The Effect of Using Solarized and Methanized Manure on Weeds Control in Eastern Moroccan Saffron Cultivation

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Abstract

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Cultivated for its red stigmas, saffron is arguably the most expensive and precious spice in the world. However, saffron production is limited by a number of factors, including weed infestation which causes damage to this crop both quantitatively and qualitatively. Solarization and anaerobic digestion are techniques used to control weeds and plant diseases. It is for this purpose an experiment was conducted in 2018 with an objective to compare solarized manure and that resulting from anaerobic digestion on the development of weeds associated with saffron crop. During the trial, the parameters measured correspond, on the one hand, to morpho-metric measurements and the determination of saffron stigmas yield and, on the other hand, to the determination of density, dry biomass and weed control capacity. In this study, 16 weed species were recorded. The two treatments applied reduced weed density and biomass by about 55% of the weed species, including problematic species such as *Cynodon dactylon*, *Cyperus rotundus* and *Convolvulus arvensis*. However, there was no effect of manure treatment (T2, T3) on the populations of *Chenopodium album*, *Aster squamatus* and *Medicago truncatula*. The average stigmata yield from the addition of digested manure was 4% higher than the control. Similarly, the number, weight and percentage of daughter corms with a large diameter were higher for plants grown on treated manure. It was concluded that the incorporation of treated manure as a soil amendment slightly increased saffron yield and effectively controlled more than half of the weed species present.

Keywords: Solarization, saffron, weeds, management strategies, manure, anaerobic digestion.

Introduction

Saffron has been cultivated as a spice since ancient times (less than 3,500 years ago), and It has crossed several continents and civilizations. Throughout history, it is one of the most expensive substances in the world. Although Morocco is a small producer of saffron, its quality is highly regarded nationally and internationally. From the point of view of edapho-climatic requirements, saffron is a hardy plant, thanks to its morphology and physiology, it can withstand very severe climatic conditions (Ghoulam *et al*., 2002; Mzabri *et al.*, 2017b), which makes it one of the crops of the future for Morocco, especially with the climate changes that are becoming more and more affecting the growth and development of cultivated plants (Mzabri *et al*., 2017a).

However, saffron production is limited by several factors, including weed infestation. This is because saffron is a small, slow-growing plant that does not provide a well-developed aerial part (Maia Júnior *et al.,* 2018), and the dense and rapid growth of weeds intensifies the damage to the saffron crop. Being a perennial crop, saffron is infested by different types of annual, biennial, and perennial weeds. Rimani *et al.* (2019) classified *Convolvulus arvensis*, *Bromus rubens*, *Lolium perenne*, *Hordeum murinum*, *Isatis tinctoria*, *Malva parviflora*, *Lamium amplexicaule* among the twelve most problematic saffron weeds in Morocco. Manual weeding is the method most used by Moroccan farmers, however, this practice is time-consuming and labour intensive, which reduces the profit margin of small and medium-sized farmers.

In Morocco, the practice of saffron fertilization is carried out by adding manure at the time of soil preparation. However, manure is a source of dissemination of viable weed seeds and thus the contamination of cultivated plots (Mkhabela & Materechera, 2003). Therefore, special attention should be paid to improve saffron yield by using more hygienic sources of fertilizer.

Given the renewed interest in biogas technology in Morocco, the use of digestate as a fertilizer or organic amendment in cultivated soils has begun to gain momentum. This comes down to the fact that it presents a minimal risk of transmission of bacteria, viruses, and weed seeds. Research results showed that anaerobic digestion effectively reduces the germination capacity of plant seeds present in the raw materials (Sahlström, 2003; Sahlström *et al.,* 2008). According to Angelidaki & Ellegaard (2003), a thermophilic treatment (anaerobic digestion) at a temperature of at least 52°C and a guaranteed minimum retention time of 10 h effectively corresponds to controlled sanitation at 70°C for 1 h. Most problematic weeds and pathogens are eliminated under these conditions. Furthermore, the solarisation of manure is considered among the alternatives to reduce the risk of crop contamination by biotic agents. It is a safe, simple, effective, and environmentally friendly tool (Cimen *et al*., 2010; Kapoor, 2013). The application of this method,

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alone or in combination with other techniques, has proven effective in eradicating weeds including those resistant to selective herbicides (Elmore *et al.,* 1997). The preventive action of solarisation on reducing weeds seed density makes it possible to reduce chemical treatments and employ cultural practices for saffron crop management.

Weed control is an important and costly aspect to consider when planning the production of any agricultural crop (Jenni *et al*., 2004). In general, the combination of these control methods can be an effective alternative to minimise losses caused by weed infestation in saffron cultivation.

However, little information is available on the effectiveness of these biological weed control methods for the cultivation of saffron in Morocco. The objective of this study is to test the effect of solarised and methanised manure on the control of weeds in the cultivation of saffron in eastern Morocco.

Materials and method

Site characteristics

The experiment was conducted in the open field at the experimental research station of the Faculty of Science of Oujda, located in the eastern region of Morocco at an altitude of 661 m and at 34° 39'06 -71" north and 01° 53'58 -80" west (GPS Back Track Bushnell). The climate of the area is semi-arid characterized by temperate winters. During the test period, rainfall was modest with an average of 226 mm. The average annual temperature is 18° C, reaching 29° C in summer and 10° C in winter. Saffron requirements were supplemented by drip irrigation during dry periods (Figure 1).

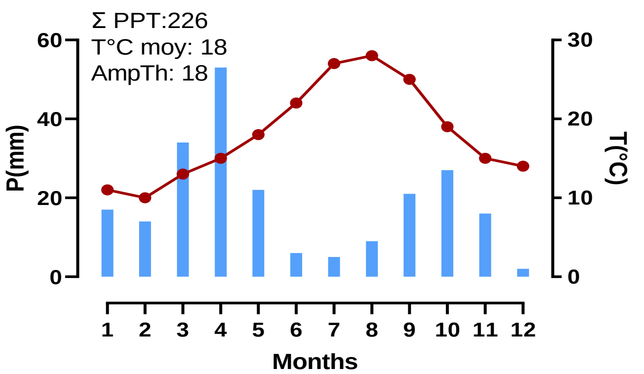

Figure 1. Average monthly meteorological data from the experimental station of the Faculty of Science in Oujda during the trial period.

Plant material

The saffron corms, more than 2.5 cm in diameter, used in this test were obtained from the experimental research station of the Faculty of Science in Oujda.

Effect of manure treatment

A survey was conducted among farmers in the region of Taliouine-Taznakht, the largest saffron producing area in Morocco. Results indicated that almost all producers use sheep manure as a source of fertilization, accordingly this type of manure was used in this study, and it was obtained from a farm located in Aklim, in the eastern region of Morocco.

Manure solarisation

Manure solarisation was carried out during the period 30 June-20 August, 2018. The manure was spread on a plastic film to avoid contact with the ground, after which it was covered with a transparent polyethylene plastic film to increase the temperature. Water was applied at the beginning of solarisation to further promote the germination of weed seeds under the plastic film. To prevent heat dissipation, the plastic film was maintained by applying topsoil around the edges. Manual turning with a shovel was carried out to ensure even heat distribution in the manure pile.

Anaerobic digestion of manure

The anaerobic digestion of manure was produced in a digester consisting of plastic bottles hermetically sealed with tight caps to recover the gas via a pipe inserted inside the bottle. The digester is installed in a controlled glass greenhouse at a temperature of 35±2°C. To promote the evacuation of biogas, a daily stirring was done, then the digestate produced was recovered after 30 days of anaerobic digestion.

Treatments and conditions of the trial

Ten days before planting, the treated manure was applied as a bottom fertilizer at a rate of 180 g/pot (30 x 35 cm) equivalent to the dose recommended for the cultivation of saffron, i.e. 20 T/ha. Subsequently, the corms of more than 2.5 cm diameter were planted at a depth of 7 cm in pots containing on of the three following treatments: T1 = peat + sand + untreated manure (control), T2 = peat + sand + solarised manure, T3 = peat + sand + manure from anaerobic digestion. The proportions of the substrates used in each treatment are shown in Figure 2. Samples of the substrates used were taken from each treatment and analyzed to determine their physico-chemical characteristics.

The experimental design adopted was a complete randomized block design with three replicates with a total of 135 plants (15 tufts/treatment x 3 treatments x 3 replicates) (Figure 2).

Measured parameters

Weed parameters - The weeds in each pot were identified and classified into monocot and dicotyledon species. Weed densities were determined monthly at each pot from October 30, 2018 to April 30, 2019. The total number of weeds was cumulative. The weeds were cut close to the ground and then dried in an oven at 70°C to constant weight. The dried plants were weighed to determine the above-ground dry biomass. The weed control capacity of the different treatments used was calculated according to the following formula (Singh *et al*., 2000):

$$\text{WSA (\%)} \quad \frac{\text{WB Control - WB treatment}}{\text{WB Control}} \quad \times 100$$

WSA= weed control capacity; WB control= weed biomass of control treatment, WB treatment= weed biomass of treatment.

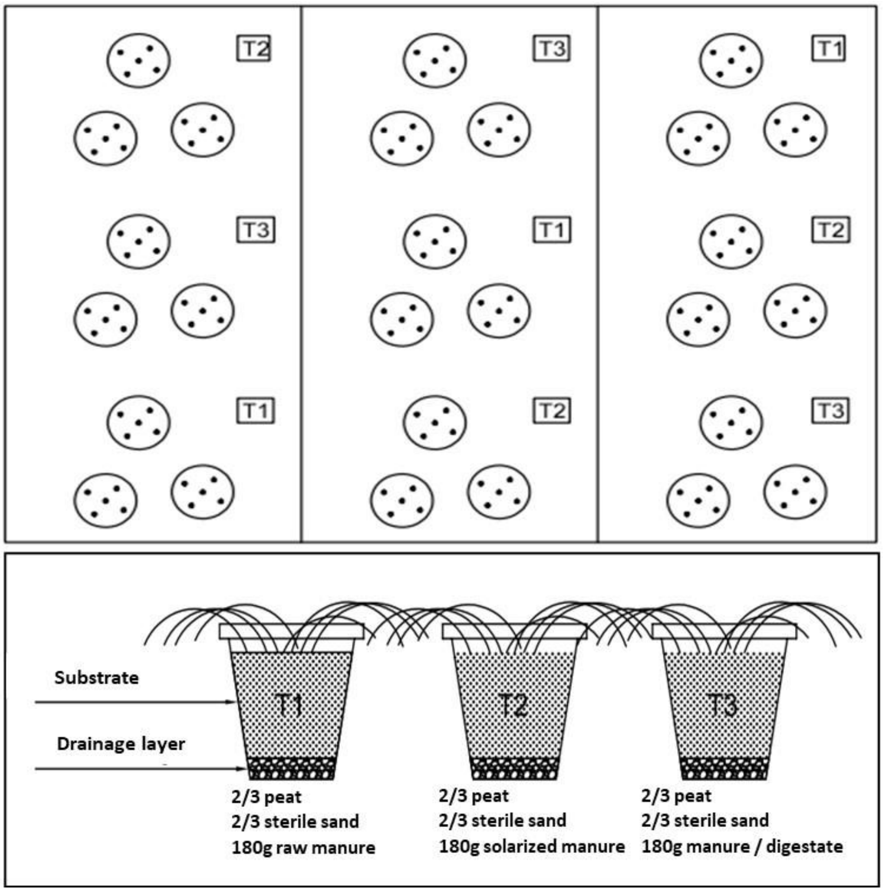

Figure 2. Experimental design in a complete randomized block and the proportions of the substrates used in each treatment

***Agro-morphological parameters of saffron* -** Biometric observations (height and number of leaves) were recorded five months after planting. Stigma yield was measured at the end of the saffron harvest after drying the fresh stigmas in the shade for a few days. The parameters of the underground part (number, weight, and diameter of the corms) were calculated at the end of the cultivation cycle after digging out the plants.

Data analysis

The data that met the assumptions of the analysis of variance (ANOVA) were subjected to an ANOVA analysis, using the "GraphPad Prism for Windows version 7" software and the comparison of means was made by Duncun's multiple range test at P=0.05. Weed density was analyzed using Wilcoxon's non-parametric multiple comparison method because the data did not meet the assumptions of normality for ANOVA. The size of the difference between the two groups was tested by Student's t-test at the 5% significance level.

Results and discussion

Effect of manure treatment on weed flora

***Weed identification* -**The list of weeds determined in the different treatments revealed the presence of 16 weed species divided into 10 botanical families (Table 1). This inventoried floristic procession is characterized by seven dominant species which represented more than 60% of the total are presented in a decending order as follows: *Malva parviflora* (malvaceae), *Medicago truncatula* (fabaceae.), *Aster squamatus* (asteraceae), *Chenopodium album* (chenopodiaceae), *Hordeum murinum* (poaceae), *Conyza* spp. (asteraceae), and *Cyperus rotundus* (cyperaceae).

Effect of manure treatment on weed parameters

The weed count presented in Figure 3-A showed that the manure treatment (T2 and T3) resulted in a decrease in the cumulative number of weeds. Addition of anaerobically digested manure led to the lowest weed density (4 plants /pot) followed by solarisation of manure with a density of 10 plants/pot, whereas the control showed a significantly higher number of weeds (16 plants/pot) (P=0.001). During the last reading in April, manure solarisation and anaerobic digestion led to a decrease of 50% and 76%, respectively. The effect in a descending order was as follows: *Malva parviflora*, *Hordeum murinum*, *Cyperus rotundus*, *Oxalis pes caprae* and *Euphorbia helioscopia*. However, there was no effect of manure treatment (T2, T3) on populations of *Chenopodium album*, *Aster squamatus*, and *Medicago truncatula*.

Likewise, the effect of manure solarisation and anaerobic digestion on weeds dry weight (g) showed a significant decrease (P=0.012). The most remarkable effect was observed in the case of anaerobic digestion of manure, which produced 45% decrease in weeds compared to the control. Whereas the difference observed between the solarisation treatment and the control was not statistically significant (P<0.05) (Figure 3-B & 3-D). The observed difference between the applied treatments was justified by the weed control ability of each treatment (Figure 3-C). The maximum control capacity (61%) was recorded for the treatment (T3), an increase of 33% compared to the solarisation manure treatment (T2).

Effect of manure input on the agro-morphological parameters of saffron

The incorporation of treated manure showed a slight increase in stigma yield (4%) which was not statistically significant at P=0.05. (Figure 4-A). A similar trend was also obtained for the number and size of corms. The T2 and T3 treatments showed the highest values compared to the control. However, the observed increases were not statistically significant at P=0.05 (Figure 4-B). In addition, the results revealed that the T3 treatment significantly increased the number and weight of corms by 32% and 40% compared to the control. However, there was no difference between the control and the solarized treatment for the parameters studied (Figure 4-C). Concerning the diameter of the saffron corms, the T2 and T3 treatments improved the proportion of corms with a large diameter (Figure 4-D). The addition of manure with anaerobic digestion showed the highest proportipon (45%) of large diameter corms, followed by solarization manure (36%).

Table 1. Weeds identity and occurrence in the different plots of the experiment.

	Treatment number		
Weed species	**T1**	**T2**	**T3**
Malva parviflora	5	3	2
Medicago truncatula	5	2	0
Aster squamatus	4	2	2
Chenopodium album	4	3	1
Hordeum murinum	4	1	0
Conyza spp.	3	3	1
Cyperus rotundus	3	2	1
Oxalis pes caprae	3	1	0
Euphorbia helioscopia	2	0	0
Anagallis arvensis	2	3	1
Sisymbrium officinale	2	1	0
Sonchus oleraceus	1	2	0
Sinapis arvensis	1	1	1
Fumaria parviflora	1	1	0
Lamium sp.	1	1	1
Melilotus sp.	1	0	1

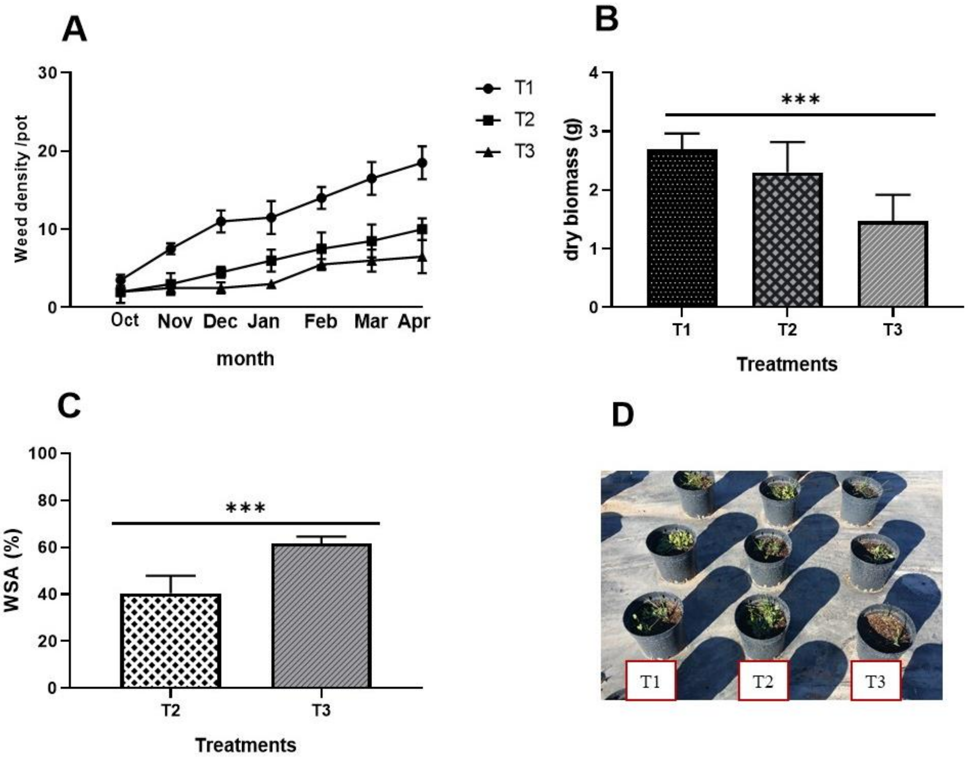

Figure 3. Effects of treated manure application on weed parameters. A=weed density/pot, B= dry weed biomass (g), C= weed control capacity (%), D= weed density in each treatment. The data are the average of five measurements. *** indicate significant differences at P≤ 0.001 at a unidirectional ANOVA.

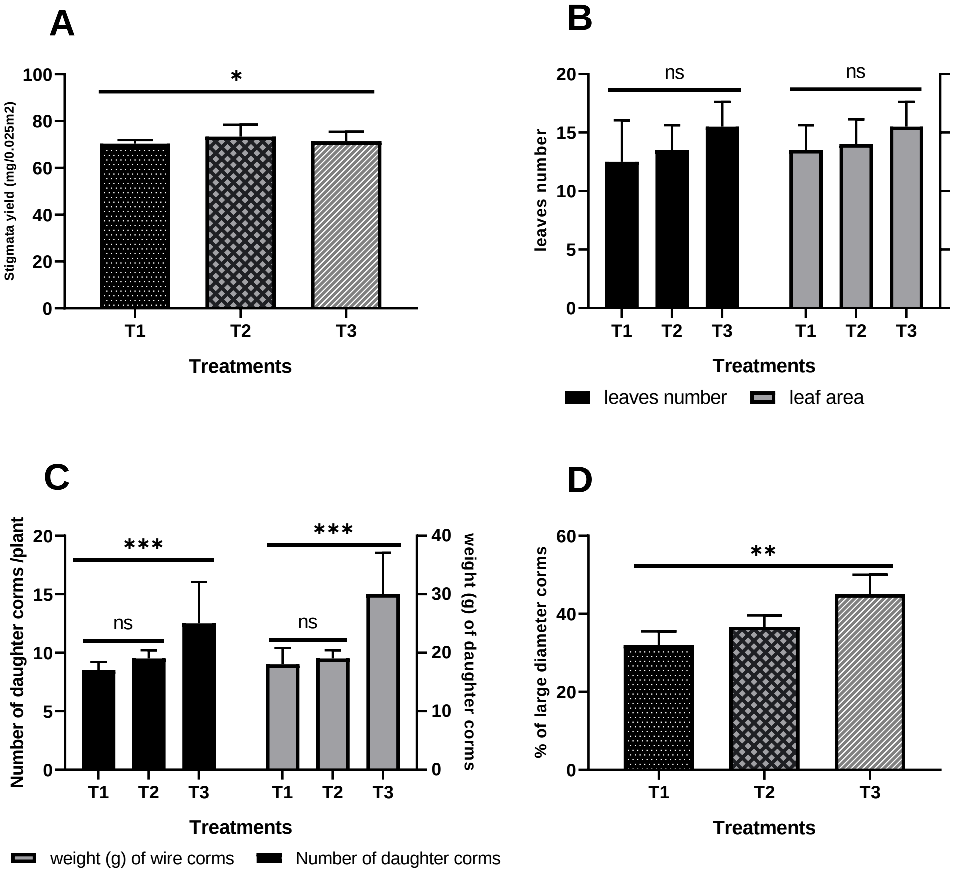

Figure 4. Effects of the contribution of treated manure on the saffron parameters. A- saffron stigmas yield, B- leaves number and area (cm²), C- number and weight (g) of corms, D- proportion of large diameter corms (%). The data are the average of five measurements. 1, 2 and three stars indicate significant differences at P ≤ 0.05, P ≤ 0.01 and P≤ 0.001, respectively, at a unidirectional ANOVA.

Discussion

In saffron, the use of manure treated by solarization or anaerobic digestion produced a significantly lower total number and total dry weight of weeds than the control. The lowest values were observed in the case of anaerobic digestion of manure (4 plants/pots, 1.4g/380cm²). This could be attributed to the weed seed bank, which was significantly lower due to a degradation of the viability and germinability of the seeds exposed to the anaerobic digestion process in the bioreactor. These results are consistent with previous studies (Jeyanayagam & Collins, 1984) reported that weed management by the anaerobic process is governed by several parameters such as temperature, water, pH, enzymes involved in decomposition, microorganisms and contaminants that entered the process via manure, in addition to weed seeds initial quality (viability, level of dormancy, physiological age). Surprisingly, *Chenopodium album*, *Aster squamatus* were the most resistant species to digestion in the small-scale bioreactor. These results corroborate an earlier study on *C. album* which ranked this sweed species among the best surviving species during anaerobic digestion (Westerman *et al.*, 2012). However, *C. album* do not pose a great threat to saffron cultivation, as the real danger lies in the spread of harmful and invasive species such as *Cyperus rotundus*, *Cynodon dactylon*, and *Convolvulus arvensis*.

The results also showed that manure solarization effectively reduced the seed bank and the dry biomass of weeds. This evidence is consistent with previous studies, which reported that thermophilic solarisation of manure is an effective method for the control of manure-borne weeds and pathogens (Candido *et al*., 2019; Cimen *et al*., 2010). In fact, Pokharel & Hammon (2010) reported that soil solarization at 37°C for at least 2-4 weeks completely inhibits seed germination of many annual weeds. As a matter of fact, Schreiner *et al.* (2001) indicated that solarization was more effective than methyl bromide and metam sodium in controlling winter annual weeds. Seed deterioration by solarization is due to the accumulation of higher manure temperatures, killing weed seeds in the manure, or by thermal destruction of emerged weeds by solar burning (Cohen & Rubin, 2007; Yildiz *et al*., 2010).

Although solarisation has been considered effective in controlling weeds, the population of *Medicago truncatula*, *Oxalis pes caprae*, and *Chenopodium album* has been increased by solarization. This observation could be explained by the fact that the germination of some seeds can be improved when the substrate temperature rises during the breaking of the dormancy imposed by the seed coat. However, the effect of solarization on *Cyperus rotundus* was drastic. The same finding was reported by Kumar *et al.* (1993) who observed that solarization can reduce the population of *C. rotundus* when it develops from seed, but not when regeneration develops vegetatively.

Concerning saffron cultivation, the treatments applied induced an improvement of certain agro-morphological parameters, especially those of the underground part. This can be attributed to satisfactory weed control by these treatments, which considerably reduced competition with growth factors, thus stimulating the saffron plant to produce more leaves, to expose more leaf surface and thus produce and accumulate more photosynthesis products in the storage organs (corm threads). Moreover, the most important increase in growth parameters was recorded in the case of using manure following anaerobic digestion. This increase can be attributed to the high availability of nutrients, bioactive substances, monosaccharides, free amino acids, vitamins, and fulvic acid, which can promote plant growth and increase tolerance to biotic and abiotic stress (Liu *et al.*, 2009; Yu *et al.*, 2010). On the other hand, the digestate contains phytohormones (e.g. gibberellins, indolacetic acid) with higher levels of indolacetic acid than the raw material of plant origin (Straub *et al.*, 2017), which explains the improvement in the growth parameters of the underground part. Overall, the digestate had a higher agronomic value compared to the undigested form (T1). These results are in perfect agreement with those reported earlier (Insam *et al*., 2015; Zhang *et al.*, 2016). On the other hand, the improvement in growth parameters following the solarization of manure could be due to the greater availability of nutrients due to the rapid mineralization (Ghosh & Dolai, 2014). Such improvement has been observed for cucumber, melon, lettuce, pepper, tomato, and onion, due to reduced weed density and many manure-borne diseases. All these factors have led to improved plant growth and increased yield (Arriaga *et al.*, 2011; Núñez-Zofío *et al.*, 2013).

It can be concluded that trial results highlighted the importance of the use of treated manure on weed control and the agro-morphological parameters of saffron. The incorporation of treated manure as an amendment (solarised or digestate) which improved the morphometric parameters of saffron. The highest values in terms of yield were obtained in the case of using digestate as an amendment, and these results were related to the highest growth parameters in terms of the number and total surface area of the leaves and the number of large-diameter wire corms. Also, better weed control was recorded in the case of using manure from anaerobic digestion (61%) followed by solarised manure (40%). Therefore, these results can be taken into consideration in the next research works aiming at improving the agronomic performances of the saffron crop, as well as in the new agronomic programs aiming at mitigating the effects of climate change on the different components of the environment.

الملخص

مزابري، إبتسام، هـ. عراجي، م. ريماني، ن. كودان و أ. بريشي. 2022. تأثير التشميس والتخمير اللاهوائي للسماد البلدي/العضوي على مكافحة الأعشاب المرافقة لزراعة الزعفران في شرق المغرب. مجلـة وقايـة النبات العربيـة، 40(1): 70-77.
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يزرع الزعفران بقصد استعمال مياسم أزهاره الحمراء، ويعدّ من أنفس التوابل في العالم وأعلاها قيمة، ومع ذلك فإن انتاجه يتأثر بمجموعة عوامل، ومن بينها تعرضه لغزو الأعشاب الضارة الأمر الذي يؤثر سلباً على المحصول من حيث الكمية والجودة. إن استخدام التشميس والتحلل اللاهوائي للسماد البلدي/العضوي من الأساليب المتبعة لمكافحة الأعشاب الضارة وأمراض النبات. ولهذا الغرض، فقد أجري هذا البحث خلال عام 2018 بهدف مقارنة تأثير السماد العضوي المشمَّس وكذلك الناتج عن الهضم اللاهوائي على نمو الأعشاب الضارة المرافقة لمحصول الزعفران. تتوافق المؤشرات المقاسة من ناحية مع القياسات الشكلية وتحديد محصول مياسم الزعفران، ومن ناحية أخرى مع تحديد الكثافة، الكتلة الحيوية الجافة والقدرة على مكافحة الأعشاب الضارة. تمّ في هذه الدراسة تسجيل 16 نوعاً من الأعشاب الضارة المرافقة لزراعة الزعفران. وبينت النتائج أن كلتا المعاملتين المستخدمة قد خفّضت من كثافة وكتلة الأعشاب الحيوية عند حوالي 55% من أنواع الأعشاب بما فيها تلك الأنواع الأكثر منافسة مثل: *Cynodon dactylon*، Cyperus *rotundus* و*Convolvulus arvensis*. وفي المقابل، لم يكن للمعاملة بالسماد العضوي (المعاملات T2، T3) أي تأثير على أنواع الأعشاب الضارة: *Chenopodium* spp.، *Aster squamatus* و Medicago *truncatula*. كان متوسط مردود مياسم الزعفران في معاملة السماد العضوي المهضوم/المعالج أعلى بنسبة 4% من الشاهد. وكذالك، كان عدد ووزن ونسبة الكورمات ذات القطر الكبير أعلى في النباتات المزروعة في معاملة السماد العضوي المعالج. خلصت هذه الدراسة إلى أن إضافة السماد العضوي المعالج للتربة قد زادت من غلّة محصول الزعفران بشكل طفيف، ومكّنت السيطرة بشكل فعال على أكثر من نصف أنواع الأعشاب الضارة التي تمّ تحديدها.

كلمات مفتاحية: التشميس، استراتيجيات الإدارة، السماد العضوي، الهضم اللاهوائي.

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