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Effects of *Trichoderma* on growth and yield of wheat and barley and its survival ability on roots and amended rock phosphate growing substrates

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Abstract

The isolates TR-B 98 (2) and TR-B 98 (3) from the phosphate mines of Morocco and the isolate *Trichoderma asperellum* were tested for their ability to survive in the soil and stimulate the growth of wheat plants (soft wheat and durum wheat) and barley on a Mamora (SM) sand-based growing medium modified with increasing concentrations of natural phosphate. *Trichoderma* isolates have shown positive effects on the germination of wheat seeds (soft and hard) and barley, on the growth and yield of plants growing on substrates containing 0%, 25% and 50% phosphate natural. However, their effect was less on plants growing on substrates containing 75 and 100% natural phosphate. They have also shown their ability to survive in different growing media with differing colonization percentages of straw fragments and roots which increases with time. However, the number of units forming *Trichoderma* colonies per gram of soil has decreased over time.

Keywords – Barley – colonization – growing substrate – growth – rock phosphate – *Trichoderma* – wheat – yield

Introduction

Cereal cultivation occupies a preponderant place in Moroccan agriculture; around 5,559,800 ha were sown during the 2016-2017 agricultural campaign more than 60% of the national useful agricultural area, with a production of 97,776,700 Qx (HCP 2019). Wheat (hard and soft) and barley are among the staple foods in Morocco. According to data from the Ministry of Agriculture, Maritime Fisheries, of Rural Development and Water and Forests, the areas cultivated with durum wheat, common wheat and barley in 2017 were 1,087,800 ha; 2,296,400 ha and 2,001,500 ha with a production of 21,990,800 Qx; 48,917,400 Qx and 24,664,600 Qx respectively.

However, national production remains far below the real potential and fluctuates from year to year. This weakness in cereal production is due to the vagaries of the weather, the agricultural techniques used, which are often ill-suited, to the soils which have become increasingly degraded

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and prone to erosion due to the non-fertilization of the soil (Anonyme 2019) and biotic constraints, cases of diseases and weeds (Lhaloui et al. 2005, Cromey et al. 2006, Zidane et al. 2010, El-Yousfi 2015).

Phosphorus is one of the major nutrients essential for plant growth and development (Arora & Gaur 1978). However, a large part of the phosphorus present in the soil cannot be assimilated by plants (Chang & Chu 1961, Gachon 1973, Fernández et al. 2007). Phosphorus deficiencies pose major agronomic problems despite the addition of phosphate fertilizers, which has become a common practice in modern agriculture (Chabot et al. 1993, De Santiago et al. 2013). In this sense, plants can only use a small proportion of applied phosphate fertilizers; the major fraction of phosphate fertilizers are quickly converted into insoluble complexes in the soil (Rawat & Tewari 2011). Thus, soils have a large reserve of insoluble phosphate that should be dissolved. Certain phosphate-solubilizing microorganisms (Fankem et al. 2006) are able to release phosphorus from these reserves and thus contribute to improving plant growth and crop production (Rawat & Tewari 2011).

There are plants in the soil and rhizosphere, species of the genus *Trichoderma* capable of dissolving the different forms of insoluble phosphates (Altomare et al. 1999). Certain strains of *Trichoderma* have been shown to be able to naturally dissolve the insoluble pulverized mineral phosphate (MP) in order to make it available for plant growth. Thus, several mechanisms are used by *Trichoderma* to ensure the stability and productivity of agricultural and natural ecosystems (Pozo et al. 2004) and to promote the development of plants: production of phytohormones, induction of systemic resistance in the host plant, reduction of the toxicity of pollutants (organic or heavy metals), regulation of the rhizospheric microflora and solubilization of sparingly soluble minerals (Vinale et al. 2006, Adams et al. 2007, Altomar & Tringovska 2011, Huang et al. 2011, Cai et al. 2013). The effect of *Trichoderma* is apparent when they have a good ability to saprophytic competition in the soil vis-à-vis the microflora.

In Morocco, *Trichoderma* isolates originating from sites adjacent to phosphate mines have shown a great capacity to solubilize rock phosphate (Kribel et al. 2019a) and tri-calcium phosphate (Kribel et al. 2019b) and have shown *in vitro* a high antagonistic power against *F. graminearum*, *F. culmorum*, *F. roseum*, *Bipolaris sorokiniana* and *Curvularia spicifera*, responsible agents for root rot of wheat and barley (Kribel et al. 2019c).

In order to verify their aptitudes for saprophytic activity and to stimulate plant development, the effect of two of these *Trichoderma* isolates has been studied on the growth and yield of wheat and barley plants growing on substrates containing increasing concentrations of rock phosphate; as well as their capacity to colonize the roots and growing substrates in comparison with a reference strain *Trichoderma asperellum*.

Materials and methods

Trichoderma isolates

Three isolates of *Trichoderma* were tested in this study (Table 1): T1 (*Trichoderma asperellum*) registered in the NCBI database and two isolates TR-B 98 (2) and TR-B 98 (3), isolated from sites adjacent to phosphate mines.

Table 1 Origins and sources of isolation of *Trichoderma* isolates spp.

***Trichoderma* spp. isolates**	**Isolation sources**	**Localities (country)**
T1 (BankIt1902509 SMis1 KU987252) *Trichoderma asperellum*	Compost	Missour/Morocco
TR-B 98 (2)	Sludge roots 1998	Khouribga region /Morocco
TR-B 98 (3)	Sludge roots 1998	

All the tested *Trichoderma* isolates were conserved on filter paper at -15°C. Young cultures of these isolates were carried out on PSA medium (200 g of potato, 15 g of Agar-agar and 1000 ml of distilled water) (Table 1) and incubated at 28°C and in the dark. After 7 days of incubation, the surfaces of the cultures were scraped and the 20 g of mycelia and conidia collected served as an inoculum which was incorporated and mixed with 2 kg of the substrate.

Culture Substrate

The soil of the Mamora forest is very sandy, of the loose structure and slightly basic pH (7.53). It has a low cationic exchange capacity (7 meq/100 g), very low salinity and an organic matter content not exceeding 0.7% (Table 2). It is also deficient in total phosphorus (0.239%), total potassium (0.15 meq/100 g) and nitrogen to (0.05%) (Mouria 2009). The required quantity for the tests was sieved and then stored dry at room temperature in a closed polyethylene bag.

The Mamora soil was mixed with 400 g of cow manure and supplemented with different doses of rock phosphate originating from the adjacent sites of the Moroccan phosphate mines (100%: 0%; 75%: 25%; 50%: 50%; 25%: 75%; 0%: 100%) (Promwee et al. 2014) and added 20 g of barley straw, cut with scissors into pieces of about 2 cm. The control consists only of the soil of the Mamora.

The experimental protocol was designed in a random block with four repetitions per treatment and each pot received four grains of wheat or barley. The pots were brought back to a greenhouse and watering with tap water has been carried out according to the needs of the plants.

Table 2 Physico-chemical characteristics of the Mamora soil.

Physico-chemical parameters	Soil
pH (water extract)	7.5
Organic material (%)	0.70
Humidity (%)	-
C/N	-
Total nitrogen	0.05
Total phosphorus P_2O_5 (%)	0.239
Total potassium	0.15 (meq/100 g)
Magnesium (Mg)	0.20 (meq/100 g)
Calcium (Ca)	6.30 (meq/100 g)

The used seeds

Soft wheat (Wafia), durum wheat (Amjad) and barley (Oussama) seeds were disinfected superficially with sodium hypochlorite diluted to 1% for 10 min, rinsed thoroughly with sterile distilled water. After drying the disinfected grains of wheat and barley were transplanted into plastic pots filled with different growing media. Four replicates per treatment and 4 plants not replicating were used in this study.

Measurement of agronomic parameters

Ten days after the installation of the cultures, the number of grains of wheat and barley germinated was counted and expressed as a percentage. At the end of the tests and after eighty days of cultivation, the pots were brought back from the greenhouse and the plants were cut at the collar. The height of the plants was measured from the soil surface to the top of the plants using a tape measure. The number of tillers between nodes leaves and grain per spike was also counted.

The roots of the plants, separated from the substrates, were washed under a stream of water to remove adhering soil particles and left to dry on absorbent paper under ambient laboratory conditions overnight. The vegetative biomass and, possibly the weight of the ears, was measured using a balance the same day while the root biomass was measured after one night so that the rinsing water does not distort the results. The dry weight of the roots and aerial parts was determined after drying at 80°C for 24 hours.

Colonization of roots and retention in the substrate

Colonization of substrates by *Trichoderma* was evaluated by the method of the saprophytic colonization of straw. In general, the *Trichoderma* have a good ability to colonize the straw of cereals, especially wheat. Cereal straw was used by Davet & Comporota (1986) to assess the suitability of *Trichoderma* for saprophytic competition. This nutrient carrier with very low lignin content did not need to be autoclaved and was widely available.

The straw fragments, incorporated into different culture substrates inoculated with *Trichoderma*, were collected after 4, 20, 40, 60 and 80 days from cultivation) washed with tap water for one minute, disinfected superficially sodium hypochlorite for two minutes, rinsed and cut into 5 mm long fragments. One hundred straw fragments were cultured in Petri dishes on PSA medium, for 7 days in the dark and at 28°C. The percentage of colonization of the fragments by *Trichoderma* was estimated relative to the total number of fragments for each treatment.

%C *Trichoderma* = (Number of fragments colonized by *Trichoderma*/Total number of fragments) × 100

Colonization of wheat and barley roots, developing on substrates containing different doses of rock phosphate, by *Trichoderma* was evaluated 80 days after cultivation. The roots of the plants were washed, superficially disinfected with 90 alcohol for 1 min, rinsed thoroughly with sterile distilled water, dried, cut into small pieces and aseptically placed in Petri dishes containing the PSA medium. The observations of the cuts were made every day for a week. The percentage of colonization of the fragments by *Trichoderma* was estimated as previously.

The presence of *Trichoderma* in the rhizosphere of wheat and barley plants was also carried out. The used technique to isolate *Trichoderma* was that of the modified Warcup (1950) soil-plates. In Petri dishes containing PSA culture medium, a small amount of soil ranging from 5 to 15 mg is deposited in the medium with 0.2 ml of sterile distilled water and then spread immediately. Cultures were incubated and observations were made after one week. The number of units forming colonies of the pathogen and/or *Trichoderma* was estimated per gram of soil.

Statistical analyzes

The data processing focused on the unidirectional variance analysis (ANOVA) and the LSD test at the 5% threshold.

Results

Effect of *Trichoderma* on growth and yield parameters

The effect of isolates of *Trichoderma* spp. was tested on the growth of durum wheat (Amjad) seedlings of common wheat (Wafia) and barley (Oussama) growing on different amended substrates with different doses of rock phosphate (RP). The test was carried out in a greenhouse between December 2018 and February 2019. The growth parameters of wheat and barley plants treated with *Trichoderma* isolates and growing on amended rock phosphate substrates were estimated eighty days after cultivation. In general, compared to the control plants, the plants growing on substrates have received an inoculum based on *Trichoderma* showed a marked improvement in the growth parameters (Fig. 2) whatever the dose of rock phosphate incorporated into the substrate of culture.

Grains of common wheat, durum wheat and barley sown in substrates containing 0% RP, 25% RP and 50% RP of rock phosphate, inoculated with T1 isolates; TR-B 98 (2) and TR-B 98 (3) showed the highest germination percentages (Table 3), with percentages of the order of 100% compared to control plants whose percentage of germination varies from 87.5 to 93.75%. In grains sown in substrates containing high doses of phosphate rock 75% and 100% PR, *Trichoderma* improved germination percentage, but less significant, varying from 56.25 to 78% for soft wheat,

from 62.25 to 75% for hard wheat and from 62.25 to 87.5% for barley compared to control plants not exceeding 66.66% for soft and hard wheat and 70% for barley.

Plants growing on 0% PR, 25% PR and 50% PR substrates, inoculated with the TR-B 98 (3) isolate showed the highest growth of aerial parts (Table 4), with sizes of 65 and 78 cm for the common wheat and durum wheat plants and 82 cm for those of the barley plants. In addition, the wheat (soft and hard) and barley plants growing on the 0% RP, 25% PR and 50% PR substrates, inoculated with the tested *Trichoderma* isolates, presented a high number of tillers which varied from 2 to 3 tillers / plants.

The internodes of wheat and barley plants growing on these substrates vary between 5 and 6. The wheat and barley plants growing on these substrates inoculated with isolates T1 and TR-B 98 (2) have also shown an improvement in the growth of the aerial part which varies between and 52 and 67 cm for common wheat and hard and between 62 and 75 cm for barley plants and internodes which always oscillate between 5 and 6.

The isolate TR-B 98 (3) also stimulated leaf formation (Table 4) in wheat (soft and hard) and barley plants growing on substrates containing 0% RP, 25% RP and 50% PR, respectively vary from 12 to 17 and from 14 to 19 leaves per plant. The number of leaves observed in plants growing on substrates inoculated with isolates T1 and TR-B 98 (2) and amended by 0% PR, 25% RP and 50% PR of rock phosphate exceeds 8 leaves per wheat plant (soft and hard) and 11 leaves per barley plant. In control plants growing on a substrate containing 0% PR, 25% PR and 50% PR of rock phosphate, the number of leaves does not exceed 7 leaves per wheat plant (soft and hard) and 9 leaves per barley plant. In plants growing on substrates containing high doses of rock phosphate 75% PR and 100% PR, *Trichoderma* improved the formation of wheat and barley leaves but to a lesser extent.

The number of spikes and the number of grains / spike observed in wheat and barley plants growing on the substrates 0% RP, 25% RP and 50% RP (Table 5), inoculated by the three tested isolates of *Trichoderma* are respectively around 2 spikes per plant and vary between 46 and 56 grains / spike for soft and hard wheat and between 48 and 60 grains /spike for barley plants. The wheat and barley plants growing on the other substrates tested at 75% PR and 100% PR and inoculated with the *Trichoderma* isolates showed a number of spikes not exceeding 1 and a number of grain / spikes that varied between 22 and 32 for wheat and between 25 and 38 for barley. The wheat and barley plants of the control substrates formed an average number of spikes that do not exceed 1 and a number of grains / spikes that vary between 39 and 46 on the substrates containing 0% PR, 25% PR and 50% PR and between 18 and 28 on the others the substrates.

The results are shown in Tables 6 and 7 show that the increase in the rock phosphate concentration in the substrate negatively affects the fresh and dry weights of the aerial (Table 6) and root (Table 7) parts of the wheat and barley cultures. However, the inoculation of the substrates with the *Trichoderma* isolates significantly improved the fresh and dry weights of the wheat (soft and hard) and barley plants, which varied respectively between 44.5 g and 60.45 g and between 16.22 g and 27.5 g for the aerial part between 5.22 g and 8.75 g and between 2.05 g and 2.93 g on 0% PR, 25% PR and 50% PR substrates. The wheat and barley plants growing on control substrates not inoculated by *Trichoderma* presented fresh and dry weights which oscillate respectively between 36.45 g and 45.2 g and between 12.5 g and 18.3 g for the aerial part, and which vary between 3.2 g and 4.5 g and between 1.62 g and 1.87 g for the root part.

The results illustrated in Fig. 1 show that the sizes of the roots of the plants growing on the 0% PR, 25% PR and 50% PR substrates and inoculated with the three tested *Trichoderma* isolates far exceed 32 cm and can reach 38 cm while those of control plants do not exceed 17 cm. However, the size of the roots of the plants of the 75% PR and 100% PR substrates inoculated by *Trichoderma* did not exceed 28 cm.

From all these results, it appears that the tested *Trichoderma*, incorporated into culture substrates, whether or not amended by increasing doses of rock phosphate, have positive effects on the development of growth and yield parameters in wheat plants and barley.

Colonization of roots and substrates by *Trichoderma*

The tested isolates of *Trichoderma* were able to colonize the roots of wheat (soft and hard) and barley plants over time (Table 8). The highest colonization percentages were noted in the roots of plants growing on substrates 0%, 25% and 50% RP, vary between 73.25% (roots of barley plants on a substrate containing 25% RP) and 84% (roots of barley plants on the substrate 0% RP). The colonization percentages of the roots of plants growing on 75% PR and 100% PR substrates vary between 62.43% in the case of durum wheat roots on the 100% PR substrate and 78.25% PR on the 75% PR substrate.

The tested *Trichoderma* isolates have also been able to maintain and multiply over time in the various studied substrates. The different doses of rock phosphate incorporated into the wheat and barley culture substrates did not significantly influence the colonization of the straw fragments, with the exception of 100% PR substrate at which a delay in the colonization of the fragments of straw has been accused (Tables 9, 10). At time T4 days, directly after the installation of the cultures, the percentages of colonization of straw revealed vary between 0 and 8% (case of durum wheat and soft wheat on the substrate 25% PR). Between twenty days and eighty days of culture, the colonization of the fragments of straw by the *Trichoderma* gradually increased. In substrates 0% PR, 25% PR, the percentages of colonization of straw fragments by *Trichoderma* noted after 40 and 60 days of wheat and barley culture exceeded 70% and reached 90%. After 60 and 80 days of culture on the substrates 50% PR, 75% PR and 100% PR, the highest colonization percentages were noted in the substrates 50% PR, 75% PR and 100% PR, they have exceeded 60% and reached 81.25%, as the maximum colonization percentage.

The tested *Trichoderma* isolates also showed the ability to survive in the soil (Tables 11, 12) around the roots of wheat and barley plants growing on different tested substrates. The high doses of rock phosphate incorporated in the culture substrates did not prevent the installation and handling of the tested isolates. Indeed, the number of *Trichoderma* units (CFU/g of soil) varied between 46.3 10^3 to 54 10^3 CFU/g of soil directly after the installation of the crops, 4 days, and fluctuated between 31.5 10^3 to 47.3 10^3 CFU/g of soil twenty days after. After forty, sixty and eighty days of cultivation, the number of CFU/g of the soil varied respectively between 18.33 10^3 and 29 10^3 CFU/g of the soil, between 10.25 10^3 to 19.5 10^3 CFU/g of the soil and between 2.25 10^3 to 8.7 10^3 CFU/g of soil.

It appears from these results that the *Trichoderma* isolates inoculated into the various culture substrates have significant abilities to colonize over time the roots of wheat and barley plants and the fragments of straw incorporated into the culture substrates. These isolates were also able to multiply in the rhizosphere of the plants, judging by the number of units forming the colonies of *Trichoderma* (CFU/g of soil).

Discussion

The tested *Trichoderma* isolates improved all growth and yield parameters in wheat plants (hard and soft) and barley compared to that observed in control plants. They significantly stimulated tiller formation, growth in length, number of nodes, leaves, spike and number of kernels/spike in plants growing on growing media containing different doses of rock phosphate.

Trichoderma isolates also stimulated aerial and root biomass of wheat and barley plants compared to that of uninoculated control plants. This increase was noted for both fresh and dry weights, which shows that it is a general increase in metabolism. Using *Trichoderma* species to stimulate growth of plants has been reported by numerous research studies. Thus, Mouria et al. (2008) reported the effect of six strains of *Trichoderma* on the growth and yield parameters of a greenhouse tomato crop. The obtained results showed that strains of *Trichoderma harzianum* were able to stimulate the growth of the tomato, in particular the vegetative and root biomass, whereas *T. viride* did not show a significantly different effect compared to the control.

Yedidia et al. (2001) reported the effect of a strain of *T. harzianum* (T-203) which may have increased the root surface, the cumulative length of the roots, dry weight, shoot length and cucumber leaf area after 28 days of sowing in soil amended with *T. harzianum*. In this sense, the

work of Baker et al. (1984) also showed that the dry weight of radish plants increased after treatment with the T-95 strain of *T. harzianum.* Besides, Gravel et al. (2005) noted that the inoculation of the tomato with a strain of *T. atroviride* made it possible to significantly increase the root surface and the weight of the tomato plants *in vitro* as well as the marketable yield in the greenhouse.

Likewise, the work of Yadav et al. (2011) showed that *T. harzianum* significantly increased the length of the shoots, the length of the roots, the dry weight of the shoots and the dry weight of the chickpea roots compared to those observed in the control plants. The work of Promwee et al. (2014) reported that treatments of rubber plants with FR-NST-009 and CB-Pin-01 of *Trichoderma* and rock phosphate (RP) increased the height of the plants, stem circumference, number of leaves and fresh, dry weight of shoots and roots compared to those observed in uninoculated control plants. Kleifeld & Chet (1992) reported that stimulation of plant growth by *Trichoderma* sp. would be due to the increase in the transfer of nutrients from the soil to the roots thanks to the colonization of these by *Trichoderma.* Similarly, the work of Saravanakumar et al. (2013) reported that the TSK8 strain of *Trichoderma* significantly increased the total biomass of mangrove seedlings when supplemented with soluble superphosphate (KH_2PO_4).

In addition, Harman (2000) reported that the T-22 strain of *T. harzianum* was as effective as a commercial rooting hormone in inducing roots in tomato and potato plants. In addition, Windham et al. (1986) and Baker (1988) reported that *Trichoderma* strains are capable of producing growth regulators that improve the germination and growth of host plants. Even better, Hibar et al. (2005) explained the stimulation of the development of a melon culture following the application of *T. harzianum* (Yedidia et al. 1999) by an activation of the defense system of the plant, an increase in activity chitinase and peroxidase and increased enzyme activity in the leaves inducing systemic resistance in these plants.

The *Trichoderma* isolates tested during this study have shown a great capacity to survive in the rhizospheric soil of wheat and barley plants growing on substrates containing different doses of rock phosphate and to migrate from these substrates to the roots of plants to colonize them. According to Nemec et al. (1996) one of the essential characteristics in a biological control agent is its ability to survive in an environment different from its original environment and to colonize the roots of plants to protect them from pathogens. Kleifeld & Chet (1992) reported that stimulation of plant growth by *Trichoderma* sp. would be due to the increase in the transfer of nutrients from the soil to the roots thanks to the colonization of these by *Trichoderma.*

Baker (1988) reported that such increases in plant growth and development can result from either control of minor pathogens, increased nutrient uptake, or increased root growth which promotes required nutrient availability. The work of Mouria et al. (2008) showed that the Tcomp and TH2 strains of *Trichoderma* were able to colonize the roots of inoculated tomato plants. Ozbay & Newman (2004) reported that *Trichoderma* isolates were able to maintain and multiply at high levels 4 weeks after their incorporation into the soil. Similarly, Besnard & Davet (1993) found that the populations of *Trichoderma* were maintained at the end of their experience in terms of growing media. Kleifeld & Chet (1992) reported that the stimulation of plants by *Trichoderma* depends on its ability to survive and maintain itself in the rhizosphere. For this, the estimate of the populations of *Trichoderma* in the culture substrate at the end of the tests showed their capacity to maintain a high level in the rhizosphere; however, this level varies from strain to strain. Ousley et al. (1994) point out that *T. harzianum* improves the nutrient delivery from the growing substrates to the roots like the effects of mycorrhizae. These results confirm the work of Kleifeld & Chet (1992) who reported that the positive effect noted in plants inoculated by *T. harzianum* is due to the increased transfer of nutrients from the soil to the roots thanks to the colonization of these by *Trichoderma*.

Conclusion

The present study noted that the inoculation of growing media, amended with different doses of rock phosphate, has a significant effect on the growth and yield parameters of wheat and barley plants. The tested *Trichoderma* were able to maintain themselves in all the substrates of the culture

and to develop in the cortex of the roots and the rhizosphere of wheat and barley plants. Thus, the application of *Trichoderma* in agriculture is a promising approach which will make it possible to reduce the use of growth regulators while minimizing the cost of production and the negative impacts on the environment.

Table 3 Effect of *Trichoderma* on the germination of wheat and barley seeds on the substrates amended with different doses of rock phosphate, after 10 days of culture (expressed in %).

		0% PR	25% PR	50% PR	75% PR	100% PR
Soft wheat *Wafia*	**Control**	100^{a}	93.75^{b}	87.5^{b}	66.66^{d}	50^{c}
	T1	100^{a}	100^{a}	100^{a}	75^{b}	56.25^{b}
	TR-B 98 (2)	100^{a}	100^{a}	100^{a}	72^{c}	56.25^{b}
	TR-B 98 (3)	100^{a}	100^{a}	100^{a}	78^{a}	68.75^{a}
Durum wheat *Amjad*	**Control**	100^{a}	87.5^{b}	81.25^{b}	66.66^{b}	50^{c}
	T1	100^{a}	100^{a}	100^{a}	75^{a}	68.75^{a}
	TR-B 98 (2)	100^{a}	100^{a}	100^{a}	75^{a}	62.25^{b}
	TR-B 98 (3)	100^{a}	100^{a}	100^{a}	75^{a}	68.75^{a}
Barley *Oussama*	**Control**	100^{a}	93.75^{b}	87.5^{b}	75^{c}	56.25^{c}
	T1	100^{a}	100^{a}	100^{a}	83.3^{b}	68.75^{a}
	TR-B 98 (2)	100^{a}	100^{a}	100^{a}	81.25^{c}	62.25^{b}
	TR-B 98 (3)	100^{a}	100^{a}	100^{a}	87.5^{a}	68.75^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 4 Effect of *Trichoderma* on the agronomic parameters of wheat plants (durum and soft) and barley growing on substrates amended with different doses of rock phosphate, after 80 days of culture.

		0% PR			25% PR			50% PR			75% PR			100% PR		
		BT	**BD**	**O**	**BT**	**BD**	**O**	**BT**	**BD**	**O**	**BT**	**BD**	**O**	**BT**	**BD**	**O**
Size of the aerial part (cm)	**Control**	48^{d}	47^{d}	59^{d}	46^{d}	49^{d}	52^{d}	42^{d}	42^{d}	45^{d}	28^{d}	28^{d}	30^{d}	22^{d}	25^{d}	26^{c}
	T1	69^{b}	67^{b}	75^{b}	57^{c}	59^{c}	62^{c}	54^{b}	53^{b}	63^{c}	38^{b}	36^{b}	36^{c}	30^{c}	31^{c}	36^{b}
	TR-B 98 (2)	62^{c}	60^{c}	74^{c}	59^{b}	64^{b}	71^{b}	52^{c}	52^{c}	64^{b}	37^{c}	34^{c}	40^{b}	35^{b}	32^{b}	36^{b}
	TR-B 98 (3)	76^{a}	75^{a}	82^{a}	72^{a}	74^{a}	78^{a}	65^{a}	65^{a}	69^{a}	43^{a}	43^{a}	49^{a}	37^{a}	34^{a}	38^{a}
Number of internodes	**Control**	4^{c}	4^{c}	5^{b}	4^{b}	4^{c}	5^{b}	4^{b}	4^{b}	5^{a}	3^{b}	3^{b}	4^{a}	3^{a}	3^{a}	3^{a}
	T1	5^{b}	5^{b}	6^{a}	5^{a}	6^{a}	6^{a}	5^{a}	5^{a}	5^{a}	4^{a}	4^{a}	4^{a}	3^{a}	3^{a}	3^{a}
	TR-B 98 (2)	5^{b}	5^{b}	6^{a}	5^{a}	5^{b}	6^{a}	5^{a}	5^{a}	5^{a}	4^{a}	4^{a}	4^{a}	3^{a}	3^{a}	3^{a}
	TR-B 98 (3)	6^{a}	6^{a}	6^{a}	5^{a}	6^{a}	6^{a}	5^{a}	5^{a}	5^{a}	4^{a}	4^{a}	4^{a}	3^{a}	3^{a}	3^{a}
Number of tillers	**Control**	1^{b}	1^{c}	2^{b}	1^{b}	1^{c}	1^{c}	1^{b}	1^{c}	1^{c}	1^{a}	1^{a}	1^{b}	1^{a}	1^{a}	1^{a}
	T1	2^{a}	2^{b}	2^{b}	2^{a}	2^{b}	2^{b}	2^{a}	2^{b}	2^{b}	1^{a}	1^{a}	2^{a}	1^{a}	1^{a}	1^{a}
	TR-B 98 (2)	2^{a}	2^{b}	2^{b}	2^{a}	2^{b}	2^{b}	2^{a}	2^{b}	2^{b}	1^{a}	1^{a}	2^{a}	1^{a}	1^{a}	1^{a}
	TR-B 98 (3)	2^{a}	3^{a}	3^{a}	2^{a}	3^{a}	3^{a}	2^{a}	3^{a}	3^{a}	1^{a}	1^{a}	1^{b}	1^{a}	1^{a}	1^{a}
Number of leaves	**Control**	7^{d}	7^{d}	9^{d}	7^{d}	7^{d}	8^{d}	5^{c}	7^{c}	7^{c}	5^{d}	7^{c}	7^{c}	5^{b}	7^{b}	7^{d}
	T1	10^{b}	9^{b}	11^{c}	12^{b}	13^{b}	15^{b}	8^{b}	12^{a}	14^{b}	6^{c}	7^{c}	10^{b}	5^{b}	7^{b}	9^{c}
	TR-B 98 (2)	9^{c}	8^{c}	13^{b}	10^{c}	12^{c}	14^{c}	8^{b}	10^{b}	15^{a}	7^{b}	8^{b}	10^{b}	5^{b}	7^{b}	10^{b}
	TR-B 98 (3)	15^{a}	14^{a}	16^{a}	17^{a}	16^{a}	19^{a}	12^{a}	12^{a}	14^{b}	10^{a}	10^{a}	11^{a}	8^{a}	9^{a}	11^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 5 Effect of *Trichoderma* on the yield parameters of wheat plants (durum and soft) and barley growing on substrates amended with different doses of rock phosphate, after 80 days of culture.

		0% PR			25% PR			50% PR			75% PR			100% PR		
		BT	**BD**	**O**	**BT**	**BD**	**O**	**BT**	**BD**	**O**	**BT**	**BD**	**O**	**BT**	**BD**	**O**
Number of spike	**Control**	1^{b*}	1^{b}	1^{b}	1^{b}	1^{b}	1^{b}	1^{b}	1^{b}	1^{b}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}
	T1	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}
	TR-B 98 (2)	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}
	TR-B 98 (3)	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	2^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}	1^{a}
Number of grains/ spike	**Control**	44^{c}	42^{c}	46^{c}	43^{c}	44^{c}	45^{b}	39^{c}	41^{c}	44^{c}	22^{c}	24^{b}	28^{c}	18^{c}	18^{c}	20^{c}
	T1	50^{b}	50^{b}	56^{b}	51^{b}	51^{b}	58^{a}	46^{b}	48^{b}	48^{b}	28^{b}	26^{b}	34^{b}	22^{b}	23^{b}	25^{b}
	TR-B 98 (2)	53^{a}	54^{a}	60^{a}	54^{a}	54^{a}	60^{a}	50^{a}	50^{ab}	54^{a}	30^{ab}	32^{a}	36^{ab}	24^{ab}	22^{b}	25^{b}
	TR-B 98 (3)	54^{a}	54^{a}	60^{a}	56^{a}	54^{a}	60^{a}	52^{a}	52^{a}	56^{a}	32^{a}	32^{a}	38^{a}	26^{a}	28^{a}	28^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 6 Effects of *Trichoderma* on the growth of the aerial part, estimated by the fresh and dry weight (in g) of wheat and barley plants growing on substrates amended with different doses of rock phosphate, after 80 days of culture.

	Treatments	0% PR		25% PR		50% PR		75% PR		100% PR	
		PF	**PS**	**PF**	**PS**	**PF**	**PS**	**PF**	**PS**	**PF**	**PS**
Soft wheat *Wafia*	**Control**	42.5^{c*}	18.2^{c}	40.5^{c}	16.3^{c}	36.45^{c}	12.5^{c}	32.25^{c}	9.5^{c}	18.5^{c}	6.6^{b}
	T1	57.25^{a}	25.5^{a}	54.5^{a}	22.5^{a}	51.25^{a}	19.13^{a}	41.5^{a}	16.35^{a}	27.5^{ab}	10.8^{a}
	TR-B 98 (2)	52.7^{b}	23.5^{b}	50.25^{b}	21.25^{a}	48.8^{b}	16.34^{b}	38.8^{b}	14.45^{b}	26.45^{b}	9.02^{a}
	TR-B 98 (3)	56.8^{a}	25.3^{a}	54.5^{a}	22.5^{a}	51.5^{a}	18.76^{a}	42.5^{a}	16.25^{a}	28.22^{a}	10.5^{a}
Durum wheat *Amjad*	**Témoin**	40.5^{c}	17.2^{c}	38.5^{c}	16.5^{c}	36.45^{c}	12.5^{c}	26.5^{d}	8.41^{b}	17.75^{d}	5.38^{b}
	T1	55.5^{a}	23.5^{a}	52.25^{a}	21.25^{ab}	48.45^{a}	18.22^{a}	36.25^{b}	12.64^{a}	26.4^{b}	10.25^{a}
	TR-B 98 (2)	50.2^{b}	21.6^{b}	48.45^{b}	19.25^{b}	44.5^{b}	16.22^{b}	34.8^{c}	12.5^{a}	24.25^{c}	10.25^{a}
	TR-B 98 (3)	54.2^{a}	23.5^{a}	52.22^{a}	22.5^{a}	49.5^{a}	19.75^{a}	38.8^{a}	12.86^{a}	28.5^{a}	10.25^{a}
Barley *Oussama*	**Témoin**	45.2^{d}	18.3^{d}	42.25^{c}	18^{c}	40.5^{d}	14.5^{c}	32.5^{c}	8.75^{c}	19.5^{d}	6.87^{c}
	T1	59.2^{b}	25.2^{b}	55.5^{ab}	22.5^{a}	50.5^{b}	20.42^{a}	42.5^{a}	16.45^{a}	30^{b}	11.98^{ab}
	TR-B 98 (2)	56.5^{c}	23.5^{c}	54.6^{b}	20.5^{b}	48.25^{c}	16.5^{b}	38.5^{b}	14.45^{b}	26.25^{c}	10.22^{b}
	TR-B 98 (3)	60.45^{a}	27.5^{a}	56.25^{a}	22.73^{a}	52.25^{a}	20.45^{a}	42.5^{a}	17.5^{a}	32.5^{a}	12.5^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

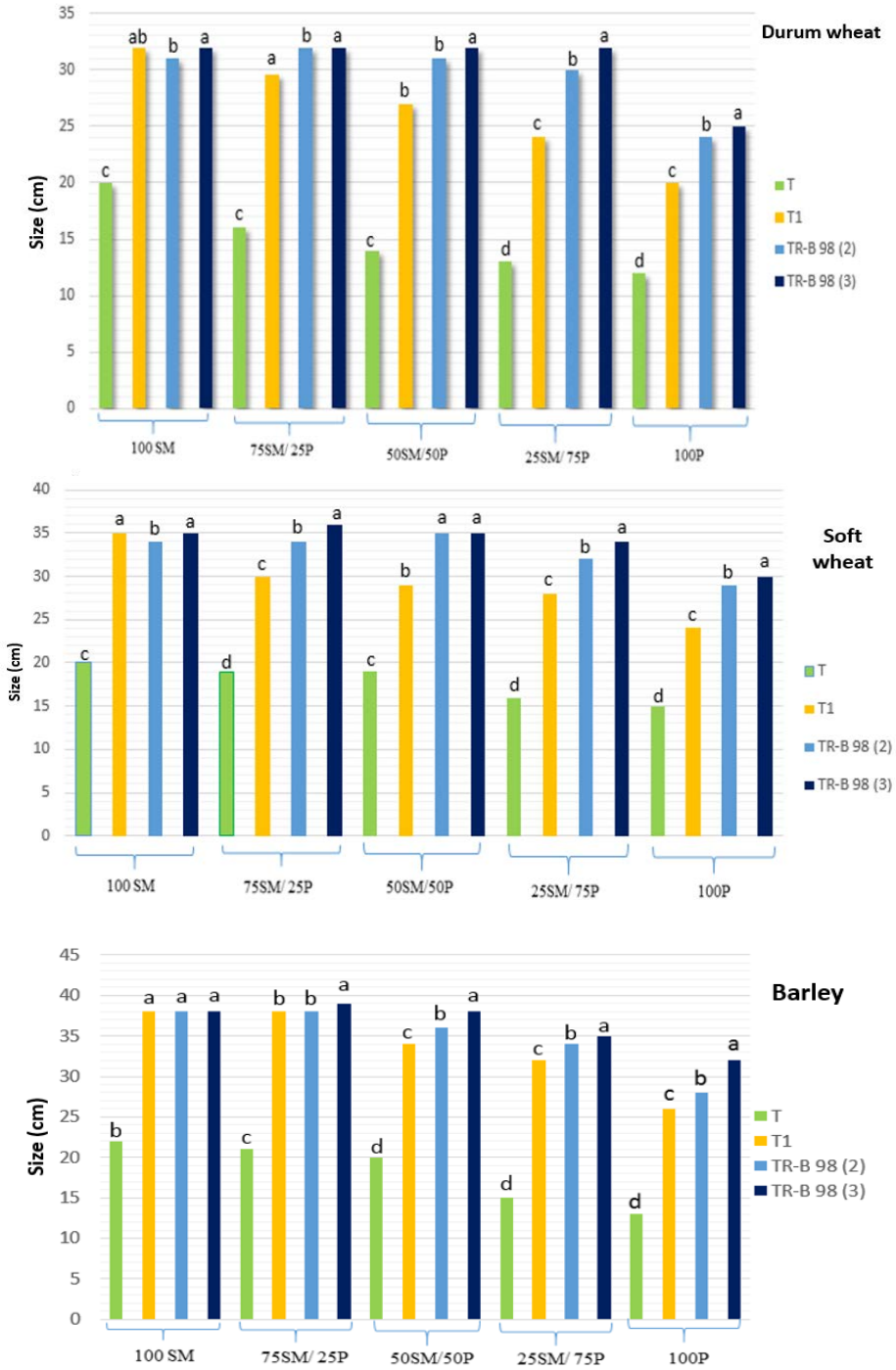
Table 7 Effects of *Trichoderma* on the growth of root mass, estimated by the fresh and dry weight (in g) of the roots of wheat and barley plants growing on substrates amended with different doses of rock phosphate, after 80 days of culture.

		0% PR		25% PR		50% PR		75% PR		100% PR	
		PF	**PS**	**PF**	**PS**	**PF**	**PS**	**PF**	**PS**	**PF**	**PS**
Soft wheat *Wafia*	**Control**	4.5^{c*}	1.87^{b}	4.3^{c}	1.83^{c}	3.2^{c}	1.8^{c}	2.6^{c}	1.2^{b}	2.2^{b}	0.92^{c}
	T1	6.24^{b}	2.6^{a}	6.56^{b}	2.3^{b}	5.4^{b}	2.6^{b}	3.7^{a}	1.9^{a}	2.6^{a}	1.2^{b}
	TR-B 98 (2)	7.62^{a}	2.9^{a}	6.83^{b}	2.4^{b}	5.8^{b}	2.6^{b}	3.3^{b}	1.8^{a}	2.5^{a}	1.6^{a}
	TR-B 98 (3)	7.02^{a}	2.9^{a}	8.69^{a}	2.9^{a}	6.4^{a}	2.8^{a}	3.7^{a}	1.8^{a}	2.6^{a}	1.6^{a}
Durum wheat *Amjad*	**Control**	4.2^{c}	1.72^{b}	4.53^{d}	1.84^{c}	3.63^{c}	1.98^{c}	3.01^{c}	1.5^{c}	2.15^{c}	0.8^{b}
	T1	6.85^{b}	2.68^{a}	6.38^{c}	2.5^{b}	5.22^{b}	2.05^{b}	3.25^{b}	1.64^{b}	2.6^{ab}	0.98^{b}
	TR-B 98 (2)	7.42^{a}	2.62^{a}	7.64^{b}	2.87^{a}	5.73^{a}	2.13^{b}	3.52^{ab}	1.82^{a}	2.56^{b}	1.06^{b}
	TR-B 98 (3)	7.67^{a}	2.51^{a}	8.25^{a}	2.64^{b}	5.74^{a}	2.33^{a}	3.79^{a}	1.84^{a}	2.86^{a}	1.72^{a}
Barley *Oussama*	**Control**	4.31^{d}	1.85^{c}	4.12^{c}	1.78^{c}	3.6^{c}	1.62^{c}	2.18^{c}	1.12^{c}	2.4^{c}	0.92^{b}
	T1	7.52^{c}	2.87^{b}	7.87^{b}	2.78^{ab}	5.73^{b}	2.23^{a}	4.23^{b}	1.29^{b}	2.78^{b}	1.09^{a}

Table 7 Continued.

	0% PR		25% PR		50% PR		75% PR		100% PR	
	PF	**PS**	**PF**	**PS**	**PF**	**PS**	**PF**	**PS**	**PF**	**PS**
TR-B 98 (2)	8.41^{a}	2.96^{a}	8.64^{a}	2.63^{b}	6.22^{a}	2.12^{ab}	4.35^{b}	1.32^{b}	2.92^{b}	1.12^{a}
TR-B 98 (3)	8.75^{a}	2.93^{a}	8.42^{a}	2.75^{a}	6.53^{a}	2.09^{b}	5.67^{a}	1.79^{a}	3.12^{a}	1.18^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold



*Two values, for each treatment, followed by the same letter are not significantly different at 5%

Fig. 1 – Effect of *Trichoderma* on the length growth of the roots of wheat and barley plants growing on fine substrates with different doses of rock phosphate, after 80 days of culture.

Table 8 Colonization of the roots of wheat and barley plants growing on substrates amended with different doses of rock phosphate by *Trichoderma* (expressed in %).

Cultures	Treatments with *Trichoderma*	% of root colonization by *Trichoderma*				
		100 SM	75SM/25P	50SM/50P	25SM/75P	0SM/100P
Soft wheat *Wafia*	**Control**	0^{b}	0^{c}	0^{c}	0^{b}	0^{c}
	T1	83.5^{a}	74.12^{b}	78.15^{ab}	70.5^{a}	62.8^{b}
	TR-B 98 (2)	82.12^{a}	80.15^{a}	76.85^{b}	72.6^{a}	68.3^{b}
	TR-B 98 (3)	86.4^{a}	83.25^{a}	80.75^{a}	73.5^{a}	74.25^{a}
Durum wheat *Amjad*	**Control**	0^{c}	0^{c}	0^{c}	0^{c}	0^{c}
	T1	73.5^{b}	76.5^{b}	66.5^{b}	64.25^{b}	62.43^{b}
	TR-B 98 (2)	77.50^{b}	82.25^{a}	68.3^{b}	67.5^{b}	67.5^{b}
	TR-B 98 (3)	83.25^{a}	80.12^{a}	86.12^{a}	78.25^{a}	72.15^{a}
Barley *Oussama*	**Control**	0^{c}	0b	0c	0c	0^{b}
	T1	76.75^{b}	80.25^{a}	79.25^{ab}	76.5^{a}	72.25^{a}
	TR-B 98 (2)	80.75^{a}	83.75^{a}	73.25^{b}	73.25^{a}	76.02^{a}
	TR-B 98 (3)	84.25^{a}	82.25^{a}	83.25^{a}	77.50^{a}	74.5^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 9 Colonization of the straw fragments by the *Trichoderma* (expressed in %) brought to the amended substrates with different doses of rock phosphate.

			% of colonization of straw fragments by *Trichoderma*				
			4 days	20 days	40 days	60 days	80 days
0% PR	**Soft wheat** (Wafia)	**Control**	0^{c*}	0^{c}	0^{b}	0^{c}	0^{c}
		T1	7^{a}	32.5^{a}	87.4^{a}	82.4^{a}	72.12^{a}
		TR-B 98 (2)	0^{c}	26.55^{b}	88.8^{b}	71.3^{b}	66.27^{a}
		TR-B 98 (3)	3^{b}	35.5^{a}	90.6^{a}	83.4^{a}	74.36^{a}
	Durum wheat (Amjad)	**Control**	0^{c}	0^{c}	0^{b}	0^{b}	0^{c}
		T1	0^{c}	28.5^{ab}	83.75^{a}	79.14^{a}	76.35^{b}
		TR-B 98 (2)	3^{b}	26.25^{b}	86.25^{a}	82.50^{a}	79.12^{b}
		TR-B 98 (3)	6^{a}	30.6^{a}	84.75^{a}	84.25^{a}	72.29^{a}
25% PR	**Soft wheat** (Wafia)	**Control**	0^{b}	0^{c}	0^{b}	0^{c}	0^{c}
		T1	0^{b}	40.5^{a}	79.3^{a}	72.25^{a}	62.25
		TR-B 98 (2)	0^{b}	32.2^{b}	85.25^{b}	83.25^{b}	68.75^{a}
		TR-B 98 (3)	8^{a}	39.25^{a}	89.4^{a}	86.45^{a}	72.55^{a}
	Durum wheat (Amjad)	**Control**	0^{c}	0^{d}	0^{d}	0^{c}	0^{c}
		T1	5^{b}	30.5^{c}	73.5^{c}	66.75^{b}	62.55^{b}
		TR-B 98 (2)	0^{c}	34.75^{b}	76.6^{b}	72.2^{a}	65.25^{b}
		TR-B 98 (3)	8^{a}	36.25^{a}	84.25^{a}	73.33^{a}	67.7^{a}
50% PR	**Soft wheat** (Wafia)	**Control**	0^{c}	0^{d}	0^{c}	0^{c}	0^{c}
		T1	5^{b}	32.5^{c}	61.14^{b}	68.6^{b}	66.5^{b}
		TR-B 98 (2)	0^{c}	36.5^{b}	68.35^{a}	67.3^{b}	66.5^{b}
		TR-B 98 (3)	6^{a}	32.5^{a}	63.12^{b}	86.6^{a}	82.25^{a}
	Durum wheat (Amjad)	**Control**	0^{c}	0^{c}	0^{d}	0^{c}	0^{c}
		T1	2^{b}	24.15^{ab}	55.25^{c}	79.03^{ab}	66.3^{b}
		TR-B 98 (2)	0^{c}	21.55^{b}	61.05^{a}	76.5^{b}	68.5^{b}
		TR-B 98 (3)	4^{a}	28.5^{a}	58.12^{b}	81.25^{a}	72.75^{a}
75% PR	**Soft wheat** (Wafia)	**Control**	0^{c}	0^{c}	0^{c}	0^{c}	0^{d}
		T1	4^{b}	22.5^{b}	53.75^{b}	66.3^{c}	61.14^{c}
		TR-B 98 (2)	6^{a}	21.55^{b}	53.75^{b}	75.75^{b}	66.3^{b}
		TR-B 98 (3)	0^{c}	28.25^{a}	55.14^{a}	75.6^{a}	68.75^{a}
	Durum wheat (Amjad)	**Control**	0^{b}	0^{c}	0^{c}	0^{d}	0^{d}
		T1	0^{b}	29.5^{b}	61.14^{b}	68.5^{c}	62.5^{c}
		TR-B 98 (2)	0^{b}	28.25^{b}	62.5^{a}	73.12^{b}	67.7^{a}
		TR-B 98 (3)	4^{a}	30.5^{a}	62.25^{a}	78.5^{a}	64.15^{b}

Table 9 Continued.

			% of colonization of straw fragments by *Trichoderma*				
			4 days	**20 days**	**40 days**	**60 days**	**80 days**
100% PR	**Soft wheat** (Wafia)	**Control**	0^{c}	0^{c}	0^{c}	0^{c}	0^{c}
		T1	3^{a}	20.25^{b}	34.25^{a}	62.5^{b}	72.75^{b}
		TR-B 98 (2)	2^{b}	21.5^{b}	32.2^{b}	66.75^{a}	72.75^{b}
		TR-B 98 (3)	0^{c}	26.55^{a}	34.75^{a}	62.5^{b}	76.6^{a}
	Durum wheat (Amjad)	**Control**	0^{b}	0^{d}	0^{c}	0^{d}	0^{c}
		T1	2^{a}	20.25^{c}	32.5^{b}	64.5^{c}	73.12^{b}
		TR-B 98 (2)	0	22.5^{b}	32.5^{b}	66.3^{b}	75.75^{a}
		TR-B 98 (3)	2^{a}	28.5^{a}	36.25^{a}	68.6^{a}	75.75^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 10 Colonization of the straw fragments by the *Trichoderma* (expressed in %) provided to the amended substrates of different doses of rock phosphate in barley (Oussama).

		% of colonization of straw fragments by *Trichoderma*				
		4 days	**20 days**	**40 days**	**60 days**	**80 days**
0% PR	**Control**	0^{b*}	0^{c}	0^{b}	0^{b}	0^{c}
	T1	5^{a}	32.5^{a}	83.5^{a}	82.25^{a}	72.25^{a}
	TR-B 98 (2)	0^{b}	28.25^{b}	83.75^{a}	80.25^{a}	74.50^{b}
	TR-B 98 (3)	0^{b}	29.3^{b}	85.5^{a}	86.12^{a}	76.15^{a}
25% PR	**Control**	0^{b}	0^{c}	0^{c}	0^{b}	0^{c}
	T1	0^{b}	40.5^{a}	75.6^{b}	72.3^{a}	59.5^{a}
	TR-B 98 (2)	5^{a}	41.25^{a}	78.5^{b}	71.15^{a}	64.15^{b}
	TR-B 98 (3)	0^{b}	36.25^{b}	82.25^{a}	72.55^{a}	66.5^{a}
50% PR	**Control**	0^{c}	0^{c}	0^{c}	0^{c}	0^{c}
	T1	4^{b}	29.5^{b}	53.75^{b}	75.75^{b}	69.55^{b}
	TR-B 98 (2)	6^{a}	34.25^{a}	62.5^{a}	79.25^{a}	76.25^{a}
	TR-B 98 (3)	0^{c}	36.55^{a}	64.25^{a}	73.12^{b}	72.15^{ab}
75% PR	**Control**	0^{c}	0^{c}	0^{d}	0^{d}	0^{c}
	T1	2^{b}	$28 .25^{b}$	57.02^{c}	72.75^{c}	72.75^{b}
	TR-B 98 (2)	0^{c}	32.4^{a}	59.5^{b}	79.25^{b}	73.12^{b}
	TR-B 98 (3)	6^{a}	32.25^{a}	64.12^{a}	82.25^{a}	76.5^{a}
100% PR	**Control**	0^{c}	0^{d}	0^{d}	0^{d}	0^{d}
	T1	0^{c}	21.5^{c}	36.55^{b}	61.14^{c}	76.6^{b}
	TR-B 98 (2)	3^{b}	24.8^{b}	34.75^{c}	67.3^{b}	72.55^{c}
	TR-B 98 (3)	4^{a}	26.4^{a}	39.25^{a}	68.35^{a}	79.3^{a}

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 11 Re-isolation of *Trichoderma* from the soil (rhizosphere) of wheat plants growing on substrates amended with different doses of rock phosphate, after 80 days of culture.

		Treatments with *Trichoderma*	**CFU/g of soil**				
			0 day	**20 days**	**40 days**	**60 days**	**80 days**
0% PR	**Soft Wheat Wafia**	**Control**	0^{d*}	0^{d}	0^{d}	0^{d}	0^{d}
		T1	$48.5\ 10^{3c}$	$34.5\ 10^{3c}$	$23.5\ 10^{3b}$	$12.5\ 10^{3c}$	$7.5\ 10^{3b}$
		TR-B 98 (2)	$49.5\ 10^{3b}$	$36.5\ 10^{3b}$	$22.5\ 10^{3c}$	$13.5\ 10^{3b}$	$5.2\ 10^{3c}$
		TR-B 98 (3)	$53.2\ 10^{3a}$	$41.2\ 10^{3a}$	$26.2\ 10^{3a}$	$18.25\ 10^{3a}$	$8.7\ 10^{3a}$
	Durum Wheat Amjad	**Control**	0^{d}	0^{d}	0^{d}	0^{c}	0^{d}
		T1	$46.2\ 10^{3c}$	$31.5\ 10^{3c}$	$21.5\ 10^{3c}$	$14.5\ 10^{3b}$	$6.5\ 10^{3a}$
		TR-B 98 (2)	$48.25\ 10^{3b}$	$39.5\ 10^{3b}$	$24.5\ 10b^{3}$	$14.5\ 10^{3b}$	$3.5\ 10^{3c}$
		TR-B 98 (3)	$52.6\ 10^{3a}$	$44.8\ 10^{3a}$	$25\ 10^{3a}$	$17.25\ 10^{3a}$	$5.9\ 10^{3b}$

Table 11 Continued.

		Treatments with *Trichoderma*	CFU/g of soil				
			0 day	20 days	40 days	60 days	80 days
25% PR	Soft wheat Wafia	Control	0^{d}	0^{d}	0^{c}	0^{d}	0^{d}
		T1	$47.3\ 10^{3c}$	$38.75\ 10^{3c}$	$22.5\ 10^{3b}$	$14.5\ 10^{3b}$	$6.7\ 10^{3b}$
		TR-B 98 (2)	$50.25\ 10^{3b}$	$42.5\ 10^{3b}$	$26.2\ 10^{3a}$	$13.5\ 10^{3c}$	$5.3\ 10^{3c}$
		TR-B 98 (3)	$51.03\ 10^{3a}$	$45.25\ 10^{3a}$	$26.2\ 10^{3a}$	$17.25\ 10^{3a}$	$8.7\ 10^{3a}$
	Durum wheat Amjad	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
		T1	$49.05\ 10^{3b}$	$39.25\ 10^{3c}$	$18.33\ 10^{3c}$	15.510^{3c}	$6.25\ 10^{3a}$
		TR-B 98 (2)	$48.5\ 10^{3c}$	$42.5\ 10^{3b}$	$25\ 10^{3b}$	$17.25\ 10^{3b}$	$5.75\ 10^{3b}$
		TR-B 98 (3)	$53.33\ 10^{3a}$	$45.5\ 10^{3a}$	$28.5\ 10^{3a}$	$18.5\ 10^{3a}$	$6.34\ 10^{3a}$
50% PR	Soft wheat Wafia	Control	0^{c}	0^{d}	0^{d}	0^{d}	0^{c}
		T1	$48.5\ 10^{3b}$	$42.5\ 10^{3b}$	$23.5\ 10^{3c}$	$12.5\ 10^{3c}$	$3.25\ 10^{3b}$
		TR-B 98 (2)	$51.03\ 10^{3a}$	$44.5\ 10^{3a}$	$26.25\ 10^{3b}$	$13.5\ 10^{3b}$	$4.55\ 10^{3a}$
		TR-B 98 (3)	$48.5\ 10^{3b}$	$38.75\ 10^{3c}$	$29\ 10^{3a}$	$16.66\ 10^{3a}$	$4.12\ 10^{3a}$
	Duru wheat Amjad	Control	0^{d}	0^{d}	0^{d}	0^{d}	0c
		T1	$45.25\ 10^{3c}$	$34.5\ 10^{3c}$	$18.33\ 10^{3c}$	$15.5\ 10^{3c}$	$3.98\ 10^{3b}$
		TR-B 98 (2)	$47.3\ 10^{3b}$	$36.5\ 10^{3b}$	$21.5\ 10^{3b}$	$16.5\ 10^{3b}$	$5.75\ 10^{3a}$
		TR-B 98 (3)	$51.03\ 10^{3a}$	$44.8\ 10^{3a}$	$22.5\ 10^{3a}$	$18.25\ 10^{3a}$	$5.25\ 10^{3a}$
75% PR	Soft wheat Wafia	Control	0^{d}	0^{d}	0^{c}	0^{d}	0^{c}
		T1	$47.3\ 10^{3c}$	$36.5\ 10^{3c}$	$22.5\ 10^{3b}$	$11.25\ 10^{3c}$	$6.73\ 10^{3a}$
		TR-B 98 (2)	$49.5\ 10^{3b}$	$42.5\ 10^{3b}$	$24.5\ 10^{3a}$	$13.75\ 10^{3b}$	$5.17\ 10^{3b}$
		TR-B 98 (3)	$53.2\ 10^{3a}$	$45.25\ 10^{3a}$	$24.5\ 10^{3a}$	$14.5\ 10^{3a}$	$6.78\ 10^{3a}$
	Durum wheat Amjad	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}
		T1	$51.5\ 10^{3b}$	$38.75\ 10^{3c}$	$18.33\ 10^{3c}$	$10.55\ 10^{3c}$	$4.12\ 10^{3c}$
		TR-B 98 (2)	$49.5\ 10^{3c}$	$44.8\ 10^{3b}$	$21.5\ 10^{3b}$	$12.5\ 10^{3b}$	$6.25\ 10^{3a}$
		TR-B 98 (3)	$54\ 10^{3a}$	$45.25\ 10^{3a}$	$28.5\ 10^{3a}$	$13.5\ 10^{3a}$	$5.33\ 10^{3b}$
100% PR	Soft wheat Wafia	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
		T1	$47.3\ 10^{3c}$	$36.5\ 10^{3c}$	$21.5\ 10^{3c}$	$10.55\ 10^{3c}$	$2.25\ 10^{3b}$
		TR-B 98 (2)	$51.03\ 10^{3b}$	$42.5\ 10^{3b}$	$26.25\ 10^{3b}$	$12.5\ 10^{3b}$	$2.75\ 10^{3b}$
		TR-B 98 (3)	$54\ 10^{3a}$	$44.75\ 10^{3a}$	$28.5\ 10^{3a}$	$14.5\ 10^{3a}$	$3.92\ 10^{3a}$
	Durum wheat Amjad	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
		T1	$48.5\ 10^{3c}$	$38.5\ 10^{3c}$	$19.5\ 10^{3c}$	$10.25\ 10^{3c}$	$3.50\ 10^{3b}$
		TR-B 98 (2)	$52.6\ 10^{3b}$	$44.8\ 10^{3b}$	$22.5\ 10^{3b}$	$12.5\ 10^{3b}$	$2.50\ 10^{3a}$
		TR-B 98 (3)	$53.2\ 10^{3a}$	$45.25\ 10^{3a}$	$23.5\ 10^{3a}$	$13.45\ 10^{3a}$	$2.75\ 10^{3a}$

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

Table 12 Re-isolation of *Trichoderma* from the soil (rhizosphere) of barley plants growing on substrates amended with different doses of rock phosphate, after 80 days of culture.

	Treatments with *Trichoderma*	CFU/g of soil				
		0 Day	20 days	40 days	60 days	80 days
0% PR	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
	T1	$46.3\ 10^{3b}$	$34.5\ 10^{3c}$	$21.5\ 10^{3c}$	$13.5\ 10^{3c}$	$6.3\ 10^{3a}$
	TR-B 98 (2)	$45.8\ 10^{3c}$	$37.25\ 10^{3b}$	$22.5\ 10^{3b}$	$15.5\ 10^{3b}$	$5.4\ 10^{3b}$
	TR-B 98 (3)	$49.3\ 10^{3a}$	$42.5\ 10^{3a}$	$23.5\ 10^{3a}$	$19.5\ 10^{3a}$	$6.25\ 10^{3a}$
25% PR	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
	T1	$48.5\ 10^{3c}$	$43.5\ 10^{3c}$	$22.5\ 10^{3b}$	$14.5\ 10^{3c}$	$5.23\ 10^{3b}$
	TR-B 98 (2)	$50.25\ 10^{3b}$	$45.25\ 10^{3b}$	$21.5\ 10^{3c}$	$15.5\ 10^{3b}$	$5.55\ 10^{3b}$
	TR-B 98 (3)	$53.2\ 10^{3a}$	$48.25\ 10^{3a}$	$26.2\ 10^{3a}$	$17.7\ 10^{3a}$	$6.5\ 10^{3a}$
50% PR	Control	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
	T1	$49.5\ 10^{3b}$	$36.5\ 10^{3c}$	$23.5\ 10^{3c}$	$13.75\ 10^{3c}$	$4.15\ 10^{3b}$
	TR-B 98 (2)	$47.3\ 10^{3c}$	$38.75\ 10^{3b}$	$24.5\ 10^{3b}$	$14.25\ 10^{3b}$	$4.5\ 10^{3b}$
	TR-B 98 (3)	$52.6\ 10^{3a}$	$42.5\ 10^{3a}$	$26.4\ 10^{3a}$	$17.45\ 10^{3a}$	$5.75\ 10^{3a}$

Table 12 Continued.

	Treatments with *Trichoderma*	CFU/g of soil				
		0 Day	**20 days**	**40 days**	**60 days**	**80 days**
75% PR	**Control**	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}
	T1	$48.75\ 10^{3c}$	$36.5\ 10^{3c}$	$23.5\ 10^{3c}$	$12.5\ 10^{3c}$	$4.5\ 10^{3c}$
	TR-B 98 (2)	$51.03\ 10^{3b}$	$42.5\ 10^{3b}$	$26.25\ 10^{3b}$	$13.45\ 10^{3b}$	$5.16\ 10^{3b}$
	TR-B 98 (3)	$52.6\ 10^{3a}$	$47.3\ 10^{3a}$	$28.5\ 10^{3a}$	$15.5\ 10^{3a}$	$6.34\ 10^{3a}$
100% PR	**Control**	0^{d}	0^{d}	0^{d}	0^{d}	0^{c}
	T1	$49.5\ 10^{3c}$	$36.5\ 10^{3c}$	$21.25\ 10^{3c}$	$11.25\ 10^{3c}$	$3.25\ 10^{3b}$
	TR-B 98 (2)	$47.3\ 10^{3b}$	$38.5\ 10^{3b}$	$23.5\ 10^{3b}$	$14.5\ 10^{3a}$	$3.75\ 10^{3b}$
	TR-B 98 (3)	$54\ 10^{3a}$	$47.3\ 10^{3a}$	$26.2\ 10^{3a}$	$13.2\ 10^{3b}$	$4.25\ 10^{3a}$

*Two values read in the same column, for each culture, followed by the same letter are not significantly at the 5% threshold

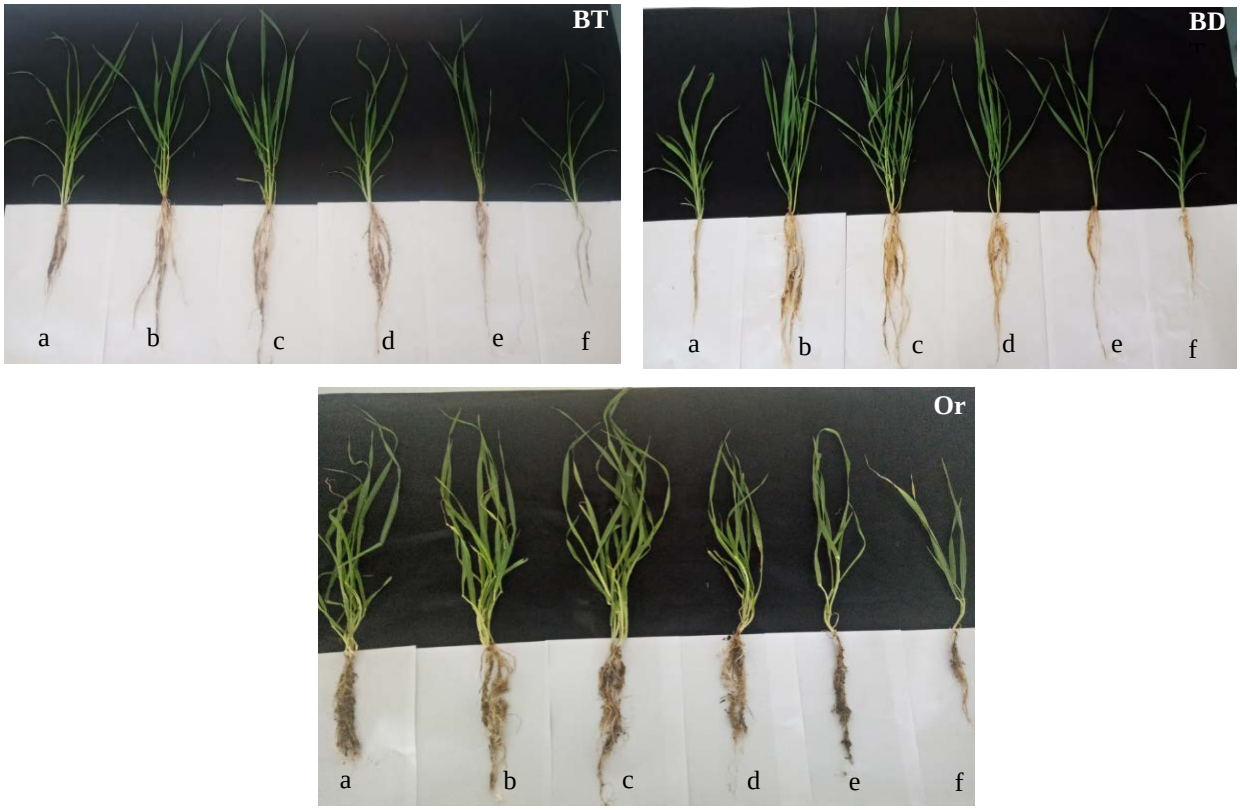


Fig. 2 – Effect of the *Trichoderma* isolate TR-B 98 (3) on the growth of Durum wheat (BD), soft wheat (BT) and barley (Or) plants, growing on different substrates amended with increasing doses of rock phosphate, after 40 days of culture. (a: control; b: 0% PR; c: 25% PR; d: 50% PR; e: 75% PR and f: 100% PR).

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References

Adams P, de Leij FA, Lynch JM. 2007 – *Trichoderma harzianum* rifai 1295–22 mediates growth promotion of crack willow (*Salix fragilis*) saplings in both clean and metal-contaminated soil. Microb Ecol 54: 306–313. Doi: 10.1007/s00248-006-9203-0

Altomare C, Norvell WA, Bjorkman GE, Harman GE. 1999 – Solubilization of phosphates and micronutrients by the plant-growth-promoting and biocontrol fungus. Applied and Environmental Microbiology 65(7); 2926–2923. Doi: 10.1371/journal.pone.0130081.

Altomar C, Tringovska I. 2011 – Beneficial soil microorganisms, an ecological alternative for soil fertility management. In: Lichtfouse E, editors. Genetics, biofuels and local farming systems. *Heidelberg.* Springer 161–214. Doi: 10.1007/978-94-007-1521-9_6

Anonyme. 2019 – Salon des céréales et légumineuses: Entre accès aux nouvelles technologies et promotion des métiers et activités d'avenir. *Agriculture du Maghreb* N 123- Novembre 2019: 14–16. (http://www.agri-mag.com/2019/07/salon-des-cereales-et-legumineuses-de-berrechid-2e-edition/) (Accessed on 12 December 2019)

Arora D, Gaur AC. 1978 – Periodic, microbial, solubilization of 32 P labelled hydroxyapatite. Indian J. Microbiol 18: 193–194. Doi: 10.3389/fmicb.2017.00971

Baker R, 1988 – *Trichoderma* spp. as plant growth stimulants. CRC Crit. Rev. Biotechnol 7: 97–106. Doi: 10.3109/07388558809150724

Baker R, Elad Y, Chet I. 1984 – The controlled experiment in the scientific method with special emphasis on biological control. Phytopathology 74: 1019–1021. Doi: 10.1094/Phyto-74-1019

Besnard O, Davet P. 1993 – Mise en évidence de souches de *Trichoderma* spp à la fois antagonistes de *Pythium ultimum* et stimulatrices de la croissance des plantes. Agronomie 13(5), 413–421. Doi: 10.1051/agro:19930506

Cai F, Yu G, Wang P, Wei Z, Fu L, Shen Q. 2013 – Harzianolide, a novel plant growth regulator and systemic resistance elicitor from *Trichoderma harzianum*. Plant Physiol Biochem 73: 106–113. Doi: 10.1016/j.plaphy.2013.08.011

Chabot R, Antoun H, Cescas MP. 1993 – Stimulation de la croissance du maïs et de la laitue romaine par des microorganismes dissolvant le phosphore inorganique. Can. J. Microbiol 39 (10): 941–947. Doi: 10.1139/m93-142

Chang S-C, Chu WK. 1961 – The fate of soluble phosphate applied to soils. Journal of Soil Science 12(2), 286–293. Doi: 10.1111/j.1365-2389.1961.tb00918.x

Cromey MG, Parkes RA, Fraser PM. 2006 – Factors associated with stem base and root diseases of New Zealand wheat and barley crops. Australasian Plant Pathology 35(4), 391–400. Doi: 10.1071/AP06032

Davet P, Comporota P. 1986 – Étude comparative de quelques méthodes d'estimation de l'aptitude à la compétition saprophytique dans le sol des *Trichoderma*. Agronomie 6(6), 575–581. Doi: 10.1051/agro:19860610

De Santiago A, García-López AM, Quintero JM, Avilés M, Delgado A. 2013 – Effect of *Trichoderma asperellum* strain T34 and glucose addition on iron nutrition in cucumber grown on calcareous soils. Soil Biol Biochem 57: 598–605. Doi: 10.1016/j.soilbio.2012.06.020

El-Yousfi B. 2015 – Guide du diagnostic des principales maladies des céréales d'automne. INRA, CRRA Settat. Pp. 1–13. (http://www.aclimas.eu/Attachment/Brochure%20des%20principales%20maladies%20de%20c%C3%A9r%C3%A9ales%20%20%20version3.pdf) (Accessed on 12 December 2019)

Fankem H, Nwaga D, Deubel A, Dieng L et al. 2006 – Occurrence and functioning of phosphate solubilizing microorganisms from soil palm tree (Elaeis guineensis) rhizosphere in Cameroon. Afr J Biotechnol 5(24):2450–2460. Doi: 10.4314/ajb.v5i24.56044

Fernández LA, Zalba P, Gómez MA, Sagardoy MA. 2007 – Phosphate-solubilization activity of bacterial strains in soil and their effect on soybean growth under greenhouse conditions. Biol Fertil Soils 43(6), 805–80. Doi: 10.1007/s00374-007-0172-3

Gachon L. 1973 – Vieillissement de divers engrais phosphatés en relation avec le type de sol, étudié par la méthode Chang et Jackson. Ann. agron 24(5), 585–613. Doi: 10.1023/A:1011990013955

Gravel V, Martinez C, Antoun H, Tweddell RJ. 2005 – Stimulation de la croissance de plants de tomate en hydroponie par le *Pseudomonas putida* et le *Trichoderma atroviride.* 97e Assemblée annuelle de la Société de protection des plantes du Québec, 9 et 10 juin 2005. Phytoprotection 86(3): 71–79. Doi: 10.7202/018955ar

Harman G-E. 2000 – Myths and dogmas of biocontrol – changes in perceptions derived from research on *Trichoderma harzianum* T-22. Plant Dis 84(4): 377–393. Doi: 10.1094/PDIS.2000.84.4.377

HCP Maroc. 2019 – Annuaire statistique du Maroc, 2018. HCP ed. 692 pages. URL: https://www.hcp.ma/downloads/,(file:///C:/Users/user/Downloads/Annuaire%20Statistique%20du%20Maroc,%20ann%C3%A9e%202018.pdf) (Accessed on 11 January 2019).

Hibar K, Daami-Remadi M, Khiareddine H, El-Majdoub M. 2005 – Effet inhibiteur *in vitro* et *in vivo du Trichoderma harzianum* sur *Fusarium oxysporum* f. sp. *radicis-lycopersici. Biotechnol. Agron.* Soc. *Environ* 9(3), 163–171. Doi: 10.7202/018955ar

Huang X, Chen L, Ran W, Shen Q, Yang X. 2011 – *Trichoderma harzianum* strain SQR-T37 and its bio-organic fertilizer could control *Rhizoctonia solani* damping-off disease in cucumber seedlings mainly by the mycoparasitism. Appl Microbiol Biotechnol 91: 741–755. Doi: 10.1007/s00253-011-3259-6

Kleifeld O, Chet I. 1992 – *Trichoderma harzianum*-interaction with plants and effect on growth response. Plant and Soil 144: 267–272. Doi: 10.1007/BF00012884

Kribel S, Qostal S, Ouazzani TA, Selmaoui K et al. 2019a – Quantitative and qualitative estimation of Moroccan *Trichoderma* isolates capacity to solubilize rock phosphate. *Acta Phytopathologica et Entomologica Hungarica* 54(2): 157–171. Doi: 10.1556/038.54.2019.016

Kribel S, Qostal S, Ouazzani TA, Selmaoui K et al. 2019b – Qualitative and quantitative estimation of the ability of *Trichoderma spp.* moroccan isolates to solubilize tricalcium phosphate. Plant Cell Biotechnology and Molecular Biology 20(7–8): 275–284. (https://www.researchgate.net/publication/334491783_QUALITATIVE_AND_QUANTITATIVE_ESTIMATION_OF_THE_ABILITY_OF_*Trichoderma*_spp_MOROCCAN_ISOLATES_TO_SOLUBILIZE_TRICALCIUM_PHOSPHATE) (Accessed on 11 January 2019).

Kribel S, Qostal S, Ouazzani Touhami A, Selmaoui K et al. 2019c – *In vitro* selection of moroccan phosphate sites' *Trichoderma* isolates according to their antagonism against the wheat and barley root rot pathogens. Plant Cell Biotechnology and Molecular Biology 20(15–16): 682–699. (http://www.ikprress.org/index.php/PCBMB/article/view/4718) (Accessed on 11 January 2019).

Lhaloui S, EL Bouhssini M, Nasserellah N, Amri A et al. 2005 – Les Cécidomyies Des Céréales Au Maroc : Biologie, Dégâts Et Moyens de Lutte. 54p. (https://www.inra.org.ma/fr/content/les-c%C3%A9cidomyies-des-c%C3%A9r%C3%A9ales-au-maroc-biologie-d%C3%A9g%C3%A2ts-et-moyens-de-lutte) (Accessed on 11 January 2019).

Mouria B. 2009 – Contribution à la lutte biologique contre la pourriture grise et la verticilliose de la tomate cultivée sous serre par utilisation du compost et les *Trichoderma* spp. seuls ou en combinaison. Thèse de Doctorat National. Université Ibn Tofail. Faculté des Sciences, Kénitra, Maroc, 295 p.

Mouria B, Ouazzani T-A, Douira A. 2008 – Effet de diverses souches du *Trichoderma* sur la croissance d'une culture de tomate en serre et leur aptitude à coloniser les racines et le substrat. Phytoprotection 88(3): 103–110. Doi: 10.7202/018955ar

Nemec S, Datnoff L, Strandberg J. 1996 – Efficacy of biocontrol agents in planting mixes to colonize plant roots and control root diseases of vegetables and citrus. Crop Prot 15: 735–742. Doi: 10.1080/03235400701453311

Ousley M-A, Lynch J-M, Whipps J-M. 1994 – Potential of *Trichoderma* spp. as consistent plant growth stimulators. Biology and Fertility of Soils 17, 85–90. (https://www.researchgate.net/publication/312599921_POTENTIAL_OF_TRICHODERMA_AS_CONSISTENT_PLANT_GROWTH_STIMULATORS_OF_STRAWBERRY) (Accessed on 11 January 2019)

Ozbay N, Newman SE. 2004 – Biological Control with *Trichoderma* spp. with Emphasis on T. harzianum. Pakistan Journal of Biotechnological Sciences 7 (4): 478–484. Doi: 10.3923/pjbs.2004.478.484

Pozo M-J, Baek J-M, Garcia J-M, Kenerley C-M. 2004 – Functional analysis of tvsp1, a serine protease-encodinggene in the biocontrol agent *Trichoderma virens*. Fungal Genet Biol 41: 336–348. Doi: 10.1016/j.fgb.2003.11.002

Promwee A, Issarakraisila M, Intana W, Chamswarng C, Yenjit P. 2014 – Phosphate Solubilization and Growth Promotion of Rubber Tree (Hevea brasiliensis Muell. Arg.) by *Trichoderma* Strains. Journal of Agricultural Science 6(9): 8–20. Doi: 10.5539/jas.v6n9p8

Rawat R, Tewari L. 2011 – Effect of Abiotic Stress on Phosphate Solubilization by Biocontrol Fungus *Trichoderma* sp. Current Microbiology 62(5), 1521–1526. Doi: 10.1007/s00284-011-9888-2

Saravanakumar SS, Kumaravel A, Nagarajan T, Sudhakar P, Baskaran R. 2013 – Characterization of a novel natural cellulosic fiber from *Prosopis juliflora* bark. Carbohydr Polym 92(2):1928–1933. Doi: 10.1016/j.carbpol.2012.11.064.

Vinale F, Marra R, Scala F, Ghisalberti E-L, Lorito M, Sivasithamparam K. 2006 – Major secondary metabolites produced by two commercial *Trichoderma* strains active against different phytopathogens. Lett Appl Microbio 43: 143–148. Doi: 10.1111/j.1472-765X.2006.01939.x

Warcup J-H. 1950 – The Soil-Plate Method for Isolation of Fungi from Soil. Nature 166(4211), 117–118. Doi: 10.1038/166117b0

Windham M-T, Elad Y, Baker R. 1986 – A mechanism for increased plant growth induced by *Trichoderma* spp. Phytopathology 76: 518–521. Doi: 10.1111/jam.13245

Yadav J, Verma J-P, Tiwari K. 2011 – Plant Growth Promoting Activities of Fungi and their Effect on Chickpea Plant Growth. Asian Journal of Biological Sciences 4(3): 291–299. Doi: 10.3923/ajbs.2011.291.299

Yedidia I, Benhamou N, Chet I. 1999 – Induction of Defense Responses in Cucumber Plants (*Cucumis sativus* L.) by the Biocontrol Agent *Trichoderma harzianum*. Applied and environmental microbiology 65(3); 1061–1070. Doi: 10.1128/AEM.65.3.1061-1070.1999

Yedidia I, Srivastva A-K, Kapulnik Y, Chet I. 2001 – Effect of *Trichoderma harzianum* on microelement concentrations and increased growth of cucumber plants. Plant and soil 235(2), 235–242. Doi: 10.1023/A:1011990013955

Zidane I, Guines D, Léotoing L, Ragneau E. 2010 – Development of an in-plane biaxial test for forming limit curve (FLC) characterization of metallic sheets. Measurement Science and Technology 21, (5), 055701. Doi: 10.1088/0957-0233/21/5/055701