

Impact of Innovation Platforms in Promoting the Dissemination of Biotechnological Innovation – Case of Compost in Date Palm in Southeastern Morocco

Kaoutar Hamriri^{1,2*}, Majid Atmani¹, Larbi Aziz², Ali Abidar²,
Rachid Bouamri³, Moustapha Mouhamadou Kane²

¹ Laboratory of Functional Ecology and Environmental Engineering, Sidi Mohamed Ben Abdellah University, Route of Imouzzer, P.O. Box 2202, Fez 30000, Morocco

² Department of Rural Development Engineering, National School of Agriculture, 10 km., Route Haj Kaddour, B.P. S/40, Meknès 50001, Morocco

³ Department of Plant and Environment Protection, National School of Agriculture, 10 km., Route Haj Kaddour, B.P. S/40, Meknès 50001, Morocco

ABSTRACT

The sustainability of date palm production in Tafilalet's palm groves is threatened by many constraints related to the dryland's severe environment, climate change, and improper human activities. Biotechnological innovations are new agricultural research discoveries increasingly used to improve agricultural sustainability. For example, compost has proven its benefits in facing date palm production constraints, improving its productivity, and enhancing soil health. Using linear approaches has proven their ineffectiveness to disseminate the advantages of innovations to small producers. As an alternative, Innovation Platforms (IPs) constitute a participatory approach based on a multi-stakeholder alliance for disseminating innovations. This article aimed to study the effects of IPs on the compost adoption and dissemination process as well as evaluate compost impacts on the production of dates. Two types of investigation tools were conducted on members of 47 IPs. Data were analyzed using factorial analysis, content analysis, and communication network analysis. The results show that IPs are a new organizational innovation impacting positively on date palm social systems. They create powerful collective learning through their strong dynamism and interaction. The producers who adopted compost are characterized by a high level of education, take a responsible position in GIE, have a large social network, interact with the research team and other producers, engage and participate in the activities of IPs, search for agricultural news, and have the ability to accept change and develop their skills. Compost can improve the water-holding capacity of soil, increase yield, and reduce expenses by decreasing the need for water, fertilizers, and phytosanitary treatments. Compost is the best alternative to face the environmental and climate change drawbacks on the production of dates.

Keywords: innovation platforms, dates production, compost, biotechnological innovation, adoption, dissemination, sustainable development, Tafilalet's palm groves.

INTRODUCTION

Agricultural research, extension, and education can contribute to a significant improvement in agricultural productivity through sustainable means, contributing to eradicating poverty in the developing world (Waters-Bayer et al., 2012). Agriculture research has a great impact on Africa's

socio-economic growth (Fatunbi et al., 2016). It is being especially discussed in worldwide debates on innovation, technology, institutions, and development (Sumberg, 2005). Agricultural research is perceived as the origin of innovation and farming output development outcome from disseminating scientific technologies to farmers (Hounkonnou et al., 2012).

However, applying the existing extension systems fails to promote the adoption and dissemination of innovations among smallholder farmers (Brown et al., 2021). Linear approaches are the ‘top-down’ processes frequently used to disseminate innovations (Rogers, 2003). They are defined by three compounds: researchers as creators of innovations, extension actors as distributors, and producers as adopters (Adekunle & Fatunbi, 2012; Knickel et al., 2009; Waithaka, 2005). At present, those processes became outdated (Agboton et al., 2018; Sanyang et al., 2016). Since they focused their research on the idea of “adoption,” the adoption rates turned out to be substantially lower than anticipated based on neo-classical behavioral models (Knickel et al., 2009). Many interdependent factors are involved in the failure of the innovation process. In this sense, several authors related its inability with the inadequate innovations with smallholder farmers’ cases (which may not align with farmers’ interests and/or require additional supplementary inputs not available in their fields), not being appropriate for the implementation setting (infrastructure, trading possibilities), and farming households (demographic factors, access to credit or attitudes towards risk) (Feder et al., 1985; Pamuk et al., 2014; Sunding & Zilberman, 2001). Some other authors claimed that the marginalization of farmers’ opinions, their lack of power over innovation systems beyond learning and dissemination, and their inferiority to extension agents in defining innovation techniques and processes (Fløysand & Jakobsen, 2011; Friederichsen et al., 2013; Ngwenya & Hagmann, 2011).

Smallholder farmers in semi-arid Africa are typically more vulnerable due to the direct and indirect consequences of climate change, demographic pressure, and resource degradation (Tittonell et al., 2012). Moroccan oases are among the agricultural ecosystems most threatened by the constraints mentioned above (Assini et al., 2019). Thus, date palm (*Phoenix dactylifera L.*) production, which constitutes the pivot of the oasis ecosystems (El-Juhany, 2010), is constantly declining. The disadvantages of climate change in oases, the spread of “Bayoud” disease (El Khoumsi W. et al., 2016; Essarioui & Sedra, 2017; Kradi et al., 2002), as well as inappropriate human activities (overexploitation of natural resources and low soil fertility) (Anli et al., 2020; Belarbi et al., 2004; Mbarga & Vidal-Mbarga, 2005) negatively

impact oasis biodiversity and worsen the socio-economic situation of small farmers.

To face these environmental, technical, and socio-economic constraints as well as to enhance date palm productivity many technological innovations are being generated and tested in the field and greenhouse. Among these, a novel organic biofertilizer technology biotechnological innovation was created in a Moroccan laboratory. The biofertilizer combines the use of natural beneficial soil microorganisms, as, Arbuscular Mycorrhizal Fungi (AMF), Plant Growth-Promoting Rhizobacteria (PGPR) and compost. Various agricultural researchers have proven the importance and the advantages of organic fertilizer applications, such as compost and biofertilizers, on date palm trees and soil fertility (e.g. Anli et al. (2020); Barje et al. (2016); El Kinany et al.(2019); Naser et al.(2016); Souna et al. (2010); Vengadaramana & Jashothan (2012)).

Notwithstanding these efforts, the date palm is still deteriorating and suffering from a lack of care and attention (De Haas & Ghanjou, 2000). Among the causes of this decline, most of this research is still confined in university laboratories and libraries and remains ignored by date producers. On the other hand, the failure to disseminate innovations can be linked to the inefficiency of Moroccan extension systems, which is characterized by the absence of a coherent agricultural research strategy as well as weak and dysfunctional interaction between extension agents, researchers, and farmers (El Bilali et al., 2016)—bearing in mind that farmers remain a vital social, cultural, and economic force in rural communities (Knickel et al., 2009). It is recognized that the four main actors in agricultural innovation and research for development (research, extension services, education and training, and organizations) should work closely together to coordinate innovation (Knickel et al., 2009).

To contextualize these novel bio-fertilizers, Innovation Platforms (IPs) are the best tool to support the dissemination of technological innovation. Innovation platforms (IPs) are seen as a multi-collaborative space, bringing together all stakeholders. They are quickly replacing traditional project and program structures in agricultural research for development (Schut et al., 2019). IPs provide an opportunity to interact with different value chain participants and give voice to small farmers (Glin et al., 2016). IP establishment is a dynamic, highly context-specific

process that combines all the necessary components for successful innovation at once and gives local inventions a chance to succeed while also feeding the previously introduced innovations (Tenywa et al., 2011). They underline the great potential of farmer–researcher collaboration for rural innovation (Hoffmann et al., 2007). IPs are considered as a “multi-collaborative” space, regrouping all concerned stakeholders, these would work together to achieve a common goal (Sanyang et al., 2016), share knowledge between them and find solutions to the problems they face (Homann-Kee Tui et al., 2013).

Numerous research has been executed on IPs, but there are not enough studies on how IPs work to support sustainable soil fertility management (Tittonell et al., 2012). In the context of Moroccan country (northern Africa), there is no study made on the dissemination of innovative technology through IPs. The purpose of this study was to analyze the roles of IPs (organizational innovation) in adoption and dissemination of compost (biotechnological innovation) occurring in the Tafilalet region (Southeast of Morocco); and to pinpoint the effects of IPs on the network of IP members and the compost on date palm production system.

RESEARCH MATERIALS AND METHODS

Study context

This study was part of a research-development project, entitled “Application of an organic biofertilizer to improve the sustainable production of date palm”. It has been set up in the region of Tafilalet during 2017–2019 (<https://www.fertiledatepalm.net/fdp-about.html>). The project aims to contribute to improving date palm production by introducing biotechnological innovations, consisting of compost and compost-based biofertilizers, into the production system of date palms through IPs. This project is a “research-oriented” action focusing on solving problems at local scales with the help of research and promoted by donors for the duration of an Research & Development project and also composes an innovation. IPs have generated a new form of organization with the participation of a plurality and heterogeneity of stakeholders and a pooling of resources between these actors. Three IPs were established and implemented in the palm groves

of three zones in Errachidia provincial (in Tafilalet region), notably, in Erfoud, Jorf, and Tinejdad. These IPs are grafted onto three economic interest grouping (GIE) of these zones. IPs are community organizations integrated into the GIE (as a farmers’ organization) to facilitate communication and coordination between farmers and other stakeholders. The main stakeholders of IPs are constituted of farmers, researchers, extension actors, professional organizations, and private institutions.

The function of date palm IPs

Numerous meetings between researchers and institutional actors, as well as with farmers’ organizations, are held following the implementation of IPs and before the start of IPs’ operation. The main purposes of meetings are, firstly, to select the main stakeholders, who assist in IP activities and, secondly, to select trial fields where biotechnological innovations will be tested. The selection of stakeholder group members should ideally be made by an IP through a bottom-up, participatory approach (Pamuk et al., 2015). On the basis of GIE lists of farmers, 10 to 12 date producers are selected in each IP, in addition to institutional actors and researchers.

Many activities were planned and structured around the training sessions, researchers’ demonstrations, as well as evaluation and monitoring experimentation. To conduct IP activities, an organizing committee was constructed by three members to make sure of the great management of activities. The committee was formed by a farmer as coordinator, a researcher as a facilitator, and an institutional actor as secretary. The coordinator coordinates with all members to inform them about training program (subject, time, meeting place...); the facilitator is charged with organizing discussions and animating the training activities; and the secretary is assigned to write and save all the ideas, information, proposals, etc. Generally, the elected farmers are leaders in their area who, with institutional actors, facilitate and mediate the interaction between stakeholders in date palm IPs.

An action plan was constructed carefully to encompass the most important date palm technical production. In fact, the farmers’ training agenda targets some sustainable agricultural practices, including organic matter management, composting techniques (process and broadcasting),

biological control techniques of cochineal pests, soil, plant, and water analysis awareness, as well as pollination and thinning techniques. All training sessions are followed by researchers' demonstrations in the field, including producers and all other stakeholders in the conduction of the activity. Aside from these activities, an experiment trial field on biotechnological innovation, compost, was also run to test its efficiency on the date palm production system. These experiments have followed the subsequent criteria: date palms of the Mejhoul variety of the same age and same size, with a drip irrigation system. The experiment trial is repeated for three seasons on each IPs' site.

Study area

Date palm plays a significant role in economic, social, environmental, and cultural levels in the Tafilalet's region. This region extends over an area of 70 000 ha where agriculture remains the main economic activity (90%), for a population of approximately 663 700 inhabitants, among which 66.8% are rural (ORMVA-Tf, 2014). It is characterized by an average annual precipitation of 265 mm in the north and 60 mm in the south. Temperatures vary from -1.5 °C in January to 50 °C in July (ORMVA-Tf, 2014). This region is occupied by 1 900 000 palm trees planted over an area of approximately 48,305 ha and producing an average of 34000 tons (30% of national production), or an average of 30.5 kg/palm (ORMVA-Tf, 2014). This study was conducted in three selected sites within the Errachidia province.

Data collection and sampling

Data were collected from primary and secondary sources. Primary data sources are a participatory observation (observing farmers' interaction and dynamism), and two investigation tools were produced as well as targeted to all members of the IPs, mainly, 33 date palm farmers and 14 institutional actors. Participatory observation is a structured and conscious method of witnessing an interaction or phenomenon as it occurs (Kumar, 2019). The date palm producers were approached by a survey that addresses the following elements: (i) members' participation in IPs activities; (ii) adoption and dissemination of compost; (iii) effects of compost on the date palm production system. As for the institutional members of IPs, they were interviewed using a semi-structured interview to understand their

role and involvement in the IPs as well as the process of compost adoption and dissemination. This guide is structured around the following elements: (i) representation of the respondent and their participation; (ii) Role of IPs in compost adoption and dissemination process.

Methods of analysis

In responding to the article questions, three main methods were conducted:

- Firstly, a content analysis was made to objectively, systematically and quantitatively describe the content of the open question answers of the survey and the interview guide (it concerns qualitative data). Each question was subject of classification and organized in the form of categories that have the same aspects or subjects. These categories were transformed into quantitative data in order to calculate their occurrence frequency.
- Secondly, a factorial analysis which aimed to explain the differences between date producers who have adopted compost and those who have not, a multiple correspondences factor analysis (MCFA) through the XLSTAT (software 2014) was used.
- Thirdly, a communication networks analysis is made to consist of elaborating, analyzing, and mapping the social networks of IP stakeholdersowing to a sociogram diagram. Sociograms and graph diagrams are used in the evaluation of the relationship between people; they help researchers to visualize communication processes and social links in a particular team (Nestsiarovich& Pons, 2018). They visualize stakeholders as points, and links between stakeholders as lines joining up their endpoints (Freeman, 2000). Sociogram plays a primordial role in the assessment of interactions and connections between producers and other stakeholders.

This analysis allowed the identification of the central actors who are the driving force behind the IPs and who are likely to play an important role in the dissemination of this biotechnology innovation. To obtain a sociogram, it was necessary to establish a sociomatrix obtained from the surveys carried out. This matrix was, then, submitted to the sociometric software UCINET to visualize a graphic representation of the dialogue networks between IP stakeholders upon the dissemination of compost.

RESULTS

Impact of IPs on the social system

Members' perceptions toward date palm IPs

It was found that 95% of the surveyed perceived that IPs are innovative organizations in their area. In fact, the unanimity of date producers has declared that they have never had this experience before. They regrouped, for the first time, with researchers and institutional actors learning, exchanging, and communicating their needs as well as dates production challenges. Producers perceive date platforms as an opportunity for them to enhance their expertise in date palm cultivation and production and collaborate with multi-stakeholders and then speak out their concerns.

Likewise, 86% of institutional actors perceived IPs as an unprecedented experience in the area that constitutes an innovation in the matter. All the institutional members surveyed underlined that IPs allow the different agricultural development institutions to mobilize their resources and converge their actions, realizing that the producers need for creating a space allowing the emergence of new ideas and themes, as well as fruitful exchanges between multidisciplinary and complementary actors. In addition, 61% of date producers and 71% of institutional actors have seen in IPs a substantial improvement in the producers' "empowerment", and it encourages them to take initiatives, speak out their minds, and become involved in the decision-making process (Figure 1).

IPs create a learning space for members

Within the three IPs, numerous farmer training sessions about sustainable agricultural

practices of date palm production (described in the research methodological part) were organized for the IP members. It was found that 87% of the beneficiaries have declared having acquired new knowledge and learned innovative techniques. The degree and techniques learned are variables between the three IPs groups. In fact, in Jorf's IP, 69% of the producers stated that they have learned new pollination and thinning techniques, 18% of them have understood the organic matter management and calculated date palm fertilization needs, and 45% of them have acquired the composting technique and recognized the importance of soil, plant, and water analysis for a good date palm fertilization program. In Tinejdad's IP, 80% of the producers have learned the composting technique, 20% have also understood the biological pest control techniques, 30% have learned new pollination techniques, and 20% have understood the organic matter management of the date palm. Concerning Erfoud's IP, 86% of the date producers have declared that they have learned the composting technique owing to the platform training session. The remaining producer learned the composting technique and new pollination techniques, which he tested on his farm. As for the institutional actors, 86% declared having learned new technical practices through the IPs (Figure 1).

On the other hand, 13% of members declared that they have not learned anything, five of which have never attended IP field activities, and two were institutional actors of the regional management of ONCA.

Creation of new relationships within the IPs

The dynamism and interaction created within the IPs have allowed members to reinforce their

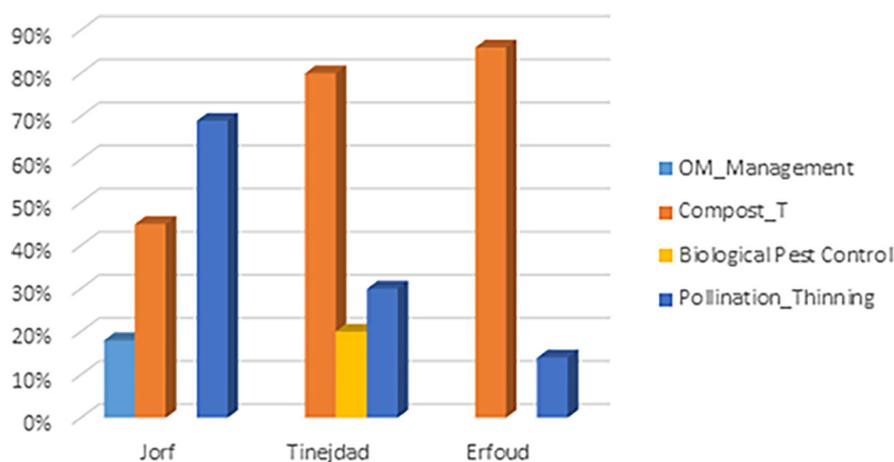


Figure 1. IP learning activity. OM_Management: organic matter management; Compost_T: composting techniques

bonds as well as establish professional and/or amicable relationships. However, the relationship development rate differs from one IP to another. At Jorf’s IP, 92% of the date producers reported that they had strengthened their friendship and improved communication between them. In addition, 42% of the producers surveyed have established new professional relationships with researchers and institutional actors. In Tinejdad’s IP, all of the date producers have built bonds through the IPs. In fact, everyone affirmed to have consolidated their relationship (professional and/or friendly) with several IP date producers. According to 80% of members, they got connected to institutional actors owing to IPs. Moreover, 70% have forged new professional relationships with researchers, whereas 40% have constructed a solid relationship with the leader farmer of the Jorf’s IP. As for Erfoud’s IP, 86% of date producers have forged friendly bonds with some IP members; 71% of the date producers confirmed that they consolidated their professional relationships with other date producers within the same IP and 43% have made new professional relationships with members of the research team.

They stayed in touch with them not only to ensure being kept informed about updates in the agricultural sector but also to share the problems they faced on their farms. Finally, 57% of the date producers assured that they have forged new links with certain date producers’ members of other IPs (Jorf and Tinejdad). All of the institutional actors

polled stated that they had formed new relationships through IPs, particularly with researchers. They claimed that IPs had made these institutions and the date producers more connected.

Impact of IPs on the adoption and dissemination of compost

As it was mentioned in the methodological part, an MCFA was carried out in order to categorize the dates producers based on their adoption of compost by crossing the variables to be explained “adoption of compost”, with other explanatory variables (socio-economic) represented in Table 1.

Characteristics of the adopters and non-adopters

The results of the MCFA allowed identifying two different groups of producers (Figure 2). The group -in red- represents the date producers who have adopted compost (49%), and a group -in blue- represents the farmers who have not adopted compost (51%).

- The group in red is characterized by a higher level of education, having a large plot of land (UAA superior to 15 ha), and producers with a high-ranked level of responsibility in their GIE (president, vice-president, treasurer, etc.). They are, in fact, entrepreneurs in the agricultural sector with significant financial means, who have developed relational networks, and have a favorable attitude to change. They have

Table 1. Presentation of the variables retained in the MCFA

Variables	Modalities	Effective	Ratio (%)
adoption_compost	Adoption	16	48.4848
	Non_adption	17	51.5152
Member since when	Ancient_Member	20	60.6061
	New_Member	8	24.2424
	No_longer	5	15.1515
Interaction_with_researchers	No	15	45.4545
	Yes	18	54.5455
Farm_Size	Average_expl	9	27.2727
	Big_expl	5	15.1515
	Small_expl	19	57.5758
Instruction	Higher	4	12.1212
	Prim_Coran	12	36.3636
	Secondary	17	51.5152
Responsability_GIE	Free	6	18.1818
	Member	17	51.5152
	Responsible	10	30.3030

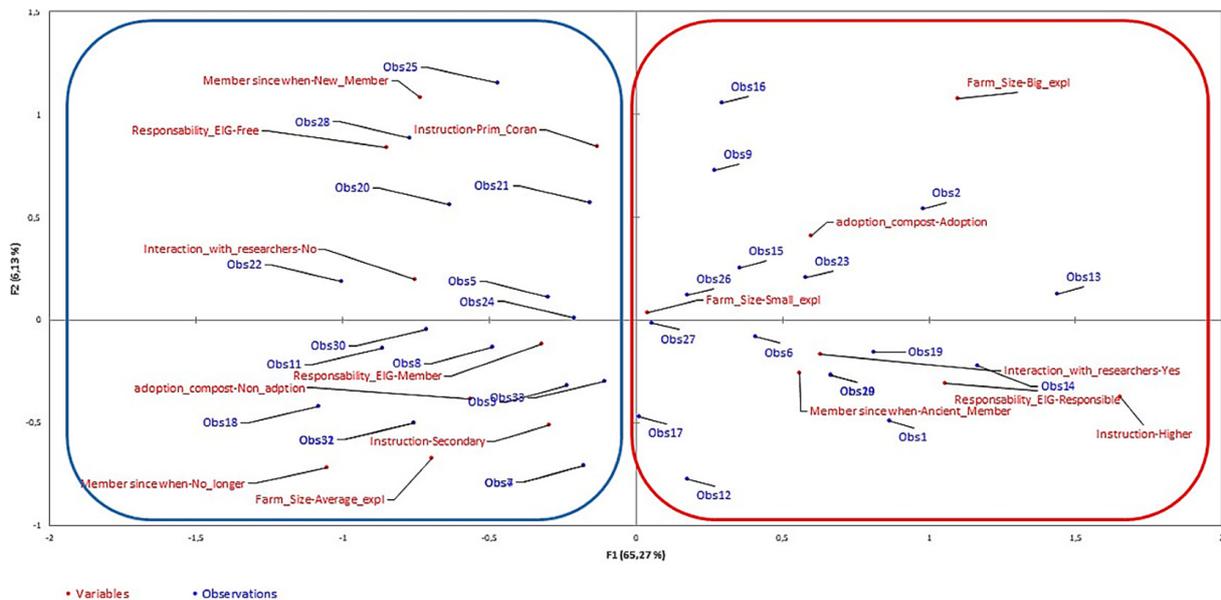


Figure 2. Asymmetric graph of variables

been members of IPs since their creation (in 2017) and interact with researchers during IP activities. These producers have attended almost all the IP activities.

- However, the group in blue is characterized by a level of secondary education (junior high or high school), and an average UAA comprised between 5 ha and 14 ha. They do not currently adhere to the GIE or are merely simple members, or simply are newcomers to the IPs (2018/2019), some of them are no longer considered members of the IPs. Thus, they do not interact with researchers' actors. They have poor relational networks which are limited on the little cercal in their GIE. They have either only participated in one IP's activity or simply in none of them.

Factors of compost adoption and non-adoption

Besides, through this analysis, it was possible to identify factors of adoption and non-adoption of compost. In fact, 38% of producers' adopters have said that they had already known about the compost (owing to a previous little project). However, through the IP activities, they have been able to improve the composting technique and its broadcasting method. In this manner, one of our respondents told that *"I have discovered compost a long time ago, but I got to know it more through the IPs' activities, thanks to the researchers' exposition, through training courses I have therefore decided to adopt it in my farm"* (farmer, IP's Tinejdad, 58 years old). The remaining 10/16

said that they were entirely influenced by the IP activities and also by the members (researchers and some farmers).

In addition, 94% of the adopters reported having adopted the compost because of its handiness and compatibility with their production system. Then 56% of adopters admitted having adopted compost after witnessing the promising results (among which: the greenish leaves of date palms treated with compost and the permanent humidity of the soil around the trees...) in demonstration plots carried out by the project. Actually, 7 of them, including six belonging to Jorf's IP and one to Erfoud's IP, have adopted compost based on the observed results on the IP of the Jorf leader. Finally, 5/16 of the adopters were influenced by the members of the research team (4 of them are members of the IP of Jorf and the remaining producer belongs to the IP of Tinejdad).

Conversely, nearly 60% of non-adopters (10/17) assure that they cannot buy a crusher for the manufacture of compost due to the lack of financial means. Nine of them are small farmers, having a land portion of fewer than 5 hectares. These date producers wanted to have their own crusher to avoid the risk of contamination or propagation of the bayoud disease and other pathogens. Then, 7 of the 10 non-adopters were hesitant because they did not have sufficient information about compost. The latter counted among the members of the IPs who are not used to attending compost training course. Finally, 2/17 did not adopt compost, because they were satisfied

with the traditional fertilization method (manure). Therefore, the remaining 16 farmers can be considered as potential adopters of compost.

Impact of IPs on compost dissemination

The analysis of the social influence networks helped detect the main IP actors who prompted and encouraged the adoption of compost to other producers, and then, their roles in its dissemination. The figure below shows the communication diagram of the different IP stakeholders.

The Figure 3 shows the centrality of two actors (19 and 50) who are the locomotive to compost dissemination. It was found that 7 adopters (among which 6 belong to Jorf’s IP and one to Erfoud’s IP) affirm they have been encouraged by individual 19, leader of Jorf’s IP. They appreciated the compost effects observed on his date palm trees. As for individual 50, he is a member of the research team, and an expert in techniques of composting, vermicomposting, soil fertilization, etc.

Impact of compost on date palm production system

The compost testing has clearly shown its effectiveness in the production system of date palm. In fact, producers have noticed that their palms have become more greenish with no more weeds around. In contrast, the palm trees (that were not treated or those treated with chemical fertilizers) had yellow leaves and too many weeds around (Figure 4).

In addition, the manager of Erfoud IP farm added that the date palms treated with compost have better inflorescences compared to others. According to him, the surroundings of the date palms with compost are always wet. He stated in this sense, that “compost improves the structure of the soil and its capacity to retain water. This facilitates hoeing (shallow tillage) in the pits.”. He added that there is even a time saving for tillage: “now we spend less time working the soil in the pits. Previously, this work often lasted more than 15 minutes, but now in less than 5 minutes, we get the job is done” (Technician, 30 years old).

The adopters have observed many changes in their oasis:

- Soil water retention capacity – all adopters reported that the soil surrounding the date palm trees treated with compost remains continuously wet. For them, compost allows the soil to have a good capacity for water retention.
- Water supply – according to the adopters, the water supply is directly related to the water retention capacity of soil owing to compost treatment. In fact, 76% of adopters confirmed that they had significantly reduced the water supply needs in terms of quantity and irrigation frequency. On the other hand, 12% of farmers did not change either the supply quantity or the irrigation frequency.
- Fertilizer supply – concerning chemical fertilizers supply, 69% of adopters say that they have considerably reduced its utilization. In turn, 73% of them have definitely abandoned using chemical fertilizers after adopting compost. Whereas,

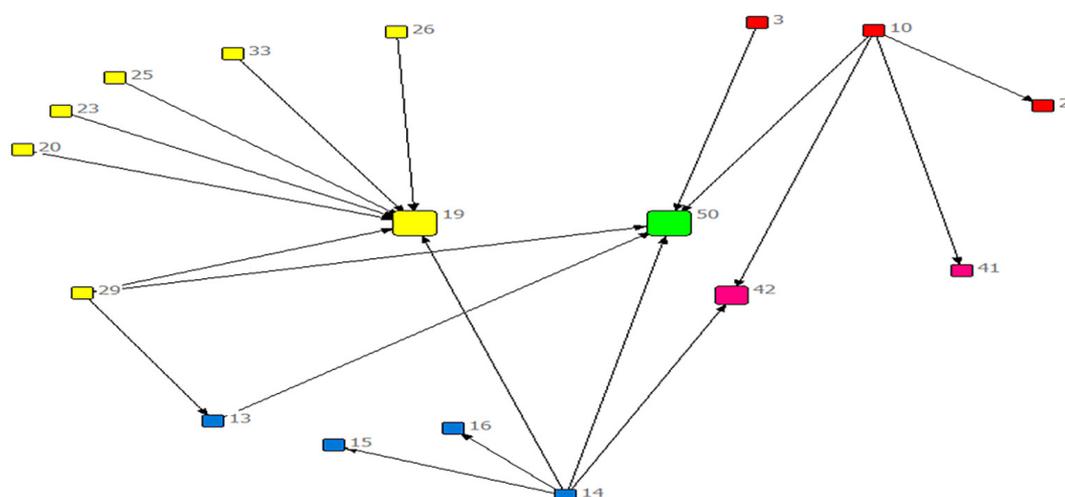


Figure 3. Compost discussion network. Red: date producers who are members of Erfoud’s IP; yellow: date producers’ members of Jorf’s IP; blue: date producers’ members of Tinejdad’s IP; green: research team

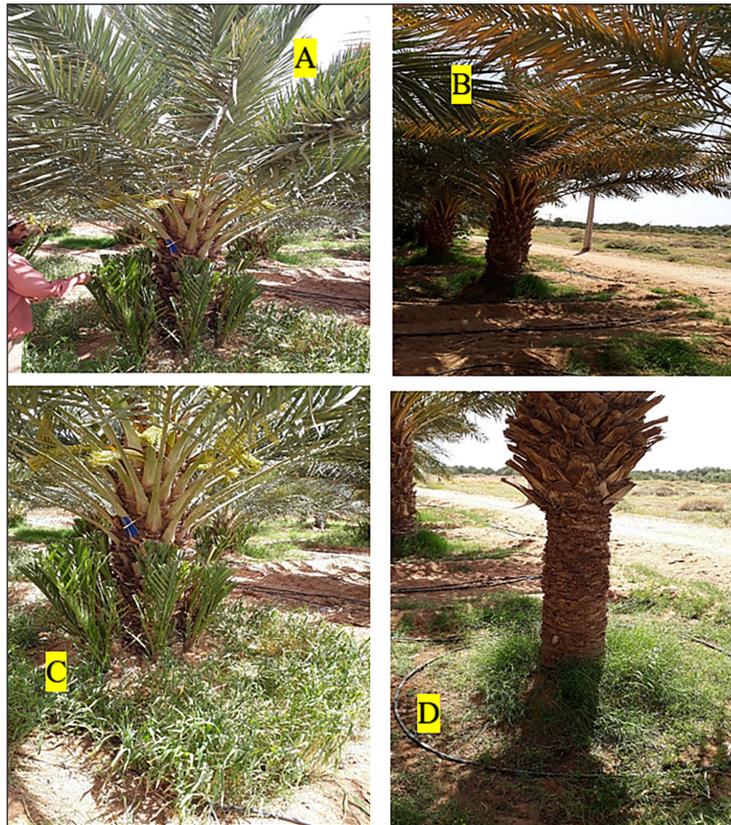


Figure 4. Date palm treated with compost associated with the bean vs. control date palm (without any treatment). A: greenish color of the palms; B: yellowish color of the palms; C: existence of rejections around the palm tree; D: absence of suckers and presence of weeds around the trunk of the palm tree

the remaining date producers 31% have never used chemical fertilizers on their farms.

- Phytosanitary treatment – 69% of the farmers noticed a decrease in the use of phytosanitary treatments following the adoption of compost. To them, the date palms treated with compost looked healthier.
- Weeds – all date producers’ adopters of compost have unanimously noted a considerable reduction of weeds around palm trees. Moreover, 81% confirm that there are nearly no weeds around their palm trees anymore. This would explain the reduction in using plant treatment products mentioned above.
- Soil cultivation – two categories of date producers were selected. The first one is constituted of the producers (56%) who have decreased the number of occasional workers, after using compost which has drastically reduced weeds around trees. In fact, these are small producers who have farms of less than 10 hectares (less than 5 hectares for the most part) and who have hired laborers only for weeding. The second category is composed of 3 producers who

affirm having increased the number of occasional labor to apply compost on their farms, they are producers with more than 30 ha.

- Yield – 69% of adopters noted a considerable increase in the size of dates and therefore in yield after using compost. The remaining 31% are waiting for next season’s harvest to be able to make any judgment.

DISCUSSION

Through the lens of interviewees, the alliance of multi-actor in date palm’s IPs (producers, researchers, institutional actors, funders, and private partners) was a new organization in their area. The IPs are an organizational innovation that makes heterogeneous actors involved to improve date palm production. Through these platforms, date producers express clearly and closely their production issues and exchange, with a feedback loop, with the key date palms development actors. In these platforms and together with producers, planned farmers’ training sessions could

to be established in order to endow them with technological innovation that goes together with their local conditions and resolve production issues. The diversity of actors allows the analyzing of date palm production challenges through different viewpoints. In this way, actors could stimulate their creativity and innovativeness in terms of solving complex problems. Date producers and institutional actors find in IPs the archway that connects them with researchers and all other development actors.

Through this experience, IPs show that is the suitable means to promote change and break the septum between producers, researchers, and institutional actors. Instead of linear approaches that marginalized farmers' opinions and put them in the second-rate (Fløysand & Jakobsen, 2011; Friederichsen et al., 2013; Ngwenya & Haggmann, 2011), IPs with its participatory approaches gives to producers a strong place in the decision making as well as empower them with the capacity to react and debate with researchers and institutional actors. by thus, IPs could realize a great move on adoption and dissemination of innovation (bio)-technology. The power alliance of the multidisciplinary actors changes the thinking way of farmers, institutional actors and researchers, ensuring that agricultural development cannot be realized without consolidating together their power and cooperation and collaboration batwing them. According to Sanyang et al. (2016): "Sustainable agricultural development requests a transition from conventional thinking to innovative thinking".

The organizational structure of farmer training sessions undergoes a striking transformation as a result of the discussion, trade, interaction, and experimentation among multiple actors. They make date producers and institutional actors more aware of their important role in developing this sector. Producers become implied in the process of decision-making and learn to organize their production issues. Institutional actors are the principal coordinators, animators, and facilitators that share new technologies. There are farmers and rural actors among IPs who adapted themselves to these new conditions and proved to be innovative and redefine their job (Knickel et al., 2009). To better facilitate IPs, facilitators and practitioners need to learn to observe, recreate, test, and perfect the IP process (Sanyang et al., 2016), without forgetting the important place of researchers who take this opportunity to understand and analyze producers' needs and challenges, which could be

a strong base to produce innovations suitable to producers' context.

In small exploitations and subsistence production systems, IPs are typically created through initiatives that seek agricultural development, using participatory and inclusive approaches to developing locally appropriate technologies (Swaans et al., 2014), and ensure the equitable participation of all the different concerned multi-stakeholder groups (Amaru & Chhetri, 2013; Pereira & Ruysenaar, 2012). From a more restrictive perspective, IPs are the best shot to enhance oasis producers' situation. The Oasis system is considered one of the complex systems that require the intervention of various actors to solve complex challenges with an adequate solution. Like socio-ecological systems (van Rooyen et al., 2017) and organic farming systems (Knickel et al., 2009). In that perspective, date palm IPs are an organizational innovation that suggests a new method to transfer innovation bio-technology. They consist in involving all its members into thinking, analyzing, and experimenting with new techniques in the field involving producers and institutional actors in the research process. IPs present an opportunity to transfer innovations with a real reaction and feedback.

The approach of IPs focuses on developing date palm productivity and enhances producers' socio-economic situation. For that purpose, IPs activities tried to develop all date palm value chain through the introducing of the sustainable agricultural practices with a special attention on date palm fertilization. The particularity of these activities based on learning by doing, this method positively impacted the learning process. Using demonstrations just after the training sessions, by including producers in the process, the knowledge level of producers and all IPs' members was remarkably fostered. The design program of these activities encourages all producers' members to take initiative in the training sessions discussion, participate in field demonstrations, and monitor the experimentation of biotechnological innovation (compost). Taking action and becoming involved in field activities are the best way to foster learning and understand new practices. Besides, through IP activities, producers have the opportunity to integrate their know-how into technical practices and develop other skills. Institutional actors found a new way to facilitate the adoption and dissemination of biotechnological innovation. As Homann-Kee Tui et al. (2013) characterized IP

as a place for learning and initiative-taking where stakeholders (who frequently represent organizations) from various backgrounds and specialties engage to diagnose issues, spot opportunities, and develop solutions to their challenges. In essence, IPs are spaces mainly created for dialogue where actors obtain information and express their knowledge in order to resolve their issues. Actors can evaluate and contest various sorts of innovation through learning sessions that are conducted alongside practical activities (Tittonell et al., 2012). They are a space for close advice about new techniques (Aziz et al., 2019). Aziz et al. (2019) highlighted that the main purpose of IPs is to mobilize human resources in participatory multi-stakeholder cooperation and foster collective learning. This new learning approach—social learning—is an efficient method that envisages a sustainable development change in complex systems like the date palm production system.

The results of this study and observation in the field show that by the sincere engagement of the producers, in the IP activities, a powerful dynamism and interaction between actors can be created. Through this interaction, different types of social networks are created (amical relationship and/or professional) and other ones are consolidated. The date producers' interaction has strengthened their capacity to react and build trust between them as well as with researchers and institutional actors. This reflection is already highlighted by different authors, such as Kilelu et al. (2013); Lundy et al., (2005); Neef & Neubert (2011); Pali & Swaans (2013); Penot (2018); Sulaiman (2015) who claimed that IPs have the ability to establish a dynamic environment for interaction, fostering innovation and collaboration in the field of agricultural research and development. This encourages the development of the organization, and then the social system (Kilelu et al., 2011, 2013; Struik et al., 2014). Trust and understanding among actors are the keys to IP success (Koné, 2012). The effectiveness of extension and diffuser agents (advisors) can be reinforced by increasing trust between them and date producers (Roussy et al., 2014). These factors impact the willingness of producers to explore, examine, and decide to implement innovation in their fields. Thus, IPs process of date palms includes five steps of adoption decision illustrated by Rogers (2010): (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation.

Dynamic action and interaction share creating and promoting good perception and innovation understanding level. These factors foster the adoption and dissemination process of the compost innovation. This fact is related to scientist experts and institutional actors (extensors) proficiency in the explication of innovation's advantages. The scientists' expertise in compost technology and other date palm practices attract the date producers' attention. Moreover, institutional actors' coordination and easily exchanged discussions keep date producers engaged in the social learning process and make them eager to know more about the biotechnological innovation advantages. As a result, compost innovation is appreciated by almost all date producers' members. This shows that date producers see it as the best alternative to face date palms fertilization challenges.

The compost adoption is, generally, based on specific agro-economics and psycho-socials factors. The agro-economic factors are related to the farm characteristics. These characteristics determine whether its owner will adopt the new innovative biotechnology. The size of the farm and its financial level are good examples of these agro-economic factors. As for the psychosocial factors, they are related to the social environment of producers and their interaction, such as the agricultural entrepreneurs, a high level of education, a responsible position in GIE, a strange social network, interaction with other dates producers and with researchers, engagement, and participation in almost all IP activities, search for new information and ideas, field activities, and the desire and ability of the farmer to accept change and develop his skills. Mackeracher et al. (2019); Roussy et al. (2014) highlighted that innovation adoption depends on agro-economic and psychosocial factors. These farmers' characteristics are considered a decisive factor in terms of innovation adoption. In fact, El Amrani (2001) claimed that the farmers who fill these criteria assimilate innovations more quickly.

In addition to the extensors and scientists who play an important role in explaining and convincing date producers about innovation's usefulness, leaders (champions) play an essential role in disseminating this innovation. As depicted by the conducted social network analysis (Figure 3), actor 19 and actor 50 are pivotal of spreading out compost adoption. The first one (19) is a producer leader of Jorf's IP. His influence can be explained

by the friendly relationship and trust that existed between him and other producers. The other one is a searcher expert in biotechnologies, by his expertise, he built strong bonds and trust with producers. Their good reputation and their goodwill to help other producers have made them the main influencers who share compost innovation. This was conducted by using different means, mainly, through face-to-face conversation in public locations such as coffee shops, guided tours on trial fields, or by phone and social media.

Having actors on the IPs who take the role of a “champion” is important to compost promotion as they prove to be enthusiasts and determined to make this innovation common and successful (Nederlof & Pyburn, 2012; Ngwenya & Hagmann, 2011). Innovation dissemination is a process in which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003; Sahin & Rogers, 2006). Mannan et al. (2017) claimed that interpersonal communication, mass media, and awareness have an influence on green fertilizer technology adoption among the local farmers. The idea at the origin of the dissemination notion is that inter-individual interactions are the driving forces of an individual’s behaviors, beliefs, and representations of evolution (Steyer & Zimmermann, 2004).

In order to decide to adopt technological innovation, farmers evaluate the information about its characteristics (Flight et al., 2011). The characteristics of this innovation defined by its attributes help reduce uncertainty about it and increase the adoption rate (Robertson et al., 2012). These attributes consist of five characteristics: relative advantage, compatibility, complexity, trial-ability, and observability (Rogers, 2003). Date palm IPs lead to approaching all stakeholders to explore all these five innovation characteristics. Through training courses, producers understood the basic information about compost fertilization advantages on date palm production and on the soil. Since they were not used to applying chemical fertilizers, the compost now represents the fittest product they need to facilitate their conversion into organic dates cultivation, so it is a relative advantage for them. Moreover, the compost demonstration allowed them to learn the right way to apply it to the date palm tree. This demonstration proved that there is no complexity in applying this new fertilization.

On another hand, compost was the subject of a trial field (trial-ability) in three selected sites allowing date producers to observe closely (observability) its effect on the date palm production system. Date producers have declared the compatibility of compost with their production system, mostly, if it is produced based on the date palm by-product.

Recycling date palm by-products as compost can be a beneficial strategy to reduce by-product accumulation in farms subject to diseases spread out (especially bayoud disease) or fire. The biotechnological innovation has proved its benefits such as protection of soil health (improving the water-holding capacity of soil, soil structure), enhancing date yielding, and reducing inputs and variable charges (workforces, phytosanitary product, mineral fertilizations product). Compost is a great alternative to face vulnerability to climate change and promote the sustainability of agricultural palm groves by enhancing water soil capacity, improving soil nutrition, and increasing productivity. Composting can increase soil organic matter levels, improve the nutritional and structural health of the soil, as well as substitute mineral fertilizers (Pérez-Piqueres et al., 2018). Compost has proven to be an option for recycling organic waste (Paul et al., 2017); therefore, its use is the key solution to these fragile environments (Sarwar et al., 2008), like oases.

Through this experience, IPs proved their efficiency and effectiveness strategy by impacting a positive change in farmers’ organization, social learning, and social system, improving the innovation process. They are a suitable approach for complex systems such as the date palm production system. IPs, as described by Adekunle & Fatunbi (2012), are workable multi-stakeholder approaches that are implemented temporarily at the local level to solve or resolve challenges facing date production. IP organizations are destined for small producers for reinforcing their alliance and cooperation in order to face market concurrence. Their establishment depends on project funding, so by the end of the project, a huge question arises about the sustainability of IPs: what option can be used to sustain this type of alliance? Which institution can take the relevance of the coordination?

CONCLUSIONS

IPs are an organizational innovation that may be used to conduct socio-technical and economic change. Their research-action program is adapted to the oasis social system. Information sharing has improved the performance of the date palm production system. Communication and continuous exchange enhance interaction between all stakeholders, and therefore, develop a strong social network. Cooperation and collaboration facilitate developing skills in taking decisions and elaborating an efficient action plan. These interactions build trust between stakeholders and ensure the sustainable development of date palm production.

IP approach is the most suitable instrument to disseminate sustainable agricultural practices. They are a useful instrument to encourage conversion to the biological production of date palm. They are an archway for multi-stakeholder to discuss, learn, exchange, and experiment the biotechnological innovations in the field. This research-action method will be extremely beneficial to the development of practitioners in the field. IPs are a platform that could regroup organisms, institutions, and universities to study, monitor and evaluate current issues in order to find solutions that fit the local conditions of the farmers.

Acknowledgements

We would like to thank all the actors for their participation and support of time. This work was supported by the R4D project “Application of organic bio-fertilizer technology to improve the sustainability of date palm production and cultivation” with the grand number IZ07Z0_160904 funded by the R4D program, the Swiss Program for Research on global Issues for Development, a partnership of the Swiss Agency for Development and Cooperation and the Swiss National Science Foundation.

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