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EXPLORING THE ADOPTION OF INNOVATIVE SPRAYING EQUIPMENT

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Abstract

The purpose of this paper is to explore factors impeding the adoption of innovative spraying equipment as well as farmers' information and training needs (i.e. demands for/from extension/innovation support services). Data have been collected, in the framework of INNOSETA project, through a survey in 7 EU countries, based on a questionnaire addressing both adopters and non-adopters of innovative spraying equipment. A total of 348 questionnaires were collected and analysed using multivariate data analysis. Furthermore, 32 experts representing research/academia, the industry and extension/advisory organisations have been interviewed, based on an aide-memoire. The combination of the analyses of the two data sets produce interesting results concerning the support of the adoption of such technologies (including subsidizations, legislation, equipment characteristics, etc.) and the role of advisory/extension services.

Introduction[1]

Plant Protection Products (PPP) industry and research have been developing more sustainable, novel PPPs; at the same time, spraying technologies have experienced important improvements in terms of efficiency and safety, including in their development the latest advances in electronics, data management and safety aspects. But unfortunately, there is still an important gap between research developments and the actual use of the available equipment by farmers, especially the large number of small and medium producers with limited access to relevant information[2]. If this gap closes, then European agriculture could become more sustainable with minimum environmental, socioeconomic and human health impact. Therefore the need for agricultural stakeholders to gain knowledge of existing and future technological advancements in spraying technology as well as of adequate training in all of the European territory which

[1] See INNOSETA project proposal.
[2] www.topps-life.org

will allow for the implementation of the EU legal framework and thus the production of food in a better and more sustainable way.

The H2020 project INNOSETA is organized to explore spraying application needs in the most commonly used crops (cereals, vegetables, orchards, vineyards and greenhouses) in seven European hubs (see below). The aim of INNOSETA is to set-up a Thematic Network on “Innovative Spraying Equipment, Training and Advising” designed for the effective exchange between researchers, industry, extension services and farming community. This network will link directly applicable research and commercial solutions and grassroots level needs and innovative ideas thus contributing to close the research and innovation divide in this area.

Among others, the INNOSETA project aims at assessing end-users’ needs and interests and at identifying the factors that influence farmers’ generation shift, adoption and diffusion of innovative spraying technologies. In this paper some of the results of the data analysis, collected through farmers’ survey (see below) are presented.

Theoretical background

The literature review (Koutsouris and Kanaki, 2018) undertaken in order to provide an understanding of farmers’ innovation-related behavior explored, on the one hand, main theories and models (e.g. Diffusion of Innovations – DOI (Rogers, 2003); Technology Appeptance Model – TAM (Venkatesh and Davis, 2000; Venkatesh and Bala, 2008); Agricultural (Knowledge and) Innovation Systems – A(K)IS (see Koutsouris, 2019); the Spiral of Innovations (Wielinga and Koutsouris, 2018),‘Triggering Change’ model (Sutherland et al., 2012), etc.) and, on the other hand, papers and reports related to spaying equipment and best practices adoption as well as elevant meta-analyses, focusing on the developed world.

With reference to the latter, for example, Thornton et al. (2017), in the first place, underline that the adoption of improved agricultural technologies and practices by farmers has often been less than expected despite demonstrated benefits. And quoting Orr (2012), they state that there are many contributing factors to that, including inherent limitations of supply-led approaches, limited attention to context-specificity and to farmers' priorities, and lack of appreciation of the socioeconomic, political and institutional contexts within which smallholder farmers operate.

Long et al. (2016) in their exploration of climate-smart agriculture (CSA) claim that its adoption in OECD countries is slow. Based on their literature review and a series of interviews in the Netherlands, France, Switzerland and Italy, they came to the conclusion that major impending factors are costs and other financial factors, overly complex language and ‘jargon’, and policy and regulatory issues (subsidies as well as lack of appreciation, in policy and research, of day-to-day farm realities) along with a lack of awareness of CSA and associated technological innovations.

Antolini et al. (2015) in their review of studies (largely concerning Brazil and the U.S.) on determinants of adoption of Precision Agriculture Technologies (PAT), show that the adoption drivers of major influence are related to: a) socio-economic factors (gender, age, education, family size, residence place, influence in decision making, experience in agriculture, experience with PAT, ability to obtain and process information, networking, membership in associations and cooperatives, financing and credit sources, risk aversion and organization level of producers in the region); b) agro-ecological (i.e. biophysical) factors (farm tenure, size, technologies and specialization, productivity, revenue, etc.); c) institutional factors which influence the behavioral change of the farmer

(region and distance to input and output markets); d) information sources (access and perceived usefulness of consultants, extension services, technical companies, etc.); e) farmer's perception of the technological attributes such as relative advantage of certain technology, visibility of results, compatibility with existing technologies in the farm and the opportunity to experiment PAT; and f) technological factors, i.e. level of mechanization technology and adoption of technologies by the farmer.

Pignatti et al. (2015) based on a series of interviews with key-informants in Greece, Turkey and Italy, conclude that adoption of ICT and technological innovations in agriculture is strongly connected with a list of drivers including: a) farmers' socio-demographic characteristics: age, education, behavioural traits (entrepreneurial attitude, open-mindedness, attitude towards changes, propensity, fear and anxiety, etc.), knowledge and awareness; b) farms' structural features: land ownership, farm size, economic status, farm business and targeting markets, perspectives and planning, production type and farm's organization, location; c) innovations' features, such as: ease of use, usability, simplicity, compatibility with existing systems, flexibility, along with effectiveness, usefulness, observability of performance, reliability, degree of fitting, potential and perceived benefits, profitability, price/performance ratio and return on investments as well as provision of understandable feedbacks and ready-to-use information outputs; d) external environment: trusted and competent support system (re: farmers' awareness raising, decision process and evaluation); and, e) public funding, agricultural policies and market conditions.

De Baerdemaeker (2014) based on a number of examples of new technology adoption in the U.S. (tractors, milking robots, renewable energy technologies, rollover protective structures on tractors) note the difficulty of new technologies to replace existing technologies and highlight that the adoption of new technologies involves considerable change in farming practices. The author, in the same vein with Diekmann and Batte (2014), who explored the adoption of precision weed control technologies among U.S. farmers, states that the adoption of new technologies is affected by the perceptions of the potential users, learning requirements for their introduction, economics (costs both for the user and the supplier) and the financial or regulatory stimuli/incentives (including support in the form of demonstrations, extension services, etc.) from governments, nongovernment organizations, retailers, and/or consumers along with a systemic approach to integrated weed management (i.e. the building of robustness and redundancy into the system).

Pierpaolia et al. (2013), with reference to their literature review on Precision Agriculture (PA) technologies, claim that the most important aspects influencing the adoption of PA technologies are: farm size; costs reduction or higher revenues to acquire a positive benefit/cost ratio; total income; land tenure; farmers' education; familiarity with computers; access to information (via extension services, service provider, technology sellers); location. On the other hand, the intention to adopt depends on perceived 'usefulness' and 'ease of use' along with technology costs (a perception of both high monetary cost and cost related to the difficulty in the use of technology), the quality of soil and farm size and farmers' skills and relevant competences. They therefore suggest that on-farm demonstrations, free trial and support services (which promote the perception that new technologies are easy to use) along with the simplicity and compatibility of PA tools can enhance adoption.

Knierim et al. (2019) in their exploration of the adoption of smart-farming technologies (SFTs) in 7 European counties found out that farmers, although they have a positive view towards them, underline a broad range of barriers vis-à-vis their implementation. This, in

turn, requires a better adjustment of technologies to farmers' needs and farm conditions as well as an improved enabling environment, in particular access to SFT related information, training and advisory services and to reliable digital infrastructure.

In their review Koutsouris and Kanaki (2018), along with Knierim et al. (2019), made clear that innovation adoption and diffusion is undoubtedly multifactorial with various factors, such as farmers' and farms' characteristics, biophysical, socio-cultural and institutional environment influencing the process of adoption, that is, if and how innovations are adopted; furthermore, the heterogeneity of both farms and farmers affects what is adopted, to what extent, and when. Moreover, the inconsistent evidence found in the literature review further points to the need for caution regarding, on the one hand, the use and measure of variables and, on the other hand, the different contexts (biophysical environment and cultural-historical patterns) within which research is conducted along with the characteristics of the technology under research. Reference has also to be made to the role of extension/advisory services and consultants which, in the framework of Agricultural Knowledge and Innovation Systems (AKIS), influence farmers' awareness, knowledge and skills. The literature review (theories and research results) provided the rational for the construction of both the questionnaire for the farmers' survey and the interview schedule for the experts' interviews carried out in the framework of the INNOSETA project.

Methodology

Our study covered 7 different European hubs: France, Greece, Italy, The Netherlands and Belgium, Poland, Spain, and Sweden. Five cropping systems were selected throughout all regions, i.e. arable crops, open field vegetables, orchards, greenhouses and vineyards (Table 1).

Table 1. Cropping systems per hub.

Spain	Orchards, Vineyards, Greenhouses
Italy	Orchards, Vineyards, Cereals
France	Orchards, Vineyards, Cereals
Greece	Orchards, Vineyards, Greenhouses
The Netherlands & Belgium	Cereals, Vegetables, Greenhouses
Sweden	Cereals, Vegetables, Orchards
Poland	Cereals, Vegetables, Orchards

Source: INNOSETA Grant Agreement

According to the project's Grant Agreement a) attention should be given to the fact that both adopters and non-adopters are included in the sample; b) the objective is to account and grasp the different needs and priorities of farmers in relation to their different socio-economic characteristics; and c) up to 50 interviews with farmers from the pre-classified groups should be conducted by the national partners, either personal or telephonic, using the specifically designed for this project questionnaire. Therefore, in the first place, it was decided to interview 50 farmers in each hub, comprising 25 adopters and 25 non-adopters per hub. Following, based on the contribution (%), in terms of utilized agricultural area (UAA), of each of the selected cropping systems per country a first estimation of the sample (no of farms/farmers per cropping system per country) was

made. In order to grasp differences, we categorized the population (total number of farms/farmers) in each cropping system into size classes (ha.) following EUROSTAT 2013 data sets. Thus, based on the EUROSTAT 2013 data concerning the farm size classes for each of the cropping systems per country, a detailed sampling schedule (no of farms/farmers per size per cropping system per country) was put together. Finally, in order to have enough farms/farmers in the least represented cropping systems (ca 10 farms/farmers in each hub and around 30 farms/farmers in total with respect to each of greenhouses, open field vegetables and vineyards), with a view to data analysis, the sample was adjusted as shown in Table 2 (following again the farm size classes rationale in order to select farms/farmers).

Table 2. INNOSETA sampling (farmers' survey)

	Initial sampling	Adjusted sampling	Collected questionnaires
Cereals	200	144	142
Open field vegetables	18	34	29
Orchards	104	102	101
Greenhouses	10	32	32
Vineyards	24	40	44
TOTAL	356	352	348

The questionnaire comprised 102 closed, Likert-type and open questions divided in 8 sections: farm's characteristics; spraying equipment and machinery; innovative spraying equipment; adopters (or non-adopters) opinions on innovative spraying equipment; best management practices (PPP application); information seeking; farmer's innovativeness; and farmer's characteristics. Data were collected by partners, entered in appropriate EXCEL data basis (built by AUA) and analyzed with the use of SPSS for Windows (ver. 23.0).

Furthermore, a number of experts, i.e. those who are involved in agricultural technology development and innovation processes such as researchers/ academics, industry representatives, extensionists/advisors and/or farmers (representatives of cooperatives/ associations) were interviewed; the target was to interview 5 experts per hub. The interview guide comprised 18 open questions/topics addressing issues such as the current challenges and the role of innovative spraying equipment in overcoming them; the advantages and disadvantages of innovative spraying equipment for farmers; reasons for which farmers adopt (or do not adopt) innovative spraying equipment and the like. The expert interviews were conducted face-to-face, via telephone or Skype, recorded and transcribed to produce computer-generated documents and analysed per topic (exploratory analysis; Sarantakos, 2005). Overall 35 interviews were conducted. Emphasis was given to the expert groups *Research* (9), *Industry* (9) and *Advisors* (9) especially vis-à-vis the *Farmers*' group (3) as farmers were specifically targeted through the survey; 5 *Academics* were also inetrviewed.

Results

Farmers' survey

General characteristics

The vast majority of the interviewees own the spraying equipment they use (93%). In 20 out of the 348 cases they use a subcontractor (in 15 cases along with the use of their own equipment by themselves). The adopters of one of the innovative spraying equipment (selected by the project experts) are 204 (58.6% of the sample).

Farming is the primary occupation for 81.3% of all the interviewees. The majority of the interviewees operate their own family farm (83%); companies represent 16% and cooperative farms 1% of the sample.

The majority of the interviewees fall in the age category 40-59 years old (55%); farmers up to 40 years old account for 28% of the sample with farmers aged 60 years old and over being the 17% of the sample[3]. Up to 10 years of experience in farming have 24% of the interviewees with 29% having more than 30 years in farming. All other classes of experience (11-20 and 21-30) account, each, for 19-28% of the farmers[4].

In general, the interviewees have good (secondary 26% and technical 42%) to higher educational level (university 22%)[5]. Furthermore, 93.6% hold the Training Certificate on PPP use according to the Directive 2009/128/EC while 61% have attended training courses in spraying machinery[6].

In general, adopters and non-adopters do not show any statistically significant difference in terms of age, gender, education and farm size (both owned and rented land) as well as years in farming and the existence of a successor - or not. Non-family farms (companies, cooperatives) are more likely to use innovative spraying equipment than family farms ($P=0.001$). Adopters and non-adopters do not differ in terms of holding a Training Certificate on PPP use but adopters are more likely to have attended a course on spraying machinery ($P<0.10$).

The interviewees claim that usability and user-friendliness are very important to them when they buy new things (97%) thus that they prefer to have some experience with something before they buy them (78%) and wait to buy new things, until they know that others have positive experiences with it (74%). Therefore, although they are the first to know about new machinery/technology in their social circles (54%) they are not the first to buy (63%). In general, they don't like taking risks (risk avoidance) with their farming business (65%). Finally, if interested, they would buy new equipment even if their (social) environment would be negative on it (63%).

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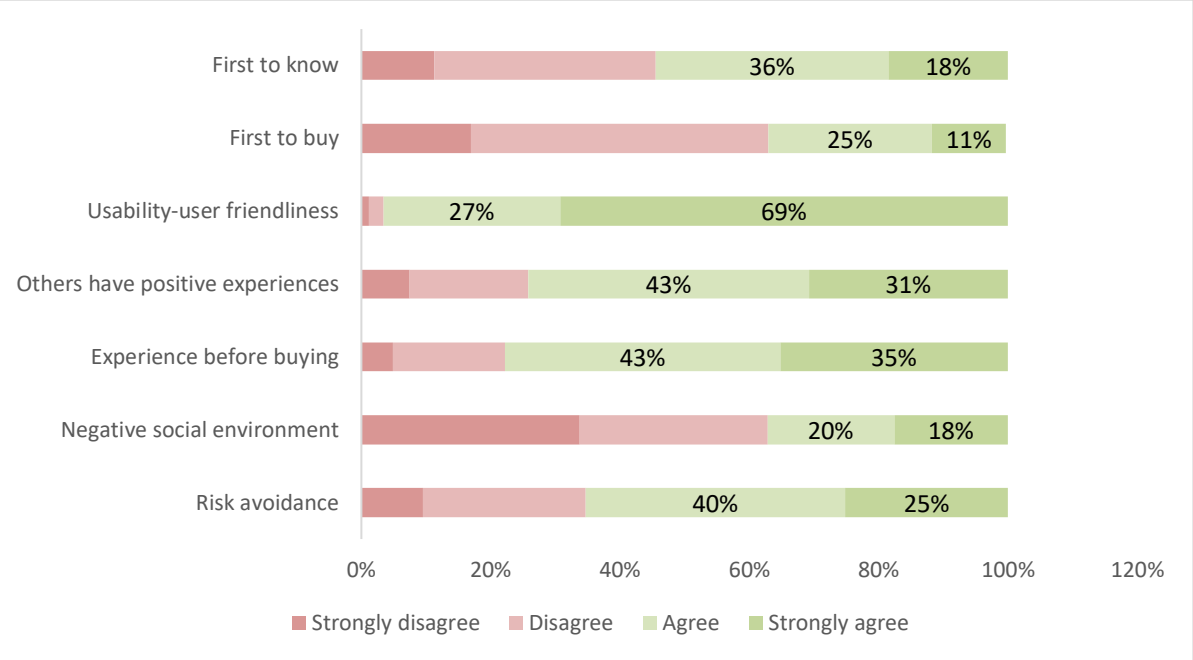
[3] Farmers' age is differentiated per cropping systems with orchards and vineyards cultivators being younger.

[4] Farmers with orchards or vineyards are the least experienced in farming and with spraying applications ($P<0.05$).

[5] The majority of the farmers with greenhouses have primary and secondary education while the majority of the farmers with cereals and vegetables have technical education; more farmers (%) with orchards or vineyards have tertiary education as compared to the farmers with other cropping systems.

[6] Farmers with cereals or open filed vegetables are the ones who have been mostly trained on both PPP use and spraying machinery with farmers with greenhouses being the least trained in spraying machinery

Figure 1: Farmer's innovativeness



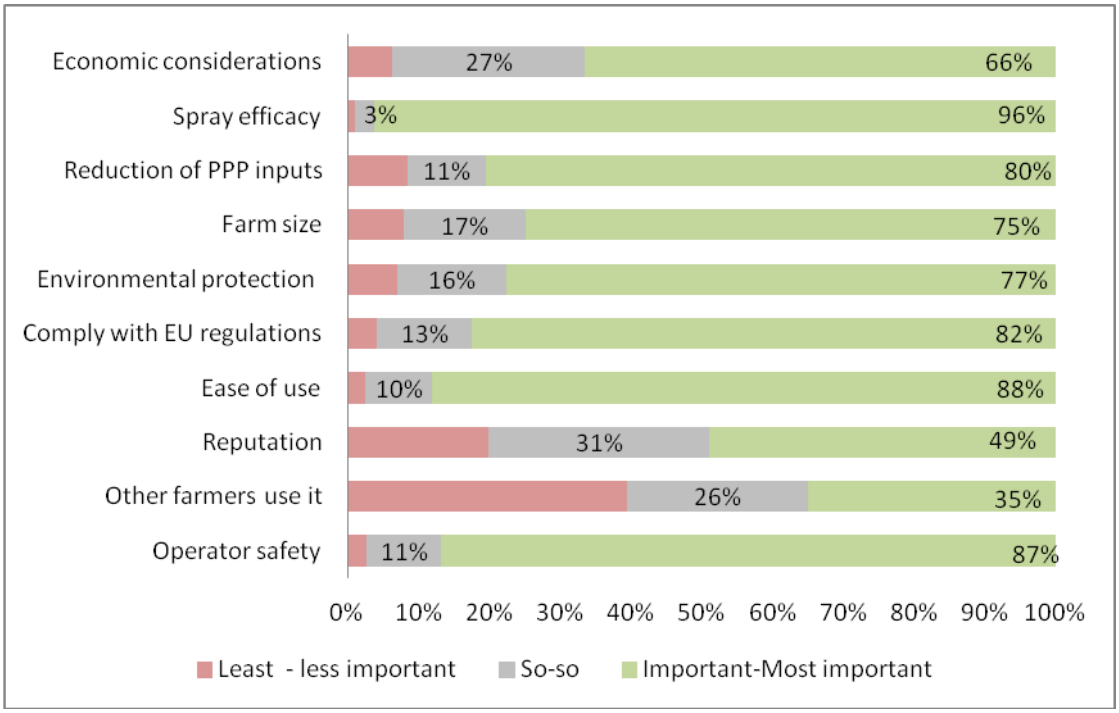
Adopters are more likely to be the first in their social circle of friends and relatives both to know about and buy new machinery/technology (P=0.000). On the other hand, non-adopters are more likely to wait to buy new things, until they know others have positive experiences with it (P<0.010) and prefer to have some experience with something before I buy it (P=0.001) as compared to adopters.

Spraying equipment characteristics and adoption

Concerning the criteria which affect interviewees' decisions on buying/choosing spraying equipment (Figure 2) 'spraying efficacy' (96%), 'ease of use' (88%) and 'operator safety' (87%) predominate followed by 'compliance with EU Regulations' (82%), 'reduction of PPP inputs' (80%), 'environmental protection' (77%) and 'farm size' (75%). 'Economic considerations' (66%) appear to be an important criterion (although less important than the aforementioned ones) with 'reputation (of the manufacturer)' (49%) and the fact that 'other farmers use it' (35%) being least important. Some farmers further added reliability (14 cases) and technical support/service (13 cases). Economic considerations are more important for non-adopters (P<0.05), while the reduction of PPP inputs and environmental protection are less important (P<0.05)[7].

[7] Economic consideration and farm size are less important for greenhouse growers; compliance with the EU rules is more important for farmers cultivating cereals and open field vegetables; and the fact that 'other farmers use it' is mostly important for growers with orchards/vineyards.

Figure 2: Criteria for buying spraying equipment



In general, adopters state that their innovative spraying equipment are easy to work with (96%), reliable (95%) and economically justified (90%); additionally, it is easy to get technical support for their equipment (87%) and they do not require a lot of maintenance (57%). Farmers also disagree with the statement that “sharing costs with other farmers has allowed you to use this spraying equipment” (83%).

Figure 3: Adopter’s opinions on the innovative spraying equipment they have

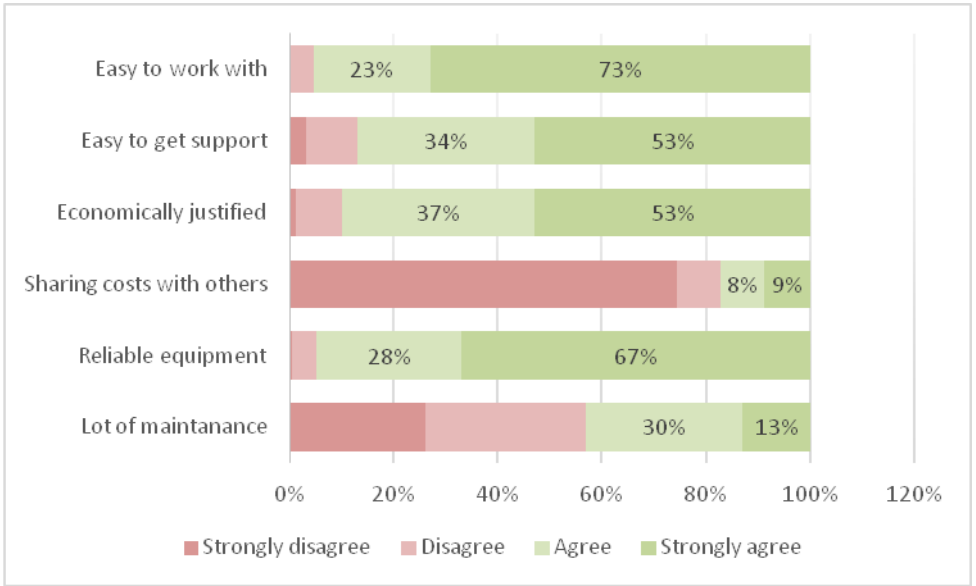
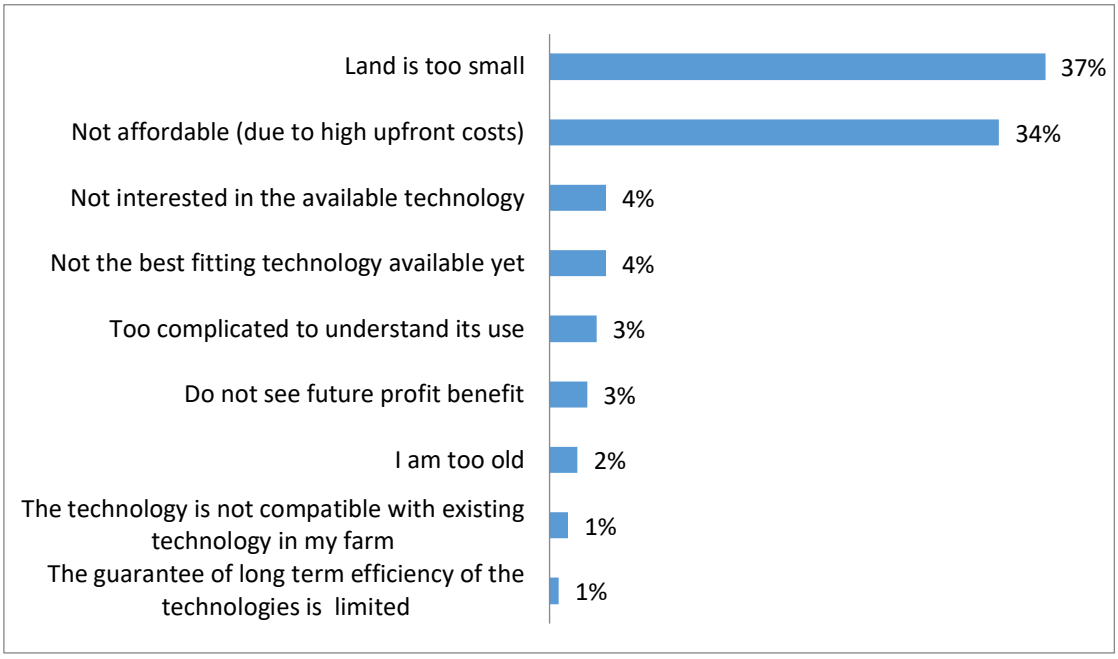


Figure 4: Most important reason for non-adopting innovatory spraying equipment



According to non-adopters the main reason for not having innovatory spraying equipment owes to their small sized farms (37%) and that they cannot afford it (34%). When five reasons pertaining non-adoption are aggregated, again the issues of affordability and small farms prevail (21% and 18% respectively)[8] with all other reasons ranging between 5% and 8%[9].

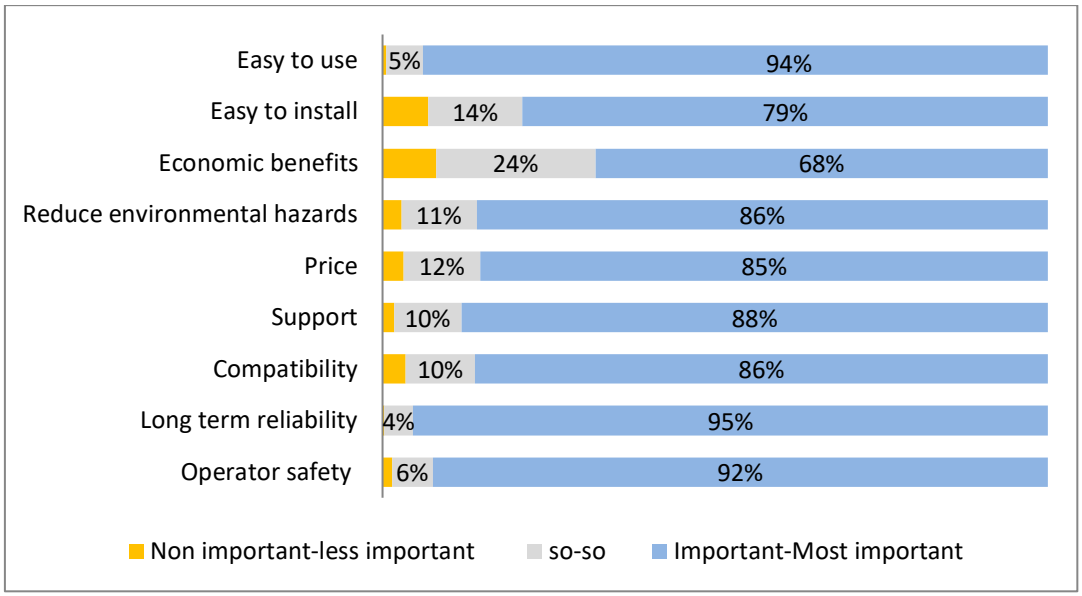
According to the interviewed farmers the most important spraying equipment characteristics that would make spraying equipment more relevant to farmers' needs (Figure 5) are long term reliability (95%), ease of use (94%) and operator safety (92%), followed by the availability of technical support (88%), compatibility with the existing machinery (86%), the reduction of environmental hazards (86%) and price (85%). Finally, easiness to install the equipment (79%) and economic benefits (68%) are important equipment characteristics for the majority. Adopters put more emphasis to the ease of use ($P<0.05$) and to the availability of technical support ($P<0.05$) than non-adopters[10].

[8] The main reason per cropping system is as follows. For cereals and open field vegetables: not affordable (19%), small size (17%), do not see future profit/benefit (12%); for orchards and vineyards: not affordable (25%), small size (19%); for greenhouses: small size (24%), technical assistance not guaranteed (13%), not affordable (10%).

[9] Other refers to 30 answers among which the most important are: 'do not need it/my old machine works well' (11), 'not handy' (3) and 'not suitable for the morphology of the farm' (3).

[10] Economic benefits and compatibility with the existing machinery seem less important for cereal and open field vegetables cultivators while long term reliability seems to be more important for orchard/vineyards growers.

Figure 5: Characteristics that would make spraying equipment more relevant to farmers' needs



Interviewees were also asked about the incentives they would like to see in future policies to facilitate the acquisition of innovative spraying equipment. Two out of three asked for some kind of financial support, in principle the subsidization of the purchase of innovative spraying equipment. Other financial incentives, albeit with few supporters, include tax reductions (8), reduced equipment prices (18) and higher/fair prices for their produces (20); some also ask for non-repayable incentives (17) as well as long term mortgages or exemption from VAT. In parallel, some ask special treatment (increased support) for small-scale farms (10), support to certified and/or high precision equipment (3) as well as the reduction of bureaucracy (6).

Furthermore, one out of seven asked for training and technical support from independent (extension/advice) providers. Training is somewhat more frequently asked for as compared to technical support and information dissemination; the demand for demonstration, on top of the demand for technical support, is also interesting to notice (12 farmers).

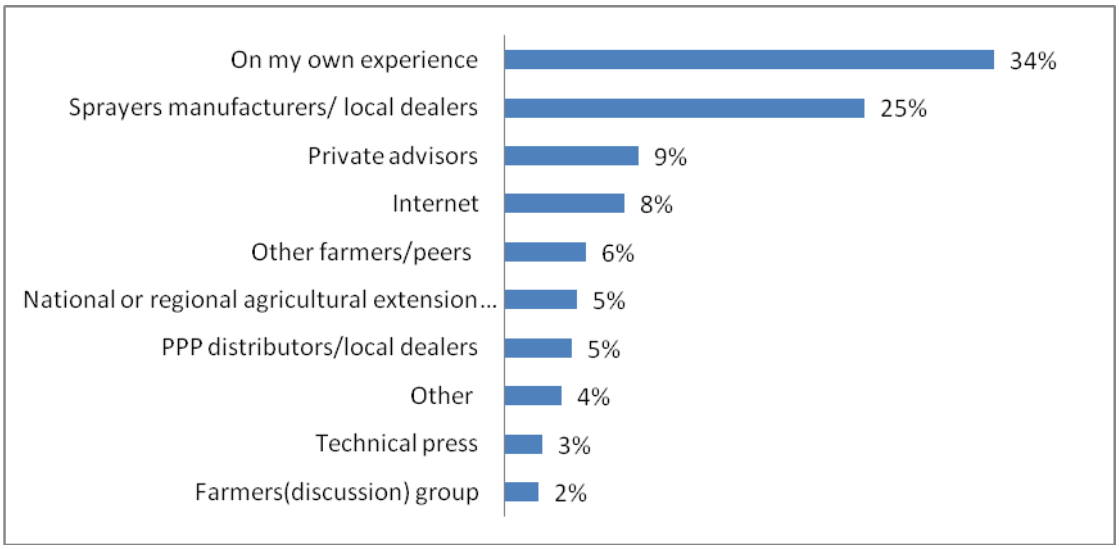
The change of regulations towards, for example, more strict inspections, compulsory use of Low Drift Nozzles and the like is supported by one out of ten. Another 10% maintain that the characteristics of the equipment (especially spraying efficiency followed by ease-of-use) could be a good incentive for adoption as well. However, around 5% of the farmers declare that they do not need/ wish to have any incentives

Sources of information

Regarding the most important source of knowledge/know-how on the use and operation of their spraying equipment is concerned (Figure 6) interviewees said that they rely on their own experience (34%) followed by information/advice from equipment manufacturers and dealers (25%) and advisors (private: 9% and public/cooperative: 5%)[11].

[11] The most important source of knowledge/know-how on the use and operation of their spraying equipment differs between farmers with different cropping systems. Farmers with cereals and open field vegetables mainly mention their own experience closely followed by the industry

Figure 6: Most important source of knowledge/know-how on the use and operation of spraying equipment

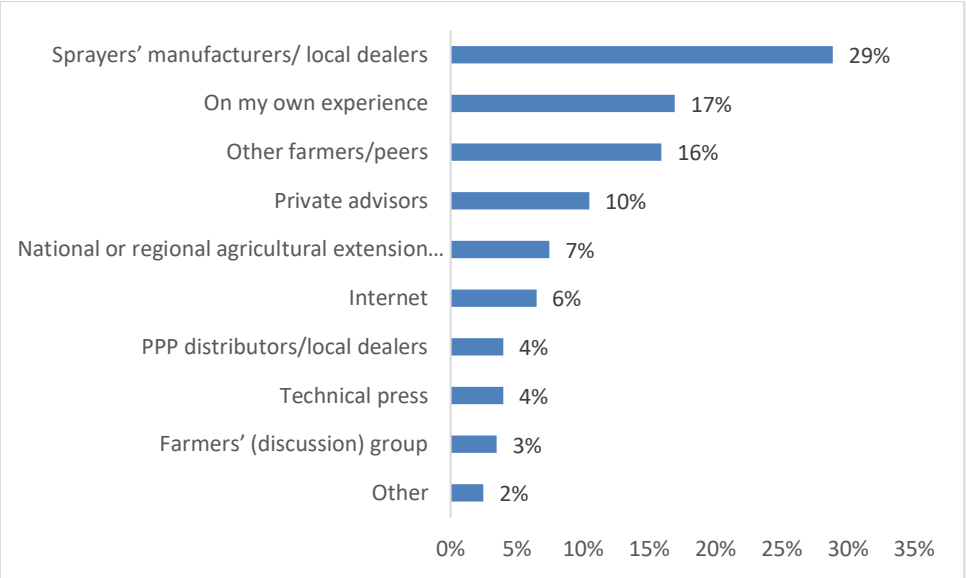


Adopters and non-adopters seem to consider different sources of knowledge/know-how on the use and operation of their spraying equipment as being more important to them ($P<0.05$). Non-adopters rely much more on their own experience (as compared to adopters as well as to other sources of information) while adopters more on the industry (sprayers' and PPP manufacturers/dealers).

When the three most important sources of information are taken together again farmers' own experience (23% of all the answers to the questions) and equipment manufacturers and dealers (21%) predominate followed by advisors (private: 9% and public/cooperative: 5%), other farmers (9% other peers and 4% farmer groups) and the Internet (11%).

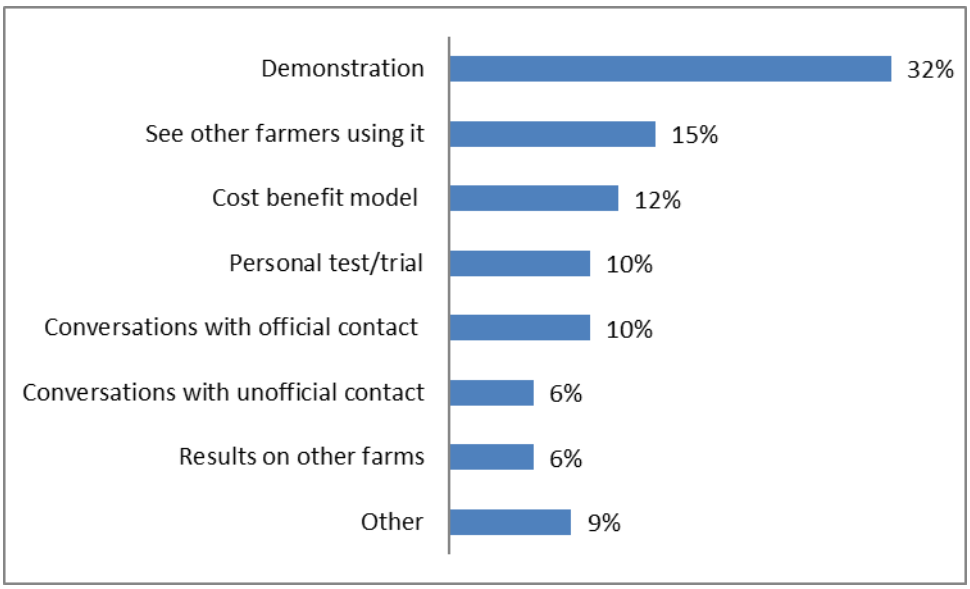
(sprayers' manufacturers, PPP distributors and their dealers); farmers with orchards/vineyards equally mention the industry and their own experience; and growers with greenhouses their own experience followed away by advisors (private or public).

Figure 7: Adopters‘ most important information source on buying innovative spraying equipment



The most important adopters’ source of information on buying innovative spraying equipment is sprayers’ manufacturers/ dealers (29%) followed by farmers’ own experience (17%), other farmers (16%) and private advisors (10%). All the other sources of information account for less than 10% each. When the three most inportant information sources are aggregated, sprayers’ manufacturers/ local dealers (24%) along with other farmers/peers and their own experience (15% each) predominate. All the other sources of information account for less than 10% each. Additionally, the majority of the adopters did not test the equipment before buying it (70.6%)[12].

Figure 8: Information source non-adopters trust the most for buying innovative spraying equipment



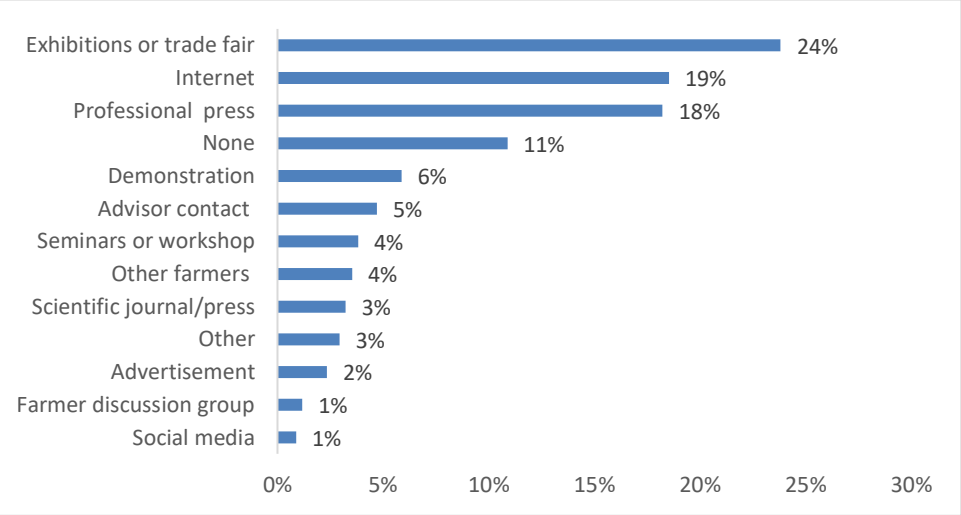
[12] This is mostly true for open field cultivations (around 27% of the farmers tested the machinery) while 50% of the farmers with greenhouses said they tested the equipment they were going to buy.

Non-adopters said that the most important source/piece of information/test they would trust before deciding to purchase innovative spraying equipment are demonstrations (32%), other farmers using the equipment (15%), a cost-benefit model tailored to their farm (12%) as well as a personal trial or conversation with someone with advisory capacity (10%). 'Other' refers to 13 cases out of which 4 refer to extension/advisory service and another 4 to the Internet. When it comes to the three most important sources/pieces of information/tests demonstrations still lead (19%), followed by personal trials (15%) and other farmers using the equipment (13%). Conversations with someone with advisory capacity as well as results on other farms are equally important at 12% closely followed by a cost-benefit model tailored to their farms (11%) and conversations with peers and neighbors (9%).

Furthermore, non-adopters claim that they would buy innovative spraying equipment if they would get a subsidy (84%) as well as relevant training (68%) and to a much lesser degree if they could share initial (purchase) costs (28%).

The majority of the sample said that they visit agricultural fairs, field days/demonstrations, or exhibitions at least once a year (86%) – notably 51% more than once per year. Only 4% said that they have never visited such an event[13]. Adopters visit agricultural fairs, field days/demonstrations, or exhibitions more often than non-adopters ($P<0.05$).

Figure 9: Most recent source of information regarding innovative spraying equipment



Interviewees claim that the most recent source of information in which they sought out information in relation to innovative spraying equipment are exhibitions or trade fairs (24%), the Internet (19%) and professional press (18%), followed by demonstrations (6%), and advisors (5%). No relevant information during the year the interview was carried out (2018) was sought by 11% of the farmers. When the three most recent sources of information are aggregated exhibitions or trade fairs (23%), the Internet (16%) and professional press (14%) prevail, followed by demonstrations (9%), peers (8%), advisors (7%) and scientific journals/press (6%) .

[13] Farmers with different cropping systems manifest different behaviors. Three quarters of the farmers with green houses visit more than once a year; 90% of the farmers with cereals and open field vegetables visit at least once a year; 20% of the farmers with orchards or vineyards visit less than once a year or never.

Experts' interviews

In general, experts agree that, on the one hand, spraying equipment has to be further improved to face current challenges and, on the other hand, farmers must become not only aware of new technology but trained and supported on both new equipment and PPP. The industry representatives notice that technology becomes 'more expensive and more susceptible to failures' and this is an additional challenge for R&D while advisers underline the need to understand the complexity of on-farm (under real conditions) plant protection.

According to the experts, the main advantage of the adoption of innovative spraying equipment relates to spraying effectiveness and its environmental and economic (reduction of costs) benefits. Other positive aspects relate to operator health and safety as well as to compliance with legislation and work comfort; professional pride and positive public image were also mentioned. These, in turn, are for the experts (although with differences in their ranking) the main incentives for farmers to adopt innovative spraying equipment, esp. when there are tangible results farmers can see 'in their environment'.

On the other hand, experts unanimously pointed to the high initial (purchase) costs of such equipment as being their main disadvantage (for some, such costs are not justified), followed by (as aforementioned) the need for the continuous training of the farmers. Some also pointed to the fact that such equipment is complex and vulnerable - thus the need for quick access to technical support. It was also argued that farmers may feel insecure due to both the fact some technologies may have not been proven in practice (under real local conditions) and the continuous changes in technology and legislation. Farmers further underline the need to combine environmental protection with agronomic efficacy and farm/household economy along with relevant legislation.

According to the experts farm size (bigger farms), farmer's age (younger farmers), education and 'personality – mentality' (technology enthusiasts, professional farmers, willing to experiment, open-minded) are most likely to be the factors that characterize the adopters of innovative equipment and practices. Production intensification, membership in farmers' groups or companies (vs. family farms) and public image were also mentioned, esp. by industry represenatives, as affecting adoption. According to extensionists the forefront factor pertaining adoption is farmers' environmental consciousness. Farmers additionally point to social pressure and legilation.

With regard to the main constraints vis-à-vis the adoption of innovative spraying equipment and practices experts point, besides affordability, to farmers' technophobia. The latter relates to the lack of training, farmers' low educational level, unawareness about new technology, along with occasionally contradicting messages from the industry, confusion about legislation and equipment vulnerability. Advisors and researchers further point to unsuitable farms' conditions and the pressure of farmers' immediate social environment while farmers also mention the fast developments in technology (including the expectation for better and cheaper equipment).

Given their preceding views, all experts state that the affordability of the innovative spraying equipment and the visibility/demonstrability of their benefits are key in supporting their wide adoption/use; the industry believes that profitability is a preceding factor. Other characteristics of the technologies, such as ease of use (user-friendliness) and maintenance, flexibility/adaptability, and reliability in time, are equally important.

Farmers once more point to the need for technology to focus both on environmental protection and farmers‘ interests.

Experts thus support the subsidization of the purchase of innovative spraying equipment (especially for small farms). Scientists do so mainly due to the need to “renovate the sprayer fleet” – although there are also reservations as to the effectiveness of subsidies and the burden of the accompanying them bureaucratic procedures. On their part, industry representatives underline that subsidies should be targeted to equipment which meet certain requirements (for example, certified as environmentally friendly; precision spraying). Moreover, experts maintain that subsidies should not be the sole measure taken; stricter legislation (for example, ban the marketing of the least efficient sprayers or reward implementation of best practices) – given that such legislation will be coherent, clear and enforced (i.e. control mechanisms are put in place) along with information campaigns concerning the benefits of innovations, are deemed equally important. Farmers once more point to the the need to bring agricultural and environmental components together.

Furthermore, experts agree that the main R&D target groups are the most dynamic businesses, including big entrepreneurial family farms and companies (professionals/entrepreneurs and/or early adopters comprising potential clients) along with younger farmers and the most profitable crops. Therefore, according to some scientists (academics and researchers), despite the need for R&D to take into account farmers’ needs farmers are actually placed at the end of the innovation pipeline and do not have any chance to influence what happens at the other end; additionally, the low level of farmers’ education negatively affects the expression of precise and realistic demands to the industry. On the other hand, it is maintained that small-scale, local/regional companies take a closer look to their clients’ needs as compared to larger national and/or international companies. Scientists said that innovation development is a process with its own dynamics and, although in spraying most developments are marginal/ incremental rather than radical ones, it is not possible to take into account all kinds of demands or to produce technology which will be suitable for everyone. Industry’s and research programmes‘ policies affect the uptake of innovative ideas (including farmers‘ ideas). Advisors and farmers largely agree with scientists; for advisors the industry is more subject to pressures from legislation rather than to demands from farmers while farmers argued that the technology is mainly supply-driven than demand-driven resulting in a ‘mismatch’. Contrary to such arguments the industry representatives maintain that there is two-way communication between farmers and the industry as well as that both actors are very important in technology development and thus their relationships must be improved.

Scientists underline the importance of extension/advisory services whose role is, on the one hand, to contribute to the wide diffusion of innovations (equipment, practices, PPP) through the provision of independent (neutral; objective), evidence-based information and practices (including training) to farmers and, on the other hand, to identify farmers’ needs and inform industry. Among others, advisory services can assist farmers through independent tests and demonstrations as well as through the examination of the suitability of recommended best practices on their fields. Furthermore, extensionists claim that the establishment of communication links between the main stakeholders is imperative.

The experts note that despite the need for all the actors (possibly) comprising AKIS (re: the branch of innovative spraying technologies) to cooperate there is a profound lack of a comprehensive discussion/innovation platform on spraying equipment and difficulty to

bring stakeholders together (especially on the horizontal level, i.e. competing manufacturers). They argue that extension/advisory services (should) intermediate between stakeholders, especially between farmers and researchers (farmers <-> extension <-> research) since they have good relationships with both of them. According to the scientists, the weakest link is policy, owing to its excessive slowness in decision-making and bureaucratic inefficiency along with the fact that decision-makers usually consult stakeholders other than farmers when they take measures about farming. The second most serious gap, according to scientists, is that between farmers and the industry; even if manufacturers interact with farmers they usually interact with a very small group which is not representative of the heterogeneity in farming. Such weak links between the interested parties result in gaps; the most characteristic one is the gap between theoretical/experimental developments and their applications in practice.

Conclusions

Innovation adoption and diffusion is undoubtedly multifactorial (Rogers, 2003); as aforementioned the heterogeneity of both farms and farmers affects what is adopted, to what extent, and when. In this piece of work, an attempt to identify factors impeding the wide adoption of innovatory spraying equipment was undertaken along with an exploration of the role of extension/advisory services in this regard.

In the first place, it is intresting to note that (most of) the interviewees/ farmers and (most of) the experts converge in their opinions concerning the measures to be taken to enhance the uptake of innovative spraying equipment. Experts agree with farmers for the need of targeted subsidization (certified machinery, best management practices, possibly more favorable for smaller farms). However, subsidies should not be the sole measure taken; stricter legislation and its enforcement, information campaigns, farmers' training and technical support by independent extension/advisory services are equally important.

Furthermore, equipment have to be improved in terms of the safety and comfort of the operator and ease-of-use, besides spraying efficacy and environmental and economic performance. The suitability of equipment for small farms as well as for difficult topographies has also to be underlined. Attention should be also given to farmers' demand for the better balance between environmental and agronomic performance of new technologies (spraying machinery and PPP).

As abovementioned, interviewees/ farmers asked for training and technical support from independent (extension/advice) providers while the interviewed experts, with reference to the low uptake and the complexity of new equipment, also stress the need to provide farmers with continuous training and technical support. On the other hand, it is important to notice the weak position of extension/advisory services among farmers' information sources on spraying equipment as well as the considerable percentage of farmers (esp. non-adopters) who are based on their experience. The need for extension/advisory services to engage with 'practice' activities like demonstrations[14] and participation in exhibitions or trade fairs as well as to assist farmers with their own trials and evaluations has been clearly shown, besides of course the intensification of other dissemination activities and the establishment of contacts with the 'hard to reach farmers' (including the internet and social media).

[14] For demonstrations see https://agridemo-h2020.eu/

Finally, the lack of functional AKIS/ innovation platform in the branch of spraying technologies has to be underlined since it results in gaps which, although rather known to the actors concerned, are not bridged (with farmers in the weakest position, or isolation). In this respect, extension/advisory services seem to be in the best position (as compared to the other actors) to play an intermediation role (see Koutsouris, 2018), i.e. to negotiate with other actors the creation of the relevant AKIS network.

Despite the particular scope and sampling methodology followed in the INNOSETA project, these results may be of wider interest. The importance of exploring the topic of the adoption of innovative spraying equipment and the (potential) role of extension/advisory services is shown; further exploration is needed and is thus very welcome.

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