and the growth of two species. In general, the root system of cereal has more benefit from intercropping and OMW application. The valorization of OMW by spreading on soil of mixed forage crop would be a sustainable agro-ecological solution to the environmental nuisances caused by the uncontrolled release of OMW.*

I. Introduction

Agriculture is facing a major challenge that is to feed an ever-growing population with still low arable land associated to a rarefaction of fertilizers.

Olive oil industry is the most important sector in the Mediterranean countries [1]. Every year, worldwide olive oil production produces in a short period of time (late autumn-winter) vast quantities of olive mill wastewater [2]. The important volumes of olive wastewater (OMW) generated, their acid pH, their high concentration in organic matters and phenols makes this material hard to purify, and therefore OMW constitutes a serious environmental and economic problem [1]. On the other hand, OMW are rich in potassium and nitrogen. Spreading OMW on soil or composting them may be a solution to this problem [3]. The agronomical valorization of the OMW is one of the ways to restore soil nutrients [2] like potassium. Potassium is an essential nutrient for the plant, it plays an important role in water saving and in the crop resistance against to predators, its role is vital under the Mediterranean climate [4]. Potassium is provided to the crops with inputs of chemical fertilizer which the cost is often prohibitive for farmers. The irrigation of the cultures with OMW rich in potassium turned out to be a good alternative to the application of these fertilizers and to the uncontrolled release of these OMW into the environment. While most natural ecosystems are constituted of a complex assembling of plant species, agro systems are characterized by extremely simple plants communities (more often one and same variety of species in the field) [5]. A better use of soil nutrients is generally expected from the ecosystems, as is the case for intercropping and agroforestry [6]. Improved acquisition of resources has been repeatedly observed in intercropping systems [6,7]and may imply several rhizosphere mechanisms [5]. Thus, enhancing crop diversity is increasingly recognized as a crucial lever for sustainable agro-ecological development [8]. Intercropping has been used since the dawn of the agriculture of humanity. It is a farming practice involving the simultaneous culture of two or more species in the same area, growing together and coexisting for a time [9]. Flexibility, maximization of profit, minimization of risk, soil conservation and soil fertility improvement, greater land use efficiency per unit land area are some principal benefits of intercropping for smallholder farmers [10]. Thus, the forages are frequently cultivated by intercropping a fodder cereal with a legume. Several studies have reported positive effects for the application of OMW on soil of annual crops [11, 1], and of olive trees [12]. Consequently, OMW could be considered as a useful and low cost fertilizer [12]. In the context of rarefaction of land resources and fertilizers, the aim of this work was to investigate the impact of OMW spreading on the rhizosphere of triticale -forage pea intercropping system. Therefore, two hypotheses have been tested: i) K in the rhizosphere of intercropped versus monocropped plants species irrigated with OMW is modified. ii) Growth of forage of cereal and legume is improved when these crops are conducted in intercropping system and irrigated with OMW.

II. Materials and methods

II.1. Experimental design

A factorial greenhouse experiment at randomized complete block design with four repetitions was carried out by growing cereal triticale and leguminous forage pea as a monocropping and intercropping at two level (0 and 50 m ^{3}ha^{1-}) OMW spreading. Triticale (x *Tritico secale rimpaui Wittm*) is an annual plant of the Poaceae family, a cross between wheat and rye. Forage pea *(Pisum sativum)* is an annual plant of the Fabaceae family widely cultivated for its seeds, used as livestock feed. Plant material obtained from the Institut Technique des Grandes Cultures (ITGC).

II.2. OMW analysis

The original OMW used in this study was obtained from an olive oil mill located in Djamaa Saharidj, North Algeria. The OMW samples were analyzed for pH, electric conductivity (EC), K concentration and organic matter.

II.3. Soil

Top soil from the plough layer (0-20 cm depth) was collected from the experimental fields of the Agricultural Institute Specialized in Mountain Agriculture (ITMAS) in Northern Algeria (36° 44′ 48.3″N; 4° 01′ 09.11″E). After collection, the soil was sieved to < 5 mm. Triticale and forage pea grown in monocropping and intercropping system in 5 l plastic pots (height=16 cm; diameter =22 cm; mass of soil=5kg). A total number of 24 pots were used (comprising 2 monocultures + 1 intercropped treatment, 2 OMW levels and 4 replicates). At a rate of 5 kg per pot, 120 kg of soil was needed to conduct the experiment. After sieving, 200 kg of soil was separated into two fractions: the first (100 kg) was left in its original state and the second one was irrigated with 19 l of OMW. The OMW applied per pot (190 ml) was calculated on the basis: a pot area of 0.038 m^{2}for and OMW spreading of 50 m^3. ha^{-1}. During two months, the two soil fractions were irrigated with water and returned twice to allow the decomposition of phytotoxic phenols supplied by OMW. Indeed, in irrigation experiments using OMW [13, 14] concluded that if OMW is applied to the soil 60 days before seeding, no detrimental effects are observed on the newly grown seeds. After two months, 24 pots were filled with two soil fractions (irrigated and non-irrigated with OMW). In order to characterize and classify the soil, a soil profile was described and the different horizons were sampled.

II.4. Bulk and rhizospheric soils sampling

Each plastic pot was delicately turned over. The root systems were gently shaken for 30 seconds. The collected soil, not adhering to the roots was considered as bulk soil. Rhizosphere was considered as aggregates (1-3mm) still adhering to the roots. It was collected by brushing the roots. For the intercropped plants, the roots of triticale and forage pea were separated and their respective rhizosphere was sampled separately. The same bulk soil was shared by the two intercropped species. All soil samples were air-dried before being analyzed.

II.5. Plant growth

Seed density for triticale and forage pea were 210 and 80 viable seeds per m^{2}in the monocropping system. Then, the number of plants of triticale and forage pea was eight and two in monocropping treatment separately. The triticale: forage pea ratio was 4:1 in the intercropping treatment. Triticale and forage pea were grown during 45 days. They were grown under natural light conditions.

II.6. Soil analysis

Soil characteristics were determined according to standard methods proposed by Jackson [15]. Particle size distribution was measured according to the Robinson pipette method (organic matter oxidation by H_2O_2, shaking in a sodium hexametaphosphate solution). Soil pH and electric conductivity (EC) were measured in a 1:5 soil distilled water suspension. $CaCO_3$was determined on bulk soil using the HCl 1M volumetric method. Exchangeable-K was extracted by shaking soil samples in an ammonium acetate 1M solution at pH 7 (soil/solution ratio of 1/10) during 1h. Non-exchangeable K (Kne) was determined as follows: 25 mL of boiling 1M HNO_3 was added to 2.5 g of soil. The suspension was boiled for 10 min and then filtered. Potassium concentration in the solution was determined by flame spectrometry. The non-exchangeable K corresponded to the HNO_3 extracted K minus the NH_4^+ -extracted K. The suspension was then filtrated and K^+ concentration in the solution was determined by flame spectrometry.

II.7. Harvest plants

Plants were harvested after 45 days after-sowing and washed with tap water. Triticale and forage pea were divided into shoot and root part of the plants. Then, total root longer plant of the two species was measured.The dry weights of shoot and root biomass were measured after drying at 75°C for 72 h.

II.8. Statistical analysis

Soil data and plant growth were analyzed by Fisher's analysis of variance technique (ANOVA). Significant difference between means was separated by LSD (least significant difference) at the 0.05 probability level (STAT BOX (v.6.30) program).

III. Results

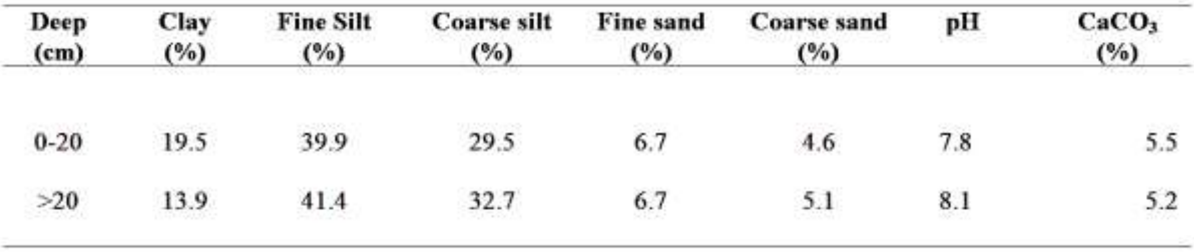
III.1. Characteristics of the OMW used for irrigation

The main characteristics of the OMW were pH 4.7; electrical conductivity (EC) 10.7 dS m^{-1}; K 1508 mg l^{-1}; organic matter 56%.

III.2. Physical and chemical soil characteristics

It is a deep soil with a silt-clay texture, alkaline pH; moderately calcaric (table 1). The WRB (2006) classified this soil as a calcaric cambisol which had developed on an alluvial calcareous parent material.

Table 1. *Some chemical and physical soil characteristics.*

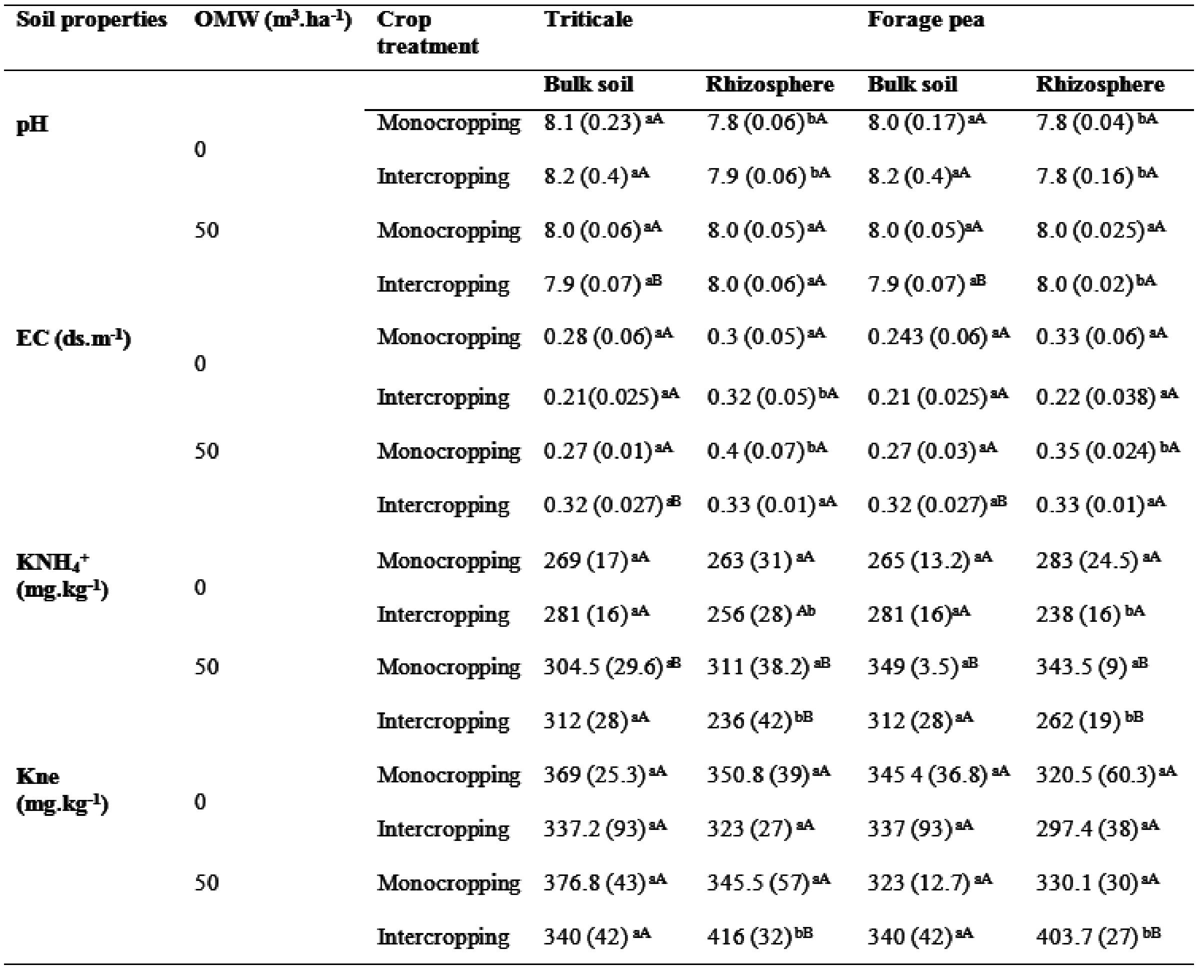


Deep (cm)	Clay (%)	Fine Silt (%)	Coarse silt (%)	Fine sand (%)	Coarse sand (%)	pH	$CaCO_3$ (%)
0-20	19.5	39.9	29.5	6.7	4.6	7.8	5.5
>20	13.9	41.4	32.7	6.7	5.1	8.1	5.2

III.3. Effect of OMW irrigation

The chemical properties of bulk soil and rhizosphere of monocropping and intercropping system with and without OMW application were presented in table 2. The soil pH varied from 7.8 to 8.2 and was alkaline. The values of EC ranged from 0.21 to 0.4 dS m^{-1}). These values are still under the norms indicated for a salty soil (0.6 dS m^{-1}). The KNH_4^+content varied from 236 to 349.7 $mgkg^{-1}$ of soil. The Kne concentration ranged from 297.4 to 416 mg $kg^{-1}$of soil. The application of OMW to bulk soil decreased significantly the pH. On the other hand, the decrease in pH was limited. Consequently, it remained alkaline. As it can be seen in table 2, OMW spreading also caused a significant increase in EC values in intercropping bulk soil. In general, application of OMW increased KNH_4^+ significantly in bulk soil and rhizosphere. OMW treatment showed a significant effect only in the rhizospheric Kne of intercropping treatment. The rhizospheric Kne with OMW spreading was significantly higher than Kne without it.

Table 2. *Values of pH, electric conductivity (EC), available potassium (KNH_4^+) and non-exchangeable potassium (Kne) of bulk (B) and rhizospheric (Rh) soils of triticale and forage pea in the case of monocropping and intercroping with (50 m^3. ha^{-1}) and without (0 m^3. ha^{-1}) OMW. Letters a and b, A and B correspond to a significant effect of the roots activity, irrigation with OMW respectively. Different letters indicate that the differences are significant at 95% (n=4).*



Soil properties	OMW ($m^3.ha^{-1}$)	Crop treatment	Triticale		Forage pea	
			Bulk soil	Rhizosphere	Bulk soil	Rhizosphere
pH	0	Monocropping	8.1 (0.23) ^{aA}	7.8 (0.06) ^{bA}	8.0 (0.17) ^{aA}	7.8 (0.04) ^{bA}
		Intercropping	8.2 (0.4) ^{aA}	7.9 (0.06) ^{bA}	8.2 (0.4) ^{aA}	7.8 (0.16) ^{bA}
	50	Monocropping	8.0 (0.06) ^{aA}	8.0 (0.05) ^{aA}	8.0 (0.05) ^{aA}	8.0 (0.025) ^{aA}
		Intercropping	7.9 (0.07) ^{aB}	8.0 (0.06) ^{aA}	7.9 (0.07) ^{aB}	8.0 (0.02) ^{bA}
EC ($ds.m^{-1}$)	0	Monocropping	0.28 (0.06) ^{aA}	0.3 (0.05) ^{aA}	0.243 (0.06) ^{aA}	0.33 (0.06) ^{aA}
		Intercropping	0.21(0.025) ^{aA}	0.32 (0.05) ^{bA}	0.21 (0.025) ^{aA}	0.22 (0.038) ^{aA}
	50	Monocropping	0.27 (0.01) ^{aA}	0.4 (0.07) ^{bA}	0.27 (0.03) ^{aA}	0.35 (0.024) ^{bA}
		Intercropping	0.32 (0.027) ^{aB}	0.33 (0.01) ^{aA}	0.32 (0.027) ^{aB}	0.33 (0.01) ^{aA}
KNH_4^+ ($mg.kg^{-1}$)	0	Monocropping	269 (17) ^{aA}	263 (31) ^{aA}	265 (13.2) ^{aA}	283 (24.5) ^{aA}
		Intercropping	281 (16) ^{aA}	256 (28) ^{Ab}	281 (16) ^{aA}	238 (16) ^{bA}
	50	Monocropping	304.5 (29.6) ^{aB}	311 (38.2) ^{aB}	349 (3.5) ^{aB}	343.5 (9) ^{aB}
		Intercropping	312 (28) ^{aA}	236 (42) ^{bB}	312 (28) ^{aA}	262 (19) ^{bB}
Kne ($mg.kg^{-1}$)	0	Monocropping	369 (25.3) ^{aA}	350.8 (39) ^{aA}	345 4 (36.8) ^{aA}	320.5 (60.3) ^{aA}
		Intercropping	337.2 (93) ^{aA}	323 (27) ^{aA}	337 (93) ^{aA}	297.4 (38) ^{aA}
	50	Monocropping	376.8 (43) ^{aA}	345.5 (57) ^{aA}	323 (12.7) ^{aA}	330.1 (30) ^{aA}
		Intercropping	340 (42) ^{aA}	416 (32) ^{bB}	340 (42) ^{aA}	403.7 (27) ^{bB}

III.4. Root activity effect

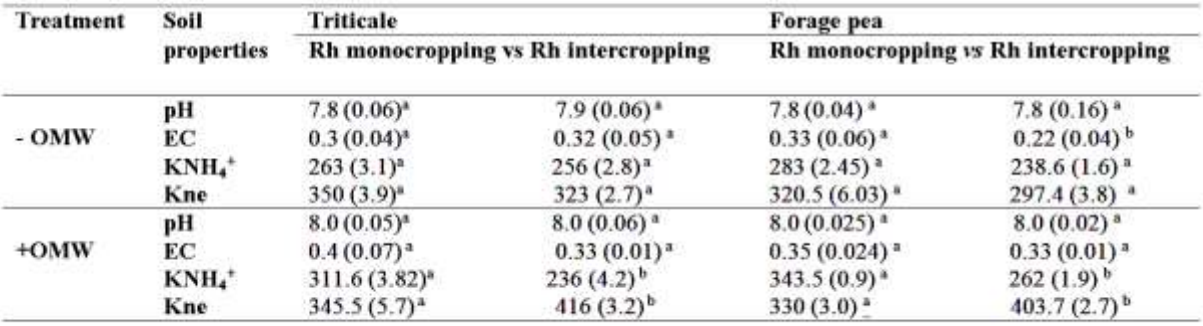
The effect of root activity on chemical properties of bulk soil and rhizosphere of monocropping and intercropping system with and without OMW application were presented in table 2**.**

First of all, the comparison of the bulk soil with the rhizospheric soil showed that pH, KNH_4^+ significantly decreased in the rhizosphere compared to the bulk soil when combining all treatments. EC was significantly higher in the rhizosphere relative to the bulk soil when combining all treatment. Without OMW spreading, pH values of rhizosphere soil were slightly and significantly lower than that of bulk soil for monocropping and intercropping treatment. With OMW irrigation, the rhizospheric pH showed a significant decrease comparing to that of bulk soil only in the case of intercropping system. For monocropping system, without OMW spreading, rhizosphere of triticale and forage pea showed a significant decrease of pH values. Thus, the pH decrease (-0.4U of pH) in rhizospheric soil of forage pea was higher in intercropping system with OMW spreading. The general trend was for an increase of EC in the rhizosphere. As seen in Table 2, root activity significantly enhanced EC in intercropped triticale without OMW. With OMW spreading, EC increased significantly in rhizosphere of both monocropped triticale and forage pea. The concentration of KNH_4^+ in the rhizosphere of intercropped was significantly ($p \leq 0.05$) lower than KNH_4^+ in bulk soil with and without OMW spreading. It was not the case of KNH_4^+ of sole crop. For Kne in rhizosphere of monocropping and intercropping system with and without OMW spreading, no effect of root activity on Kne pool was observed, except a slight increase of Kne in rhizosphere of intercropped with OMW application.

III.5. Cropping effect

Crop system (monocropping *vs* intercropping) did not affect the pH, EC, KNH_4^+ and Kne in bulk soil with and without OMW spreading. For triticale, non-significant crop effect was observed for pH, EC, KNH_4^+ and Kne in rhizosphere (table 3) without OMW spreading. It is also the case of forage pea except for EC. Without OMW spreading, significantly decrease of EC in the rhizosphere of intercropped forage pea was found comparatively to rhizosphere of corresponding sole crop. When OMW was applied on soil crops, a significantly decrease of KNH_4^+, around 24 % was observed in intercropped rhizosphere of two species (table 3).

***Table 3**. Cropping effect (monocropping vs intercropping) on pH, EC, KNH_4^+ and Kne in rhizosphere of triticale and forage pea with and without OMW spreading. The letters a and b correspond to a significant difference among the rhizosphere of monocropping vs intercropping system of two species. Different letters indicate that the differences are significant at 95% (n=4).*

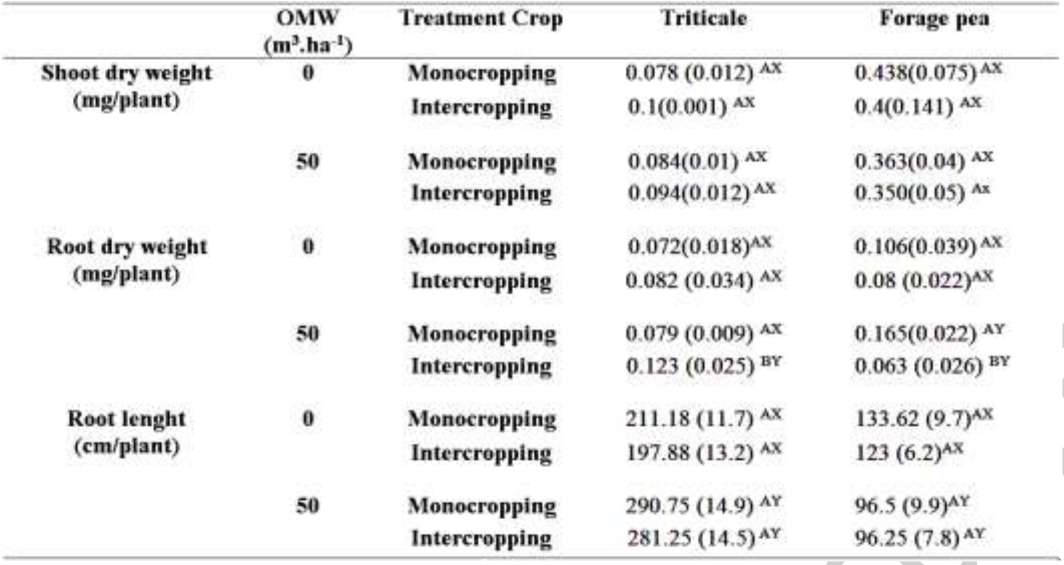


Treatment	Soil properties	Triticale		Forage pea	
		Rh monocropping vs Rh intercropping		Rh monocropping *vs* Rh intercropping	
- OMW	pH	7.8 (0.06)^a	7.9 (0.06)^a	7.8 (0.04)^a	7.8 (0.16)^a
	EC	0.3 (0.04)^a	0.32 (0.05)^a	0.33 (0.06)^a	0.22 (0.04)^b
	KNH_4^+	263 (3.1)^a	256 (2.8)^a	283 (2.45)^a	238.6 (1.6)^a
	Kne	350 (3.9)^a	323 (2.7)^a	320.5 (6.03)^a	297.4 (3.8)^a
+OMW	pH	8.0 (0.05)^a	8.0 (0.06)^a	8.0 (0.025)^a	8.0 (0.02)^a
	EC	0.4 (0.07)^a	0.33 (0.01)^a	0.35 (0.024)^a	0.33 (0.01)^a
	KNH_4^+	311.6 (3.82)^a	236 (4.2)^b	343.5 (0.9)^a	262 (1.9)^b
	Kne	345.5 (5.7)^a	416 (3.2)^b	330 (3.0)^a	403.7 (2.7)^b

III.6. Plants growth

The indicators of plant growth are presented in table 4. The seed emergence of the cereal and legume was near 100% for all treatments (crops and OMW spreading). However, seed emergence of cereal was one week before the legume's one. Shoot dry weight/plant of triticale and forage pea was not influenced by cropping or OMW application. Spreading with OMW and intercropped significantly increased root dry weight/plant of triticale when compared to those in the corresponding monoculture. OMW application significantly enhanced root dry weight/plant of monocropped forage pea compared to intercropped forage pea. Root length/plant of the two species was not influenced by cropping. However, triticale monocropped, intercropped with forage pea and irrigated with OMW exhibited longer roots than triticale growing solely. In contrast, forage pea root length was significantly lower in monocropping and intercropping system with OMW spreading compared to forage pe a cropped sole without OMW spreading.

Table 4. *Shoot dry weight/plant, dry root biomass, and root length of triticale and forage pea. Letters A and B; X and Y correspond to a significant effect of cropping and OMW irrigation respectively. Different letters indicate that the differences are significant at 95% (n=4).*



	OMW ($m^3.ha^{-1}$)	Treatment Crop	Triticale	Forage pea
Shoot dry weight (mg/plant)	**0**	**Monocropping**	0.078 (0.012) ^{AX}	0.438(0.075) ^{AX}
		Intercropping	0.1(0.001) ^{AX}	0.4(0.141) ^{AX}
	50	**Monocropping**	0.084(0.01) ^{AX}	0.363(0.04) ^{AX}
		Intercropping	0.094(0.012) ^{AX}	0.350(0.05) ^{Ax}
Root dry weight (mg/plant)	**0**	**Monocropping**	0.072(0.018)^{AX}	0.106(0.039) ^{AX}
		Intercropping	0.082 (0.034) ^{AX}	0.08 (0.022)^{AX}
	50	**Monocropping**	0.079 (0.009) ^{AX}	0.165(0.022) ^{AY}
		Intercropping	0.123 (0.025) ^{BY}	0.063 (0.026) ^{BY}
Root lenght (cm/plant)	**0**	**Monocropping**	211.18 (11.7) ^{AX}	133.62 (9.7)^{AX}
		Intercropping	197.88 (13.2) ^{AX}	123 (6.2)^{AX}
	50	**Monocropping**	290.75 (14.9) ^{AY}	96.5 (9.9)^{AY}
		Intercropping	281.25 (14.5)^{AY}	96.25 (7.8) ^{AY}

IV. Discussion

IV.1. Soil K-enrichment by OMW

OMW used in this study has low potassium concentration (1508 mg l^{-1}). The chemical composition of OMW is highly variable, which results in variable soil potassium inputs [16]. Indeed, K concentrations measured by several authors varied, for example, from 2200 to 7500 mg l^{-1} [17, 18]. This lower K concentration of the OMW used in this study was probably due to the lake of potassium fertilization of olive groves in Kabylia. Despite this, $K_{NH_4^+}$ enhanced in bulk soil and rhizosphere of legume and cereal conducted both sole, intercropped and irrigated with OMW. Compared with no OMW irrigation, only the increase of Kne rhizospheric was observed with OMW spreading. It would seem that K-fixation by clays would be higher for the rhizospheric soil compared to bulk soil. This could be attributed to the fixation of K provided by the spread effluent and the mass flow of potassium towards the rhizosphere. This significant improvement in the content soil potassium was found by Magdich et al. [19]**.** Accordingly, OMW spreading enhanced K soil fertility and reduced the need for chemicals fertilizers. According to Barbara et al. [16], the fertilizers effect of OMW should be considered when formulating a soil fertilizing plan and it also can be used as soil organic fertilizers [1]. The results showed that the application of OMW caused an increase in EC of the two soil fractions. These findings are in agreement with those reported in Magdiche et al., [19]. However, the values of the EC of two soil fractions for all treatments were below the norms for salty soil (0,6dS m^{-1} norms AFNOR). Despite the low pH (4.5) and high EC (10.8 dS m^{-1}) values of OMW, the use of OMW as a fertilizer did not induce acidification or salinization in bulk and rhizospheric soil. No effects on pH and EC of soil were observed after application of OMW [2]. In this respect, Sierra et al. [20] mentioned that the pH of soils treated by OMW at different rates (30; 180 and 360 m^3. ha^{-1}) recovered the control values after 2 months. This could also be due to the high carbonates and clay buffering effect and ammonia production resulting from the degradation of OMW organic matter.

IV.2. Rhizospheric and cropping effect

In general, root activity of triticale and forage pea for all treatments (OMW and cropping) caused a decrease in the rhizospheric pH. In addition to that, while irrigation with OMW, it caused a slight acidification in soils (only decrease of 0.2 U of bulk soil pH was measured), on the contrary, the root activity of legume and cereal when were intercropped and spreading with OMW caused a more decrease of rhizosphere pH (decrease of 0.4 U of pH was measured). This decrease of pH in the rhizosphere has already been observed for several crops by many authors: for olive tree [21, 22], legume plants [23] but also in the case of intercropping [24]. It is explained by the exudation of protons and organic compounds by the root. Legumes may take up a higher amount of cations and in the process of balancing internal charge it releases H^+ ions into the rhizosphere that results in soil acidification [25]**.** Other legumes can release a considerable amount of organic anions and lower the rhizospheric pH [26]. This decrease in pH would allow a better bioavailability of nutrients for cereal such as phosphorus and iron mainly in intercropped systems than sole culture [27]. Thus in mixed culture, plants such as cereals which do not have strong rhizosphere acidification capacity can benefit directly from nutrients solubilised by legume root exudates [28]**.** Thus, intercropping can increase phytoavailability of limiting resources and management of root/rhizosphere interactions can improve resource-use efficiency by crops [26]**.** Rhizospheric lower values of KNH_4^+ compared to their respective KNH_4^+ bulk soil were already been observed. Indeed, K-depletion in rhizosphere is already observed in pot experiments [29]. In addition, the greatest depletion of KNH_4^+ observed in the rhizosphere of intercropped crop would seem that intercropping decreased K in rhizosphere stronger than monocropping system. It could be explained by: 1) KNH_4^+-level in bulk soil of monocropping system was adequate for the needs of cereal and legume when grown as sole crops; 2) the higher K uptake by plants in the case of intercropping than in that of monocropping system. Indeed, Hauggaard-Nielsen et al., [30] indicate that in Danish and German experiments the accumulation of phosphorus (P), potassium (K) and sulphur (S) was 20%higher in intercrop than in respective sole crops. As compared to KNH_4^+, the non-exchangeable pool of K had a small contribution to K uptake by crops. Crops have preferentially taken K from the exchangeable pool rather than from the non-exchangeable pool of K. Our results clearly show that rhizosphere was modified by the OMW application and by the roots of intercropped triticale and forage pea plant.

IV.3. Vegetal growth

In general, monocropping or intercropping had no effect on dry aerial biomass and root length per plant after 45 days of cropping.

Despite phytotoxic effect of OMW spreading, no depressive effect of OMW on seed emergence and plant growth indicators were observed. This is in accordance with the results of Ros de Ursinos et al. [31].In addition, Dakhli et al.[32]indicate that the absence of a germination inhibiting effect is due to the low irrigation rate used (50 $m^3.ha^{-1}$) as well as to the sowing of the seeds 60 days after irrigation. The sowing two months after OMW irrigation allowed the degradation of the phytotoxic phenols presents in OMW. In general, after 45 days of culture, the root system seems to be more affected than the above-ground part of the crop by the application of OMW. It was the dry root biomass and root length per plant of the cereal that benefited most from the OMW application when intercropped compared to the legume. The smaller root proliferation of intercropped legume when irrigated with OMW could be explained by: 1) the environment set up by these cropping practices is sufficiently rich in nutrients for legume; 2) competition or root development shortage by associated cereal in small pots [33]**.** On the other hand, the triticale with a greater proliferation of its root system revealed by a higher root length would seem to explore the environment more intensely in search of nutrients. It is interesting to note that the OMW application was best valorized by the cereal crop whether grown in intercropping or monocropping compared to the legume.

V. Conclusion

The objective of this work was to study the impact of both OMW irrigation and cropping system on bioavailability of potassium in the rhizosphere and the growth of triticale-forage pea. OMW use as fertilizer did not induce soil salinization, and improved the potassium status of the bulk soil and rhizosphere of all crops. In general, bioavailable potassium content decreases in the rhizosphere of the monocropping and the intercropping system. However, the depletion of available potassium was more important in the rhizosphere of the cereal and legume in intercropping. Indeed, due to its high amount of K, OMW could be considered as a useful and low cost potash fertilizer. For the vegetal growth, after 45 days of sowing no depressive effect of OMW on seed emergence and plant growth indicators were observed. Root system was positively affected by OMW application. It is necessary to extend the cultivation time in order to determine more significant effects on the yields and the quality of the forage. We suggest that the OMW spreading and intercropping would be a solution for the development of sustainable food production systems, particularly in cropping systems with limited external inputs and landscapes rarefaction.

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VII. References

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