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Nano-irrigation: Hydraulic characteristics of the line-source emitters as a function of pressure heads under different soil types and bulk densities

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Abstract

The soil water discharge of line source emitters under Moistube irrigation, commonly called nano irrigation, was investigated. Moistube is a pipe made of flexible semi-permeable membranes that has recently been used in Morocco to further minimize water consumption relative to drip irrigation. Being a relatively new technology, it is still in the experimental stage, therefore, there is little data on the critical parameters that would improve the water use efficiency. Before starting the field trials to test the system on crops, a series of soil box experiments were carried out to examine the water dynamics and discharge of laterals under two soil types at different pressure heads and at different dry bulk densities. The results showed that the discharge decreased when the laterals were buried compared to non-buried laterals, and decreased further with the compaction of the soil. The laterals discharge showed a decreasing trend as the soil texture becomes finer and the discharge decreases even more with soil compaction of the tested textures. We also found that the measured discharge at 2 m pressure head for the non-buried laterals was far greater than the value declared by the manufacturer. The exponent values of the fitted power function equations were much greater than 1, showing a laminar flow regime of the laterals and high sensitivity to pressure changes. The coefficient of variation was within the acceptable range (< 20%) and decreases with increasing operating pressure. Overall, our results suggest that 1) soil texture and compaction affect the laterals discharge and should be considered in the design of nano irrigation system in terms of laterals depth and spacing, , 2) make sure to adopt a suitable design or shorten the laterals in response to their high sensitivity to pressure changes, 3) as the technology is new and is still in its experimental stage, tests that mimic field conditions are still important before installation to achieve a homogeneous laterals discharge. Our findings would provide a preliminary basis to help professionals to design the system in Morocco.

Keywords: Nano-irrigation, Moistube, soil suction, discharge, pressure head, coefficient of variation

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Nano-irrigation : Caractéristiques hydrauliques des émetteurs à source linéaire en fonction des pressions manométriques sous différents types et densités apparentes de sol

Résumé

Le flux d'eau dans le sol par des émetteurs de source linéaire sous irrigation Moistube, communément appelée nano-irrigation, a été étudiée. Le Moistube est un tuyau composé de membranes semi-perméables flexibles qui a été récemment utilisé au Maroc pour minimiser davantage la consommation d'eau par rapport à l'irrigation goutte à goutte. Étant une technologie relativement nouvelle, elle est encore au stade expérimental, par conséquent, il existe peu de données sur les paramètres critiques qui amélioreraient l'efficacité de l'utilisation de l'eau. Avant de commencer les essais sur le terrain pour tester le système sur les cultures, une série d'expériences en boîtes de sol ont été réalisées pour examiner la dynamique de l'eau et le débit des rampes sous deux types de sol à différentes hauteurs de pression et à différentes densités apparentes. Les résultats ont montré que le débit diminuait lorsque les rampes étaient enfouies par rapport aux rampes non enfouies, et diminuait davantage avec le compactage du sol. Le débit des rampes a montré une tendance à la baisse à mesure que la texture du sol devient plus fine et le débit diminue encore plus avec le compactage du sol pour les textures testées. Nous avons également trouvé que le débit mesuré à 2 m de hauteur manométrique pour rampes non enterrées était bien supérieur à la valeur déclarée par le fabricant. Les valeurs des exposants des équations de la fonction de puissance ajustées étaient bien supérieures à 1, montrant un régime d'écoulement laminaire des rampes et une sensibilité élevée aux changements de pression. Le coefficient de variation était dans l'intervalle acceptable (< 20 %) et diminue avec l'augmentation de la pression de fonctionnement. Dans l'ensemble, nos résultats suggèrent que 1) la texture et le compactage du sol affectent le débit des rampes et devraient être pris en compte dans la conception du système de nano-irrigation en termes de profondeur et d'espacement des rampes, 2) assurer une conception appropriée ou raccourcir les rampes en réponse à leur grande sensibilité aux variations de pression, 3) comme la technologie est nouvelle et en est encore à son stade expérimental, les tests qui imitent les conditions de terrain sont toujours importants avant l'installation pour obtenir un débit homogène des rampes. Nos résultats fourniraient une base préliminaire pour aider les professionnels au dimensionnement du système Nano irrigation au Maroc.

Mots clés : Nano-irrigation, Moistube, succion du sol, débit, hauteur manométrique, coefficient de variation

الري بالنانو :الخصائص الهيدروليكية لأنابيب ذات سيلان خطي تحت ضغوط مانومترية لأنواع وكثافات المختلفة للتربة

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ملخص

في هذا البحث، تمت دراسة تدفق مياه التربة لأنابيب ذات سيلان خطي تحت نظام الري Moistube، والذي يشار إليه عادة بالري بالنانو. Moistube عبارة عن أنبوب مصنوع من أغشية مرنة شبه منفذة تم استخدامها مؤخرًا في المغرب لتقليل استهلاك المياه أكثر مما هو عليه بالنسبة للري بالتنقيط الموضعي. نظرًا لكونها تقنية جديدة نسبيًا، فهي لا تزال في المرحلة التجريبية، وبالتالي، هناك القليل من البيانات التي من شأنها تحسين كفاءة استخدام المياه.

قبل البدء في التجارب الميدانية لاختبار النظام على المحاصيل، أجريت سلسلة من تجارب في صناديق من التربة لفحص ديناميكيات المياه وتدفق الأنابيب على نوعين من الأتربة عند ضغوط بارتفاعات مختلفة وبكثافات كتلة التربة مختلفة. وأظهرت النتائج انخفاض تدفق المياه بالنسبة للأنابيب المغطاة بالتربة (التحت أرضية)مقارنة بالأنابيب الغير مغطاة. أظهر تدفق الأنابيب إنخفاضا كلما .كان نسيج التربة أثقل ويقل التدفق أكثر مع انضغاط التربة .وجدنا أيضًا أن التدفق عند ضغط مترين علو للخزان بالنسبة للأنابيب غير المغطاة بالتربة كان أكبر بكثير من القيمة المعلنة من قبل الشركة المصنعة. كانت قيم الأس لمعادلات الدالة الأسية أكبر بكثير من1 ، مما يدل على نظام جريان صفيحي للأنابيب وحساسيتها العالية لتغيرات الضغط .كما لوحظ أن معامل الاختلاف وينخفض مع زيادة ضغط التشغيل20) ٪ (<ضمن النطاق المقبول.

بشكل عام، نتائجنا تشير إلى أنه 1(يجب مراعاة نسيج التربة وكثافتها في تصميم نظام الري بالنانو من حيث العمق والتباعد بين الأنابيب2(حيث أن التكنولوجيا جديدة، ولا تزال في مرحلتها التجريبية، فإن الاختبارات التي تحاكي الظروف الميدانية لا تزال مهمة قبل التثبيت لتحقيق تفريغ متجانس للأنابيب (3 التأكد من اعتماد تصميم مناسب أو تقصير الأنابيب استجابةً لحساسيتها العالية لتغيرات الضغط .ستشكل النتائج التي توصلنا إليها أساسًا أوليًا لمساعدة المهنيين على تصميم نظام النانو في المغرب.

الكلمات المفتاحية: الري بالنانو، الأنبوب المسامي، شفط التربة، التدفق، الضغط المانومتري، معامل الاختلاف.

Introduction

Irrigation with the porous tube (PT) system was originated and has been used since the 1970s (Fok and Willardson, 1971; Hermia, 1982; Lomax *et al.*, 1986). PT works like a clay pot (Ashrafi *et al.*, 2002; Cai *et al.*, 2017); additionally, it conveying and at the same time emitting water throughout its entire length under pressure. It can be used at the soil surface or subsurface and aims to provide water to crops by leakage while minimizing water consumption, particularly in arid and semi-arid areas where water is scarce. Several authors have evaluated different characteristics and aspects of the PT irrigation system (Lomax *et al.*, 1986; Yoder and Mote, 1995; Teeluck and Sutton, 1998; Khoramian and Mirlatifi, 2000). However, the PT technique was neglected for a while because of the cost of the upscaling, but particularly due to the technical difficulties and problems encountered during the implementation of the system. Among those problems a continuous decline of PT discharge, the surrounding soil clogging the micropores, clogging by fouling process, high sensitivity to the change of the operating pressure, size of micropores causing water percolation, heterogeneity of emission with respect to the PT length, tearing in swelling clays, reuse duration, unsustainable manufacturing material, recovery during ploughing (Yoder and Mote, 1995; Teeluck and Sutton, 1998; Liang *et al.*, 2009; Janani *et al.*, 2011).

Lately, with technological advances the porous tube system has been improved to produce systems made up of material and technology with less technical problem. These are generally tubes made of flexible /elastic material with smaller micropores up to nanopores, resistant to critical field conditions and which save irrigation water and energy better than drip systems (Wang *et al.*, 2016; Makavana *et al.*, 2018). There is a variety on the market called by different other names. In Morocco, it is the Moistube, commonly known as the Nano-tube or nano irrigation system which is the best known among others and which is becoming to be tested by several farmers (Yang *et al.*, 2008; Zou *et al.*, 2017). The Moistube irrigation system is a newly developed technology and currently used in China (Yang *et al.*, 2008; Dirwai *et al.*, 2021a). Instead of PT micropores, water flows through nanopores of flexible semi-permeable membranes with approximately 100,000 nanopores per square centimeter and with a pore diameter range of 10 to 900 nm (Zou et al., 2017). The review of Dirwai et al. (2021a) declared limited studies on the Moistube system and that in Africa it is South Africa and lately Morocco that uses the technology so far. Some studies have focused on the hydraulic characteristics of the Moistube, others on the response to crop yield and water use efficiency (Dirwai *et al.*, 2021a). Although studies related to yield response and water use efficiency have shown contrasting results (usually due to technical issues) the technology remains generally promising but is still in the experimental stage and therefore has not been applied on a large scale, and some critical parameters ought to be optimized.

The Regional Centre for Agricultural Research of Agadir in Morocco, considered carrying out field trials on alternative crops under Moistube to test the effectiveness and efficiency in term of water use compared to drip irrigation. Since the technology is still unknown, and the major factors in the design of Moistube system are not yet mastered by suppliers and professionals, we first came to carry out laboratory tests on

the hydraulic characteristics of the system in relation to important soil parameters. The tests results will allow us to better design and manage subsequent field experiments. In this paper, we present a series of laboratory tests to examine the water dynamics and discharge of Moistube laterals at different pressure heads under two soil types and compactions, important soil properties, that underpin successful irrigation management. This would show how PT discharge changes with changing soil properties and operating parameters which would help in determining the appropriate parameters which aided in the design of Moistube system and would improve water use efficiency.

Materials and methods

Experimental design

Comparative tests of the Moistube discharge were carried out under different conditions: i) operating pressure range of 2 to 5 m head equivalent to 5 different heights of graduated water tank, ii) free-soil tube, iii) under Loamy-Sand and Loamy soil textures, iv) compacted and uncompacted soils. The length of the Moistube (Micro-run tube; Shenzhen Moistube Irrigation Tech. Co., LTD, Item No. 08589, Model D) used was kept at 1 m (Kanda *et al.*, 2018) and the measurements were made on different laterals (n = 4) of 1 meter for each parameter. Each replicate lateral was used only once for each test combination and then discarded. This will avoid any bias or effect on the laterals during previous tests. A similar number of replicates (4) was previously used by Kanda et al. (2018).

Figure 1 shows the experimental set-up. For the free-soil laterals (n = 4), the measurements were made at 8 different water tank hights (at 1.7, 2.0, 2.25, 3.0, 3.5, 4.0, 4.7 and 5 m respectively). For the measurements within the soils, the Moistube lateral (n = 4) were carefully laid at 15 cm depth of a wooden box (30 cm deep, 105 cm long x 31.5 cm wide) filled with soil. The placement depth of laterals depends on the interaction between crop, soil type, soil evaporation losses, and deep percolation of water. 15 cm was the proper placement depth recommended by the manufacturer for vegetables in light soils. The laterals discharge was then measured for Loamy-Sand and Loamy soil textures under compacted and uncompacted conditions and for 5 different pressure heads (at 2.0, 3.5, 4.0, 4.7 and 5 m respectively). The degree of compaction was measured in terms of dry bulk density.

The Loamy-Sand was collected at the INRA experimental station of Melk Zhar in Belfaa. The loamy soil was collected in an orchard near the INRA Regional Center in Ait Melloul. The basic soils properties are summarized in Table 1. Due to logistic limitations when filling the box with soil, the pressure heads were kept at only 5 measuring points compared to free-soil laterals with 8 measuring points. For all the tests, the Moistube discharge was calculated as the difference between water levels of the graduated tank over 24 hours. The calculated volume difference for free-soil laterals was compared against the volume of discharged water which was collected at the end of the test using a graduated cylinder.

The experimental design allowed us to assess the emission uniformity of the Moistube laterals under the different experimental conditions. Uniformity of emissions is an important parameter for the design of the irrigation system to ensure the homogeneity of the water distribution in the field. Uniformity of emissions was determined by measuring the discharge of a 1 m long lateral in four replicates for each test combination (with-and-without soil x pressure heads x soil textures x compactions). For the free-soil tests, the Moistube lateral was laid horizontally in a plastic box. The volume of water discharged was collected at the end of each repetition using a graduated cylinder. This volume of water was compared against the volume calculated as the difference between the water levels of the graduated tank over 24 hours. For the soil tests, the water volume was only determined as the difference between the water levels in the tank graduated over 24 hours. The uniformity of emissions then was assessed by calculating the coefficient of variation (CV) of the manufacturer following the Laing et al., (2009) functions (equation 1).

The emission uniformity equation $$\%\mathbf{CV} = \frac{S}{Q} x\ 100 \quad (1)$$

Where CV is coefficient of variation, S is standard deviation of laterals discharge (L h^{-1} Lm^{-1}), Q is average of laterals discharge (L h^{-1} Lm^{-1}). The discharge of the Moistube was represented as a power function according to the equation

The discharge-pressure equation $$Q = krH^x \quad (2)$$

Where Q is emitter flow rate (L h^{-1}), k is a constant of proportionality, H is pressure head at emission source, and x is emitter flow exponent.

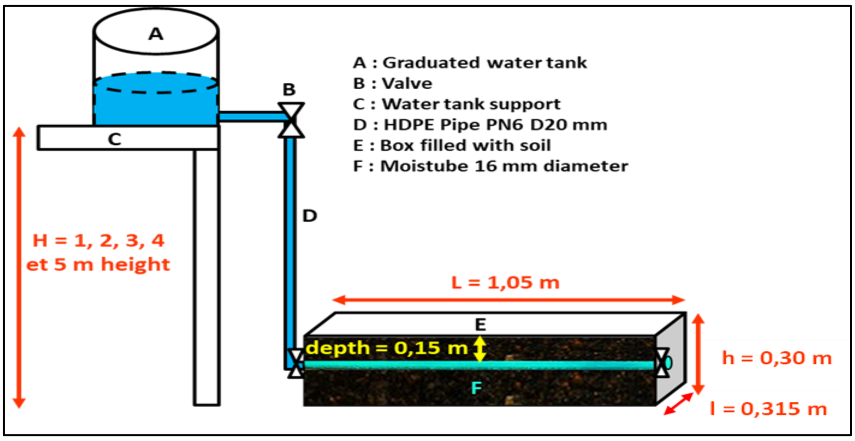

Figure 1: The laboratory experimental design. H refer to the different water tank hights (1.7, 2.0, 2.25, 3.0, 3.5, 4.0, 4.7 and 5 m for the free-soil laterals and 2.0, 3.5, 4.0, 4.7 and 5 m for the measurements within the soils).

Table 1: Physical and chemical properties of the soils used for the laboratory experiment (n = 4, mean ± standard deviation).

pH[1]	**Organic matter[2] (%)**	**Electrical conductivity (dS m^{-1})[3]**	**Available phosphorus P_2O_5 (ppm)[4]**	**Potassium K^+ (ppm)[5]**	**Total limestone[6]**	**Clay (%)[7]**	**Silt (%)[7]**	**Sand (%)[7]**	**Textural class**
						< 2 µm	**2-50 µm**	**50-2000 µm**	
7.85 ± 0.11	0.59 ± 0.32	0.15 ± 0.69	31.02 ± 11.97	293.55 ± 41.06	14.05 ± 0.85	8,80 ± 1,52	8.47 ± 1,56	82.99 ± 1,57	Loamy Sand
7,37 ± 0.07	1.04 ± 0.17	0.26 ± 0.08	5.32 ± 1.93	236.87 ± 25.84	4.50 ± 0.55	7,70 ± 1,11	41.02 ± 1,66	51.28 ± 0,96	Loamy

[1] *Determined using a ratio of 1: 2.5 (soil: water).*
[2] *Soil organic matter content determined by the Walkley-Black chromic acid wet oxidation method.*
[3] *Electrical conductivity on 1:5 soil: water.*
[4] *Available phosphorus using the Olsen method.*
[5] *The exchangeable bases with ammonium acetate extract.*
[6] *The total carbonate using the Bernard calcimeter test analyses.*
[7] *The particle size analysis using the hydrometer method.*

Results and discussion

Effect of pressure head on the laterals discharge

Figure 2 shows the mean discharge of the Moistube in liters per hour per linear meter as a function of the operating pressure for non-buried pipes (Free-soil laterals) and for loamy sand soil under compacted conditions (dry bulk density of 1.19 g cm^3) and uncompacted conditions (dry bulk density of 1.19 g cm^3). The discharge of the non-buried Moistube laterals varies from 0.38 ± 0.07 L h^{-1} Lm^{-1} at 1.7 m to 2.24 ± 0.18 L h^{-1} Lm^{-1} at 5 m pressure head. The discharge decreased when the laterals were buried, and decreased further with the compaction of the soil. The soil overburden would have decreased the Moistube laterals flow rate. The friction head loss would have increased due to the compression by soil overburden (Hills *et al.*, 1989) which would have deformed laterals from the circular into an elliptical shape and thus would have reduced the flow. The compression effect was more susceptible with increasing soil compaction and would have decreased water flow further (Gil *et al.*, 2008; Watkins *et al.*, 2010; Bammami, 2015). The likely partly-clogged laterals when burying and compacting the soil would also have reduced the flow. The extension of the three curves towards the Y axis at the corresponding pressure head of 0, shows that the flow rate of the Moistube laterals is close to zero. This is consistent with previous studies (Zhang, 2013; Niu *et al.*, 2017; Kanda *et al.*, 2018; Dirwai *et al.*, 2020) indicating that operating pressure is the primary factor controlling the system, then the water potential of the soil would have an additional impact on the discharge. However, looking at buried laterals, and in contrast to those studies, the suction effect of the surrounding soil would be negligible at very low operating pressures and would tend to be zero at zero pressure.

To help characterize the flow regime, the discharge of the Moistube was represented as a power function according to the equation (2) of Keller et al., (1974). The lower the value of the exponent of the equation, the less discharge will be affected by pressure variations. In the fully turbulent flow regime, the value of the exponent is 0.5, in the fully laminar regime the value of the exponent is 1, and values less than 0.5 indicate a self-regulating flow-pressure with approx. zero for fully pressure-compensating conditions (Karmeli, 1977). In Figure 2, the power function equations of the non-buried and buried Moistube laterals show exponent values much greater than 1, indicating that in addition to being a laminar flow regime, the Moistube laterals are highly sensitive to pressure changes. This suggests that the Moistube laterals should be shortened when installing the system or adopt a design where minimum pressure requirements for users in addition to minimum and maximum flow velocities restrictions apply (e.g looped irrigation water distribution networks).

Figure 2 shows a discharge of 0.47 ± 0.10 L h^{-1} Lm^{-1} at 2 m pressure head for the Free-soil laterals, which is far greater than the value reported by the manufacturer; 0.16 L h^{-1} Lm^{-1} at 0.2 bar. In contrast to our findings, the tests of the Hydraulic and Standardization Laboratory of Morocco reported an average, max and min flow of 0.16, 0.22 and 0.14 L h^{-1} Lm^{-1} respectively, at a pressure head of 2 m (tests report number 9261-IL-3256-09-18). It is possible that the difference in outputs reflect differences in experimental design between our study and others. In our study, we tried to mimic field conditions by using water tanks at different heights rather than pressure pumps for a short period of time. To avoid an underestimation of the resulting flow rates, the laterals were first immersed in a water box for a period of more than 24 hours, than the

discharge tests were run for 24 hours. When the newly tested laterals (made of elastic material) are filled with water, the pores gradually increase in size and the discharge takes time, causing the flow values to drop in the first testing hours. This is particularly true when low pressure head were applied and when laterals were used for the for the first time. Thus, within the limitations of the number of replicates, they are still higher than the statistical requirements for similar research work (≥ 3 replicates) and therefore one can have confidence in the results of the tests carried out. This highlights the point that caution should be exercised when handling the data and that tests that use more realistic conditions would be required for a better installation of the system in the field in order to correctly meet the crop water requirements.

We would also like to point out that the tests of the Hydraulic and Standardization Laboratory of Morocco (SEEN) were carried out at pressure heads of between 1 and 2.5 m. In practice, professionals typically recommend placing the water supply tanks between 3 and 5 meters in height. This suggests that more tests are requested from the SEEN, including larger pressure heads before being used by Moroccan farmers. Even if we had 4 replicates per test combination, in our study we made tests up to 5 m in height and we calculated the parameters of the discharge-pressure equation accordingly. This gave an overview of the flow-pressure law for that interval (Figure 2).

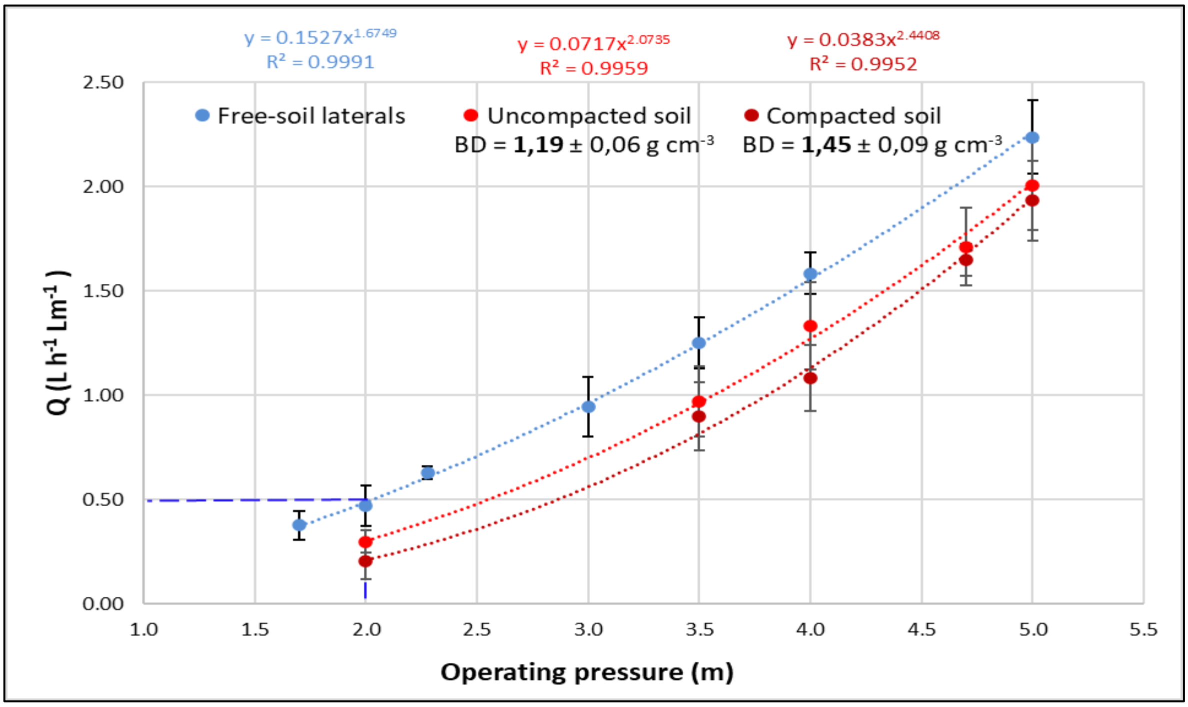

Figure 2: The mean discharge of the Moistube as a function of the operating pressure for the Free-soil laterals (blue curve) and for loamy sand soil under compacted conditions (brown curve) and uncompacted conditions (red curve). The colored equations are the regression equations corresponding to the lines of best fit to the data for each curve at the 95% confidence intervals. BD = bulk density of compacted and uncompacted soils; (*n* = 4 replicates, error bars = standard deviations).

Effect of soil texture and soil compaction

The Figure 3 below shows the flow rate of the Moistube laterals at different soil textures and compactions for a tank placed at 4.7 m height. Because laterals discharge determination within the soil with enough replicates takes a considerable time to complete, the comparative measurements were limited to two soil textures with two degrees of compaction and at a single pressure head. The chosen pressure head of 4.7 m corresponds to the height of irrigation water reservoirs from a subsequent field experiment (data not reported in this paper) to this laboratory experiment. The masses of soil of different textures occupying a comparable volume are different, which is why we observe in Figure 3 different dry bulk densities for uncompacted treatments and for compacted soil treatments. Even not significant, the laterals discharge showed a decreasing trend as the soil becomes heavier (Figure 3). The different soil textures would have more impact on the soil-water distribution, on the wetting patterns and on geometry (Kanda *et al.*, 2020a; Dirwai *et al.*, 2021b). Qualitative observations in our study showed a wetter soil surface in Loamy soils than in Loamy sand soils. Kanda et al. (2020c) showed that at different depths the wet volume under Moistube was greater in coarser textured soils than in finer textured soils. However, the water content in coarser textured soils was significantly lowest in upward and highest in downward directions, while there were no significant differences in all directions for the finer textured soil. This soil texture-water dynamic relationship implies deeper pipes depth and larger lateral spacing in fine-textured soils than in coarse-textured soils in terms of pipe depth and lateral spacing when designing the system (Kanda *et al.*, 2020a, c b). Figure 3 shows that the discharge decreases even more with soil compaction for both textures. The decrease in Moistube discharge with increasing soil dry bulk density is consistent with the findings of Peng et al. (2019). This considerably decreased the wetted soil volume and the water infiltration capacity with the increasing dry bulk density of the soil. Our results suggest that soil texture and compaction should be considered in the design of Moistube irrigation system in terms of laterals depth and spacing while maintaining a wet rhizosphere and balance between a dry surface and low losses through deep percolation. The review of Kanda et al. (2020) of suggested an utmost 20 cm laterals depth for different studied vegetable crops and soil textures. However, the installation depth is very sensitive to the operating pressure, therefore the findings from the literature should be treated with more caution.

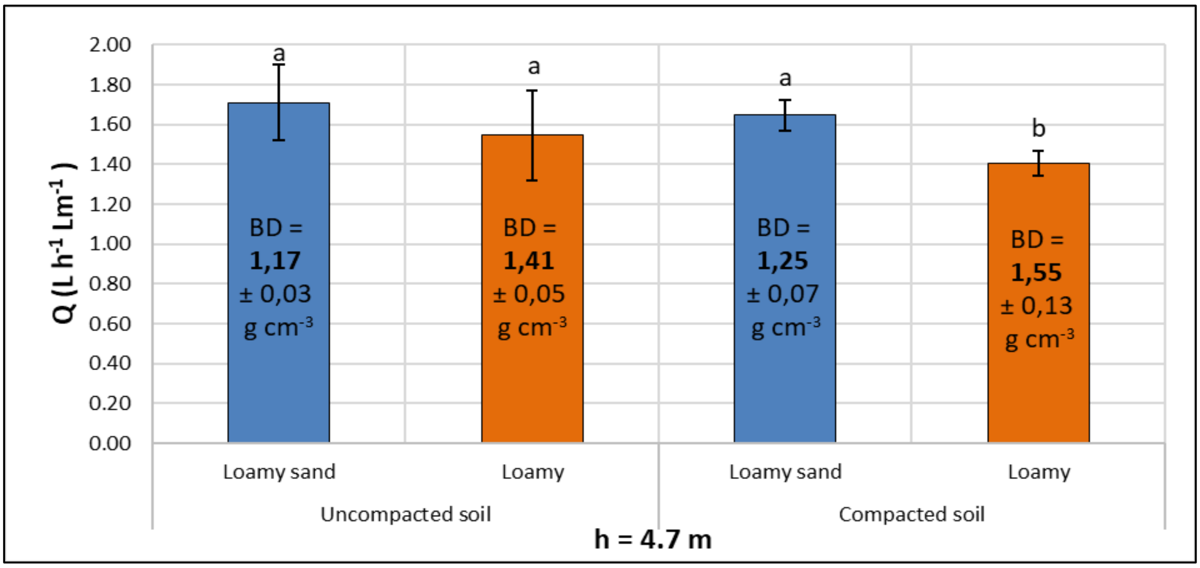

Figure 3: Mean discharge of the Moistube laterals at an operating pressure head of 4.7 for each soil texture and soil compaction. BD = dry bulk density of compacted and uncompacted soils. Columns with the same letter over them are not significantly different (*n* = 4 replicates, error bars = standard deviations).

Effect of pressure head on the performance of the Moistube

The performance of the Moistube was assessed by measuring the uniformity of emissions. The coefficient of variation (%CV) at different operating pressures and under two different soil textures and compactions is shown in Figure 4. The CV varied between 4.32% and 18.86%. The lower the CV is, the higher the uniformity of the emission rate, and the more we ensure that the crop gets the required amount of water. For point-source emitters (e.g., drip irrigation) the appropriate CV would be around 5 % (Hezarjarib *et al.*, 2008), however, the acceptable range for line source emitters (e.g., Moistube) is less 20% (Teeluck and Sutton, 1998). Our results are similar to the findings of Kanda et al. (2018) and are better than those found on porous pipe made up of recycled automobile tyres (Teeluck and Sutton, 1998). Figure 4 shows that the% CV decreases with increasing operating pressure for the free-soil laterals or in soil with different textures and compactions. The increase in pressure head would have led to increasing in the diameter of the pores of the Moistube. However, we couldn't identify any significant differences or trends for the effect of soil texture and soil compaction. Perhaps our data were not enough therefore the statistically significant trends were the same. Further testings are, however, required to better understand how soil texture and compaction impact the emission uniformity of the Moistube.

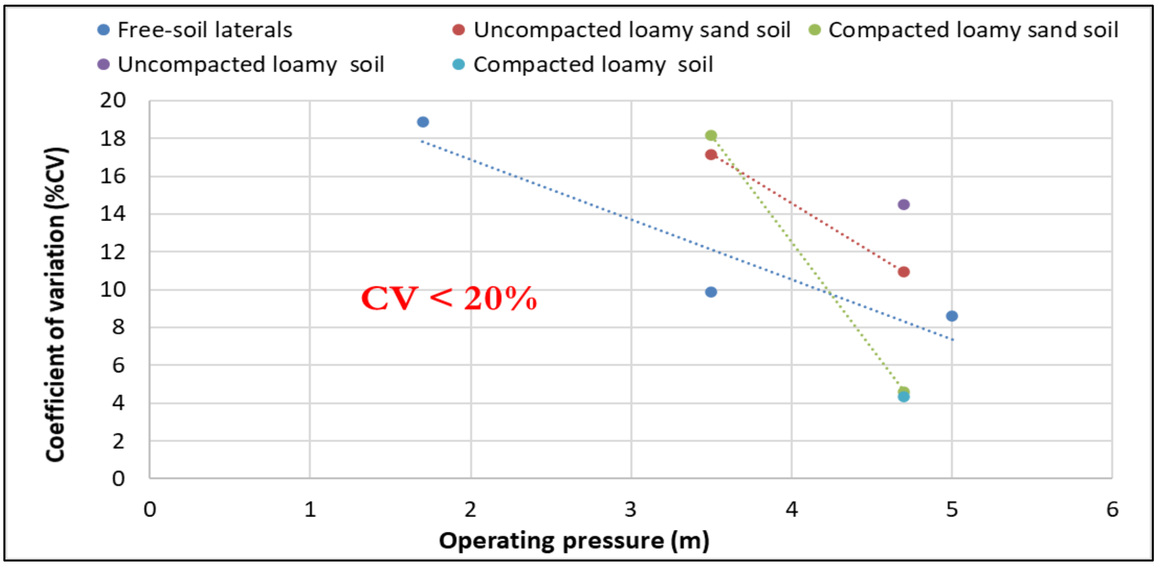

Figure 4: Coefficient of variation of the Moistube laterals (*n* = 4 replicates of tested Moistube laterals by calculated coefficient) as a function of varying operating pressures under two different textures and soil compactions.

Conclusion

Before starting the field trials on the crops, we decided to determine the parameters that would allow better installation of the Moistube irrigation system, a relatively new system not yet well Known. We mainly examined the water discharge of Moistube laterals at different pressure heads under two soil types and with and without soil compaction. Our findings suggest that the dry bulk density and texture of the soil are very important parameters which influence the lateral discharge and would help to improve the design of the system. The high sensitivity of the laterals to smaller pressure changes would be an issue to successfully achieve a homogeneous discharge in the field. Shorter laterals or a looped irrigation water distribution networks would help to solve the problem. With the likely conditions of soil compaction in the field, a reduction in the laterals length should be considered to maintain the initial uniformity of the system. To maintain a relatively dry soil surface and a humid subsoil, our observations during the tests indicate that for a sandy soil with regular compaction the installation depth of the laterals of 20 cm can be recommended particularly for vegetable crops. As the technology is still in its experimental stage, caution should be exercised when generalising the results and tests that mimic field conditions are still important before installation to achieve a homogeneous laterals discharge. The Hydraulic and Standardization Laboratory of Morocco is requested to perform further tests on laterals including pressure heads up to 5 m before being used by Moroccan farmers. Further parameters and factors need to be examined either in the laboratory or under field conditions. This would help provide sufficient information for a successful conception. Installation cost and energy consumption/efficiency compared to drip irrigation are two important areas to investigate, they are critical in choosing the appropriate irrigation system to adopt.

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