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IS BUSINESS LINKAGE AFFECTING AGRICULTURAL ADVISORY SERVICES?

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ABSTRACT

Countries have different approaches in providing agricultural advisory services to farmers; it is not clear which provide best services and lead to least human or environmental hazards. In China, agricultural extension workers, trained as plant doctors, run plant clinics with at least six varying degrees of linkage to agri-business. More than 20,000 farmer queries were recorded during > 3,800 plant clinic sessions between 2014 and 2015, including the diagnosis of > 125 plant health problems of > 70 common crops as well as the related pest management recommendations. Diagnosis and recommendations appeared of high quality across all plant clinic types. Agri-business-connected plant doctors provided slightly less complete written advice regarding integrated pest management options than did non-business plant doctors; but gave slightly more detailed advice. Business-connected plant doctors advised slightly more highly hazardous pesticides and fewer antibiotics than non-business doctors; but differences are tiny. Overall, agri-business-connected and non-business plant doctors comparably reached farmers. Farmer reach depended more on employment type (governmental, cooperative, private) than on business-connection. In conclusion, differences between agricultural advisory services with different levels of agri-business-connection seem small; with a tiny higher risk of more hazardous products advised by business-connected services. The level of expression of this risk may be different between countries, and care should be taken when considering including the private sector in agricultural extension tasks. Nevertheless, human or environmental hazards by pesticides in food chains seem less likely a result of advice quality to farmers than by potential other factors.

Keywords: Advisory services, public and private agricultural extension, Plantwise, plant clinics, integrated pest management, agricultural policy.

INTRODUCTION

Countries around the world have different approaches in providing agricultural extension services to farmers (IFPRI, 2016; Rivera *et al.*, 2009). Many countries rely on government (public) extension services; some rely on private services while some on a mix of both. Few countries (particularly in central Europe) have no structured agricultural extension services (any more). And regardless of type, in many countries extension services may not reach the farmers most in need. This

can lead, on one hand to non-optimal food production, and on the other hand to human and environmental risks due to inappropriate agricultural practices. Despite such risks, the role of government agricultural extension services have been even reduced over the last decades, and often outsourced to private entities, particularly in Europe and East Asia (IFPRI, 2016). In addition or as a consequence, larger agricultural input supplier companies have their own agricultural extension service networks for farmers, particularly in the Americas, Europe and East Asia. Alternatively, lead farmers or technical specialists in farmer groups, cooperatives or larger agricultural enterprises advise

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their colleagues. Therefore, in some countries, the non-governmental sector is a key player in extension (Wei *et al.*, 2011; IFPRI, 2016), and most of them have agri-input business linkages. This raises a number of concerns, as stated in FAO (2010) as follows “A conflict of interest can exist when extension services that provide pest management advice are also involved in the sale of pesticides, particularly when extension staff need to supplement their income by sale of inputs, or when a lack of public extension services has resulted in pesticide retailers assuming the role of pest management advisors. In many countries, such conflict of interest has been a root cause of pesticide overuse.” It remains uncertain, however, to what extent the human or environmental hazards caused by pesticides are indeed a result of advice by agricultural extension services as opposed to other factors, such as independent decisions made by farmers or a lack of safer and affordable alternatives. The global Plantwise programme gathers data on the interaction between farmers and advisors, which can be used to assess the quality of advice given to farmers (Leach & Hobbs, 2013). Furthermore, the data can be used to make comparisons between extension services with and without links to agri-input sales.

The Plantwise programme aims to increase the resilience and responsiveness of national plant health systems to emerging problems by strengthening the linkages between key plant health stakeholders (e.g., production, extension, input supply, regulation) (Danielson *et al.*, 2014). Plant clinics are a mechanism to stimulate that increased interaction by serving as a conduit for the two-way flow of information, to and from the field. The data collected in a ‘prescription form’ for each query is held in a database, such as the Plantwise knowledge bank (Leach & Hobbs, 2013), and can be used to inform decision making by various plant health stakeholders, such as for pest surveillance, monitoring the quality of recommendations from extension workers and identifying training needs, or identifying topics for research. Plant clinics are a demand-driven service run by frontline extension workers with the aim to reach more farmers than Farmer Field Schools (Van der Burg, 2004) and traditional office-based or field visit-based extension methods (Boa, 2005; Romney *et al.*, 2013). Plant clinic sessions are held periodically at public places convenient to both farmers and local extension workers, e.g. farmer markets, retailer points, or central places of

farmer cooperatives/associations/clubs (Alokit *et al.*, 2014). The local extension workers have agricultural education, but had been additionally trained as ‘plant doctors’. Once trained, the plant doctors provide on-the-spot diagnosis and advice for farmers who bring plant health queries to the clinics (Romney *et al.*, 2013; Bandara & Kulatunga, 2014). Over the last decade, Plantwise has established more than 2000 local plant clinics in more than 30 countries across Africa, Asia and Americas (numbers by 2015) and reached over 4.5 million farmers through plant clinics and complementary extension approaches (Plantwise, 2016).

The Plantwise approach aims to integrate the plant clinic concept into the standard operations of existing extension providers, such as public or private organisations. Currently, different types of plant clinics exist across the world, depending on the local situations. Of particular interest in this study is the extent of extension service linkage with agri-input sales and the effect it has on the quality of advice given to farmers. There are many different types of plant clinics that sit along a continuum from purely public sector (e.g., government extension worker operating with no link to input sales) to purely private sector (e.g. an agri-input dealer advising farmers who come to the shop). In general, these can be placed in two broad groups: (1) non-business, having no link to input sales and (2) agri-business-connected. But all provide free service to farmers, particularly small holders, enriching their ability to address crop production constraints.

China is a good example where these different types of plant clinics co-exist. Plantwise has been implemented in China since 2012. By the end of 2015, there were 42 plant clinics being run by nearly 100 trained plant doctors in Beijing, Guangxi and Sichuan provinces. Many of the plant clinics are run by public plant doctors (62%), who are frontline government extension workers at county or township levels. The remaining are run by workers in private farmer cooperatives (18%) or in agri-input shops (20%). All three groups may have different levels of and reasons for agri-business engagement. As a result, in China, there are many different types of plant doctors with a number of different levels of agri-business connection: from no connection as a government or cooperative employed extension worker, to government workers running their plant clinic next to an input shop (with or without family relationships), to workers in cooperatives with own agri-input business,

to an entirely private business approach.

A number of food scandals attributed to pesticide misuse have shaken China in recent years, such as Isocarbophos-contaminated cowpeas in Hainan province in 2010 (Jin *et al.*, 2010) or Aldicarb-contaminated ginger in Shandong province in 2013 (Ma, 2013). As a result, Chinese consumers and the government are highly sensitive in the area of food safety (Luo, 2010). In the last decade, the Chinese government issued several policies and national programmes addressing this problem, e.g. Green Control Programme (Fan, 2006), Professional Unified Control Programme (MoA, 2010) and Pesticide and Fertilizer Zero Growth Action Plan 2015-2020 (MoA, 2015). IPM-based plant clinic services could be an effective approach to implementing such policies and programmes by transferring high-quality and case-specific advice to farmers (Kelly *et al.*, 2008; Bandara & Kotalunga, 2014). The diversity of plant clinic types, as well as the serious concern over pesticide contamination of food and the environment in China, makes it an optimal case for testing the above-mentioned reservations about the involvement of private sector, especially agri-input business, in agricultural extension. Extension services' data validation is a formal assessment of the accuracy of diagnoses and quality of advice using the data recorded at plant clinics (Danielsen *et al.*, 2013). This and other analyses of a plant clinic data set can provide an important glimpse into the kinds of advice agricultural extension workers give to farmers.

By the end of 2015, there had been more than 20,000 prescriptions issued to farmers by the various types of government, co-operatives and private plant doctors with different business linkages or without. This provided an excellent opportunity to search for data-based evidence of differences or similarities in the quality of advice provided by extension workers (here plant doctors) with different levels of agri-business engagement.

It was hypothesized that non-business plant doctors provide more IPM-compatible thus safer advice than agri-business-connected plant doctors (e.g. less often and/or less toxic pesticides). Also differences in farmer reach were assumed. The results may serve as a case study for other Chinese provinces to adjust their agricultural extension implementation. In a broader sense, results may help understanding the advantages

and disadvantages of countries' different approaches in providing agricultural extension services to farmers, and lessons learnt may help to improve plant health systems across the globe.

MATERIAL AND METHODS

Survey methods: To find out data-based evidences on differences or similarities in the services provided by agricultural extension workers with different levels of agri-business connection, a survey was conducted in China between 2014 and 2015. The survey was conducted among 49 agricultural extension workers, trained as plant doctors running 34 plant clinics in three provinces, i.e. in Beijing area, Guangxi province and Sichuan province (Table. 1). Plant clinics had been step by step established in Beijing and Guangxi since 2012 and in Sichuan since 2013. The 24 Beijing plant clinics are located in 9 suburban districts, the 4 Guangxi clinics in Xing'an county of Guilin prefecture and the 6 Sichuan clinics in Pengshan and Qingshen counties. The survey followed an unaligned, clustered sample design (Bharati *et al.*, 2004) with clinic districts as clusters within three provinces as larger clusters. Over 3800 plant clinic sessions have been held in this period (Table 1).

The survey was implemented through analysing the prescription forms that plant doctors provided on the considered plant health problems to farmers (see for details below). In total, 8152 prescription forms were issued to farmers in 2014, and 12277 in 2015 (=sample sizes), and subsequently recorded, harmonized, and validated (Table 1).

The diagnosis and advice provided to farmers, and captured in the local databases, was validated by a data validation team consisting of senior agricultural extension officers and plant protection experts (see for details below). In addition, plant clinic information was collected through a questionnaire on location, regularity of service, hours of service, etc. Plant doctor information was equally collected through a questionnaire, capturing location, sex, age, education, and work experiences. Plant doctors were moreover characterised with regard to their relationship or engagement with agri-businesses (see below), being the major factor analysed in this study.

Study population and plant doctor types: The study populations consisted of 49 active agricultural extension workers (here trained plant doctors) with different levels agri-business-connection (Table 1) running 34 plant clinics in three provinces, i.e. in Beijing area, Guangxi province and Sichuan province (Table 1). Total

number of trained plant doctors was 98 (target population) but only the 49 active ones (>10 prescription sheets per year) were analysed here.

The study population was aimed to reflect the agricultural extension workers in the considered regions with different levels of agri-business

engagement; this is about 2050 extension workers in Beijing area, 20000 in Guangxi province, and 22000 in Sichuan province.

Table 1. Sample sizes of plant clinics, clinic sessions and issued prescription forms (=queries= records) per province and year in China.

Province	# plant doctors trained	# plant doctors issuing forms*	# plant clinics	# plant clinics issuing forms*	# sessions	# queries	# queries per plant doctor per year	# queries per clinic per year	# queries per session
2014 Beijing	48	28	24	23	1241	6625	237	288	5
Guangxi	11	4	4	4	242	848	212	212	4
Sichuan	18	6	6	6	139	679	113	113	5
Total	77	38	34	33	1622	8152	Av. 215	204	4.6
2015 Beijing	67	34	32	24	1947	11493	338	479	6
Guangxi	11	7	4	4	187	488	70	122	3
Sichuan	18	6	6	6	60	296	49	49	5
Total	96	47	42	34	2194	12277	Av. 261	217	4.5
All	98	49	42	34	3816	20429	238	211	5

*Plant doctors and plant clinics that issued at least 10 prescription forms per year

Plant doctors were 28 to 60 years old (47 ± 8SD years). All plant doctors had job experience in farming and agriculture (7 ± 4.6 years experiences; 40 % at least 3 years).

The large majority of plant doctors had job experience in agricultural extension (average 6 ± 5 years experiences; 97% more than 3 years). About 20% of plant doctors also had experience in agricultural research and 41% in management. In details, 1.5% of plant doctors had MSc level agricultural education, around 16% had BSc level agricultural education, 24 % agricultural college level, 7 vocational agricultural school level, 1 %

high school (= Matura) level, 3 % middle school level. About 58% of plant doctors were male.

Plant doctors were divided into two major groups, i.e. (1) non-agri-business-connected thus independent plant doctors and (2) plant doctors with relationships or engagement in agri-business (table 2). Then plant doctors were divided into six subgroups from no via different levels agri-business-connection to totally private business-driven plant doctors operating out of an agricultural input shop.

Main type 1: Non-business plant doctors with no agri-business connection: consisted of government

agricultural extensions workers as well as farmer cooperative technicians with extension tasks but with no agri-business connection (n = 25) (Table 2), as follows:

- I. Government plant doctors are government employees either under county/district level Plant Protection Stations or under township level Agri-service Centres. They run plant clinics at a public place where farmers gather, or in/next to the governmental agricultural office, or as a mobile clinic going from one farmer gathering place to the next depending on the season.

- II. Cooperatives' plant doctors are employees of farmer cooperatives. The here-considered plant doctors run the plant clinic for and at a farmer cooperative without any agri-business involvement (i.e. without agri-input shop).
- III. *Main type 2: Plant doctors with agri-business engagement:* consisted of private plant doctors with agri-businesses engagement, government extension workers with different kinds of agri-business engagement, and farmer cooperatives' plant doctors with agri-business engagement (n = 24) (Table 2); as follows:
 - IV. Government plant doctors (see above) that run their plant clinics in or next to an agri-input shop as farmers usually gather there. The here-considered plant doctors have no family or other direct and obvious relationships with the shop owners.
 - V. Government plant doctors (see above) that run their plant clinics in or next to an agri-input shop as farmers usually gather there. The here-considered plant doctors have a family relationship with the shop owner, this is, the plant doctor him/herself or a family member is the business owner.
 - VI. Cooperatives' plant doctors (employees of farmer cooperatives) that run their plant clinic in or out of a cooperative-owned agri-input shop.
 - VII. Private plant doctors with agri-business, meaning he/she is the owner of or seller in an agri-input shop (or distributor, or service provider). The plant clinic is then placed in front or next to the shop.

Table 2. Characteristics of agricultural extension workers (here plant doctors) with different levels agri-business-relationships or engagements running 34 plant clinics in three provinces, i.e. in Beijing area, Guangxi province and Sichuan provinces in 2014 and 2015. Queries = prescription forms on plant health problem diagnosis and advice issued to farmers.

Main types of agricultural extension workers	# plant doctors *	# queries 2014 / 2015	Types of agricultural extension workers	# plant doctors *	# queries 2014 / 2015
Plant doctor without agri-business connection	25	3308 / 5293	1. Government plant doctor without agri-business connection	13	1008 / 1271
			2. Cooperative's plant doctor without agri-business connection	12	2098 / 3989
Plant doctor with agri-business connection	24	4844 / 6983	3. Cooperative's plant doctor with agri-business connection	6	1308 / 1663
			4. Government plant doctor in/next agri-shop without family relationship	3	281 / 514
			5. Government plant doctor in/next agri-shop with family relationship	5	1242 / 779
			6. Agri-input dealer/supplier as plant doctor	10	2013 / 4027

*Plant doctors that are active, this is who had issued at least 10 prescription forms per year.

The prescription forms: The survey was implemented through analysing the prescription forms that plant doctors provide on a plant health problem to a farmer (figure 1). Farmers bring crop samples suffering from a plant health problem to the plant clinic, wherein the plant doctor diagnosis the problems and provides advice on how to manage the plant health problem following IPM practices. This information is captured on prescription forms (figure 1). One prescription form is issued per each single plant health problem a farmer brought to the plant clinic at a certain clinic session. In detail, prescriptions forms contain information about the plant clinic location as well as the advising plant doctor, about the advised farmer, the diagnosis of the plant health problem, and the advice details (Romney *et al.*, 2013). Altogether there are 88 tick boxes on the forms and 17 descriptive areas (Figure 1).

Each prescription form has its unique code. The original copy of the form is given to the farmer so that he/she can double-check the diagnosis in his/her field, monitor the problem, and can then decide whether and how to implement the recommended measures, including potentially visiting an agri-input dealer shop with the prescription form. A copy of the form is kept at the plant clinic and all information entered into a database (for prescription form sample sizes see Table 1).

The owners of the single prescription form data are the considered plant doctor, their supervisors and the considered farmer. The owners of the local data sets are the local extension service implementing organisations; this is the Beijing Plant Protection Station, the Xing'an Plant Protection Station in Xing'an county in Guangxi province and the Sichuan Provincial Plant Protection Station in Sichuan province. Personal information of plant doctors and farmers were anonymised.

Assessing agricultural extension service outreach: To assess the outreach of the different plant doctor types, the following parameters were assessed: the number of prescription forms on plant health problem diagnosis and management advice issued to farmers per year and per plant clinic session; the number of sessions per year reflecting regularity; gender; and crop species. The number of farmers visiting a plant clinic but not obtaining a filled prescription form remained unknown but is considered low.

Assessing quality of diagnosis: To assess the quality of diagnosis of plant health problems by the different plant doctor types, the following parameters were assessed.

First, a validation team consisting of national and local plant protection experts and senior agricultural extension officers validated the correctness (=validity) of the diagnosis through comparing it with (a) the described symptoms (descriptive part of the prescription form), (b) with the chosen symptom tick boxes (24 symptoms possible); and (c) with the causation group tick boxes (11 cause groups: Biotic: Fungi, Biotic: Bacteria, Biotic: Insect/Mite, Biotic: Nematode, Biotic: Virus, Biotic: Phytoplasma, Biotic: Weed, Biotic: Unknown, Abiotic: Nutrient, Abiotic: Environment, Abiotic: Unknown). A diagnosis was accepted as correct if a), b), and c) were plausible (i.e. problem known from the region and considered crop), and all key symptoms mentioned. Otherwise the diagnosis was rejected. In other Plantwise countries, also specificity and distinctiveness of symptoms are accessed during validation, but this was not considered here. To assess the level of detail of diagnosis, words were counted in the descriptive diagnosis part of the prescription form.

Assessing quality of advice: To assess the quality of advice on the management of plant health problems by the different plant doctor types, the following parameters were assessed. First, a validation team consisting of national and local plant protection experts and senior agricultural extension officers examined and agreed on (a) the validity of the advice through assessing efficacy, safety, practicability of the written descriptive advice on the prescription forms in relation to the made diagnosis of the plant health problem. Here, "safe" means plant protection agents and measures that are a) not highly hazardous, this is not toxicity classified as 1a, 1b active ingredients according to the World Health Organisation (World Health Organization, 2009); b) not banned internationally as organic persistent pollutant according to the Stockholm Convention (Stockholm Convention, 2010; Downie, 2013); not banned internationally as ozone layer destructive chemical according to the Montreal Protocol (UNEP, 2012), and not banned according to the prior informed consent in the Rotterdam convention (Rotterdam Convention, 2010). Finally, the considered agents must be nationally registered for the considered crop (MoA, 2015). In other words, valid advice must follow the Plantwise Pesticide Policy and the Plantwise red list of plant protection agents (Plantwise, 2015).

In addition, national or local IPM schemes/regulations may also restrict WHO toxicity class II products, prohibit plant growth regulators and/or herbicides (Boller *et al.*, 2004; Boller *et al.*, 1997; Musebe *et al.*, 2014), but are not analysed/considered here. Special cases are antibiotics that are commonly not advised in plant protection, and surely not in IPM, due to possible microbial resistance development and human health risks.

In China, however, antibiotics are regarded as one type of bio-pesticides that are allowed and encouraged in “the Green Control” programme of China (MoA, 2011). In the here-presented paper non-IPM compatible measures consist of above mentioned red list measures as well as antibiotics.

The quality of advice was additionally characterised through validating comprehensiveness of advice to farmers. Comprehensiveness was judged according to what extent most or all IPM approaches had been advised on, this is, whether direct as well as preventive pest management measures were advised on; whether pest monitoring and decision information was provided; and whether non-chemical as well as least toxic chemical options with restriction details for use were provided. Finally, words were counted in the descriptive advice part on the prescription form as a parameter for detail.

Data analyses: Data on outreach, plant health problem diagnosis, and advise were analysed per main plant doctors types (non-business plant doctors versus plant doctors with agri-business connection), as well as per six plant doctor subtypes as per table 2, and finally versus other explanatory variables such as geographical region and year. In any case, only data from plant doctors and plant clinics were included, which are active, this is, having issued as least 10 prescription forms to farmers. Most data of the survey variables were averaged per plant doctor as well as per clinic session date to obtain person- and day-independent data. Then, data were visually analysed for normal distribution using histograms, Q-Q plots and the one-sample Kolmogorov Smirnov test (Kinnear & Gray, 2000). The influence of the independent explanatory factors “plant doctor main types” (= main treatments), and “plant doctor types” (= specific treatments), “province”, “year” and their interactions were tested on each of the dependent outreach, diagnosis and advise variables described above using general linear models GLM depending on the distribution of data, lack of many

extreme data, and independency of variables. In case that effects of province and/or year were detected or any associations among data, then those were taken as fixed factors in the subsequent analyses of plant doctor type effects using multifactorial GLM. For comparing the variables among the six plant doctor types, post hoc multiple comparison tests were implemented using Tukey test in cases of equal variances, Games Howell test in case of unequal variances (Kinnear & Gray, 2000).

RESULTS

Outreach of agricultural extension service: More than 70 different crops were brought by farmers to the plant clinics at least 10 times and advised by plant doctors during the two year study period (159 crops in total, but most with less than 5 queries). The 10 most frequent crops advised on were tomato (12%), strawberry (11%), cucumber (10%), grape (6%), romaine lettuce (5.5%), Chinese cabbage and eggplant (both 5.4%), chilli, rice, and sweet pepper (all around 3%). All other crops made less than 36 % of all queries.

Plant doctors, independent of their type, issued 243 ± 217 SD prescription forms with plant health problem diagnosis and management advice to farmers per year (max 1038 forms). All the 38 to 47 active plant doctors (in 2014, 2015 respectively) issued totally around 8000 to 12000 prescription forms to farmers per year. About 36 ± 33 plant clinic sessions were held per plant doctor per year, which means a session about every other week in warm areas, and a session every week in summer and few sessions in winter in cold temperate areas. About 6 ± 5.9 prescription forms were issued to farmers per plant clinic session. Business-connected plant doctors and non-business plant doctors held comparable numbers of sessions every year (39 ± 33 vs. 32 ± 34 sessions; t test: $t_{1,40} = 0.7$, $p = 0.47$). Business-connected plant doctors issued comparable numbers of prescription forms to farmers per year (232 ± 223 vs. 198 ± 203 forms; independent samples t-test with doctor- and session-nested data: $t_{1,81} = -1.9$, $p = 0.07$). Business-connected issued slightly less prescription forms per plant clinic session to farmers than did non-business plant doctors (5.9 ± 5.8 vs. 6.3 ± 6.1 forms; t test: $t_{1,83} = 2$, $p = 0.041$).

A comparable picture appears when splitting data into subtypes of plant doctors with different levels of agri-business connection (see dark vs. white bars in Figure 2). This is, business-connected plant doctors (cooperative, government or private plant doctors with agri-business

connection) did not reach more farmers than non-business plant doctors (cooperative or government plant doctors without agri-business connection).

However, when looking into details, obvious differences appear that seem not much related to business connection or independency (Figure 2). Government plant doctors regardless of their business connection seem to reach slightly less farmers than do cooperative's or private plant doctors. Most forms were issued to farmers by cooperative's plant doctors with or without agri-business connection as well as by private plant doctors with agri-business. Most clinic sessions were held per year by cooperative's plant doctors with or without agri-business connection as well as by government plant doctors in or next to an agri-business shop. Most prescription forms were issued per plant clinic session by private plant doctors.

In general the geographic regions had a bigger effect on the number of yearly prescription forms (GLM: $F_{2;83} = 7.2$, $p = 0.001$); than the plant doctor type (GLM: $F_{5;83} = 3.5$, $p = 0.004$). This is, that the Beijing area plant doctors handled more queries than did the Guangxi or Sichuan plant doctors. The year had no effect ($F_{1;83} = 3.2$, $p = 0.27$). Overall, 63 ± 4 % SD of all plant doctors, independent of their type, were males on average across provinces and years ($n = 49$ active plant doctors). The sex ratio was comparable among business-connected as well as non-business plant doctors (61 ± 3 % males vs. 64 ± 4 %, independent samples t -test: $t_{1;85} = -0.3$, $p = 0.7$). When splitting data into subtypes of plant doctors, differences appear with regard to gender of plant doctors (GLM: $F_{5;85} = 2.7$, $p = 0.019$). However, they seem not much related to business connection or independency of the plant doctor. In general, government plant doctors are more often males than are cooperative plant doctors and much more than private plant doctors. In detail, 83 ± 8 % government plant doctors without agri-business connection were males, and 88 ± 18 % of government plant doctors in/next agri-shop without family relationship, and 80 ± 0.5 % of the same but with family relationship. In contrast, only 42 ± 12 % of cooperative's plant doctor without agri-business connection are males, but 73 ± 9 % of cooperative's plant doctor with agri-business connection. The least males were found among private plant doctor with agri-businesses, i.e. only 41 ± 2 %.

Overall, about 2/3rd of farmers were males that were advised by plant doctors across types and on average

across provinces and both years (69 ± 23 % SD, $n = 10214$ advises in 2014 and 2015). Slightly more female farmers were advised though non-business plant doctor without agri-business connection than through plant doctors with different levels of agri-business connections (62 ± 27 % males vs. 76 ± 16 % males; independent samples t -test, $t_{5;85} = -3.2$, $p = 0.002$). When splitting data into subtypes of plant doctors, slight differences appear with regard to the gender of advised farmers (GLM: $F_{5;4037} = 4.3$, $p < 0.0001$). The proportion of male farmers advised was highest for government plant doctors in/next to an agri-shop with family relationship (85 ± 1 % male farmers).

Cooperative's plant doctors with or without agri-business connection advised comparatively less males (65 ± 7 %; 68 ± 4 %), but still more male than female farmers; as did government plant doctors without agri-business (74 ± 6 % males), and private plant doctor with agri-business (75 ± 1 %). The highest proportions of female farmers were advised by government plant doctors in/next to an agri-shop without family relationship (only 55 ± 3 % males).

Quality of diagnosis of plant health problems: A total of 125 different plant health problems were diagnosed at least 10 times during the two year study period in Beijing, Guangxi, and Sichuan provinces (459 plant health problems in total, but most with less than 5 queries). The 10 most frequent plant health problems were downy mildews (13%), powdery mildews (11%), diamond back moth (6%), Botrytis grey mould disease (6%), mites (5%), aphids (4.7%), viral diseases (4%), anthracnose disease (2.9%), whiteflies (2.9%) and thrips (2.6%). All others made 42 % of all plant health problems advised on.

Overall, diagnosis quality was very good; this is, over 99% of all diagnosis made by plant doctors, regardless of their type, were accepted as "correct" according to validations by plant protection expert teams. The diagnosis quality made by agri-business-connected plant doctors was as good as by non-business plant doctors (97.6 ± 4.7 vs. 99.3 ± 2.7 , plant doctor nested independent samples t -test: $t_{1;52} = 1.6$, $p = 0.1$).

When looking into detail of plant doctor subgroups, it appeared that all plant doctor types from no to different levels of agri-business connection made more than 98% correct diagnosis. Thus, the plant doctor type had no influence on the diagnosis quality (Multifactorial GLM: $F_{5;2657} = 2$, $p = 0.056$).

The geographic region and year slightly influenced diagnosis but effects were minor (Multifactorial GLM: region: $F_{2;2657} = 5.8, p = 0.003$; year: $F_{1;2657} = 4.6, p = 0.032$). Plant doctors, regardless of their type, provided on average a 18 ± 14 word-long

written symptom descriptions on a prescription form to the farmer (max 570 words, $n = 20428$ diagnosis in 2014 and 2015), reflecting the amount of provided details. This was a minor difference between business-connected and non-

business plant doctors, the first describing slightly more diagnostic details than the latter (18.5 ± 16.9 vs. 17.6 ± 9.9 word counts of written diagnosis, independent samples t-test with doctor & session- nested data, $t_{1;3801} = -2.2, p = 0.025$).

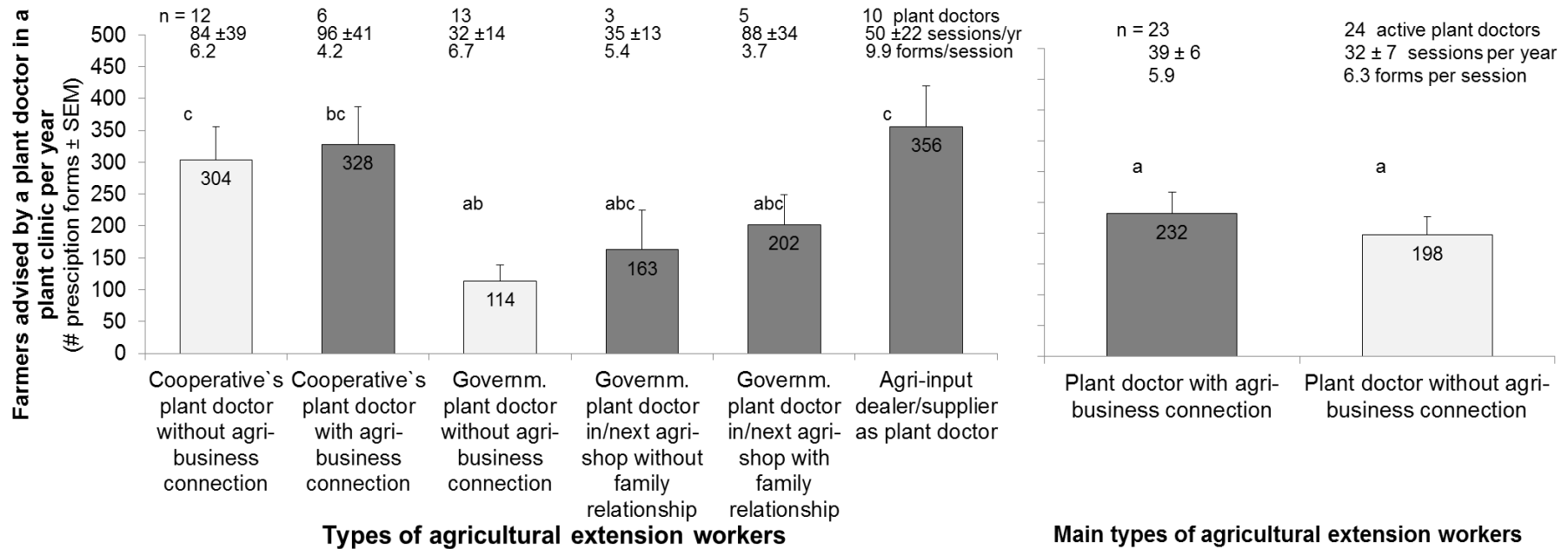


Figure 2. Number of farmers advised by different types of frontline agricultural extension workers (here plant doctors) in plant health clinics in Beijing, Sichuan, and Guangxi provinces of China in 2014 and 2015 (average prescription forms issued to farmers ± SEM). Dark grey bars = agri-business connected plant doctors; White bars = plant doctors without agri-business connection; only active plant clinics shown with more than 10 issued prescription forms per year (different letters on bars indicate differences according Tukey post hoc multiple comparison after GLM or two independent samples t-test at $p < 0.05$; using per-plant doctor- nested data).

When splitting data into sub groups of plant doctors, it appeared that government plant doctors without business-connection as well as private plant doctors with agri-business provided the most detailed diagnostic information to farmers (ca. 24 words), followed by government

plant doctor in/next agri-shop without family relationship (19), and least among cooperative plant doctors without or with agri-business engagement (15 and 16 words) and government plant doctor in/next agri-shop without family relationship (16) (compared word counts of

diagnosis using Tukey Post hoc test at $p < 0.05$ after GLM: $F_{5;3998} = 53, p < 0.0001$).

Quality of advice for plant health problem management: Overall, advice validity was very good; this is, over 99% of all recommendations made by plant doctors, regardless of their type,

were accepted as “valid” according to validations by plant protection expert teams. The advice validity of agri-business-connected plant doctors was as good as of non-business plant doctors ($99.6 \pm 1\%$ vs. $99.8 \pm 0.8\%$, plant doctor & year nested independent samples t-test: $t_{1;52} = 0.8$, $p = 0.4$). Although the different plant doctor types from no via different levels of agri-business connection slightly influenced the validity level of advice, differences were tiny as all plant doctor types made more than 99 correct advice (plant doctor & session nested Multifactorial GLM: $F_{5;2742} = 3.1$, $p = 0.005$). The geographic region and year did not influence advice validity (Multifactorial GLM: region: $F_{2;2742} = 1$, $p = 0.39$; year: $F_{1;2742} = 0.2$, $p = 0.64$). Overall, $85 \pm 30\%$ of plant doctors, regardless of their type, provided a comprehensive advice to farmers with regard to including all major IPM practices (as validated by plant protection experts).

Business-connected plant doctors provided slightly less comprehensive advice, in terms of completeness of IPM practices, than did non-business plant doctors (83 ± 33 vs. $91 \pm 21\%$ comprehensiveness accepted by expert validation team, independent samples t-test with doctor&session- nested data, $t_{1;1417} = 5.7$, $p < 0.0001$).

When splitting data into sub-groups of plant doctor types, it appeared that cooperative plant doctors with agri-business connection (91%), government plant doctors (92%), government plant doctors in/next agri-shop without family relationship (94%) as well as private plant doctors with agri-business (94%) provided a comparable, and the most comprehensive advice to farmers. This was followed by cooperative's plant doctors with agri-business connection (80%). Least comprehensive advice was provided by government plant doctor in/next agri-shop with family relationship (74%) (Tukey Post hoc test at $p < 0.05$ after GLM: $F_{5;1737} = 18$, $p < 0.0001$). Also the geographic region slightly

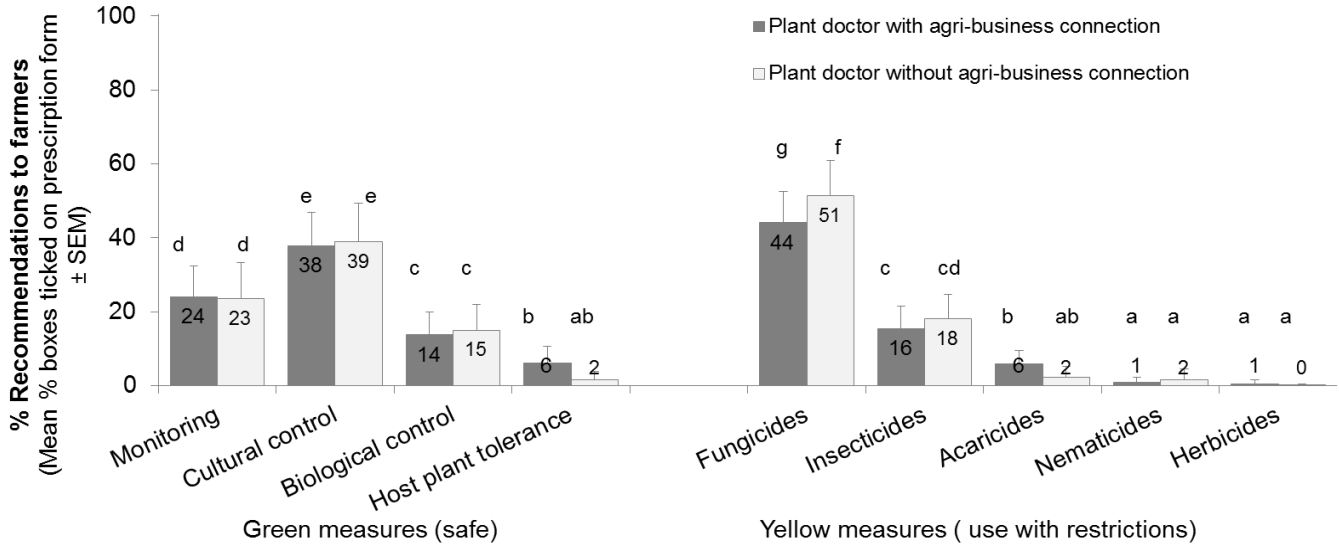
influenced comprehensiveness of advice, but year had not influence (Multifactorial GLM: region: $F_{2;1737} = 3.7$, $p = 0.025$; year: $F_{1;1737} = 0.9$, $p = 0.32$).

Plant doctors, regardless of their type, provided on average 61 ± 87 word-long written advice details in a prescription form to a farmer (max 2209 words, $n = 20100$ advices in 2014 and 2015), reflecting the amount of provided details. This means, plant doctors provided about three times more information in their plant health problem recommendations than in diagnosis and symptom information (compare to above).

Business-connected plant doctors provided slightly more detailed advice than non-business plant doctors (53 ± 53 vs. 46 ± 37 words of written advice, independent samples t-test with doctor & session- nested data, $t_{1;3969} = -5.1$, $p < 0.0001$)

When splitting data into sub groups of plant doctor types, it appeared that government plant doctors without business-connection, government plant doctor in/next agri-shop without family relationship as well as private plant doctors with agri-business provided most detailed advice to farmers (78 to 85 words); this is more than government plant doctor in/next agri-shop with family relationship (36), and cooperative plant doctors without agri-business engagement (both 35 words) (compared word counts of diagnosis using Tukey Post hoc test at $p < 0.05$ after GLM: $F_{5;3998} = 109$, $p < 0.0001$).

Proportions of different types of advised IPM measures were mostly comparable between plant doctors with and without agri-business connection (Figure 3). However, non-business plant doctors without agri-business connection advised slightly more often synthetic fungicides than did agri-business connected plant doctors. Nematicides and synthetic herbicides played no role in advice to farmers, the first being too toxic and largely banned for small holder farmer use, the latter being usually not part of IPM measures.



Integrated pest management measures

Figure 3. Type of recommendations given to farmers on managing plant health problems depending on agri-business connection of agricultural extension workers (here plant doctors) in plant clinics in Beijing, Sichuan, and Guangxi provinces of China in 2014 and 2015. Dark grey bars = agri-business connected; White bars = without agri-business connection; only active plant clinics shown with more than 10 issued prescription forms per year (different letters on bars indicate differences according Tukey post hoc multiple comparison after GLM at $p < 0.05$; using per- plant doctor & clinic session - nested data).

Very few farmers used IPM-non-compatible plant protection products prior getting advice, i.e. in only $0.36 \pm 6\%$ SD of cases a farmer had used red list products and in $0.86 \pm 96\%$ SD of cases antibiotics, (73 and 174 out of 20429). Very few plant doctors, independent of their type, advised red list plant protection products to farmers, i.e. for only $0.62 \pm 8.8\%$ SD of queries (127 out of 20428 advises; (table 3, figure 4a). Business-connected plant doctors advised $1 \pm 11\%$ red-list products, and non-business plant doctors advised $0.07 \pm 2.6\%$ (plant doctor & clinic session nested independent samples t -test, $t_{1; 4003} = -4.8, p < 0.0001$). Overall there was a decreasing tendency of advising such products (see 2014 vs. 2015 in table 3)

When splitting data into sub groups of plant doctors, it becomes clear that private plant doctors advise, although very few, slightly more red list products than any other plant doctor types ($1.8 \pm 15\%$ vs. $\leq 0.5\%$ for other types, $n = 6040$, figure 4a, $p < 0.05$ for Tukey post hoc test after multifactorial GLM: region: $F_{5; 4037} = 27, p < 0.001$, figure 4a). The geographic region did, and the year did not influence red list product advise (Multifactorial GLM: region: $F_{2; 4037} = 9.2, p < 0.001$; year: $F_{1; 4037} = 0.14, p = 0.7$, adjusted $R^2 = 0.07$).

Few plant doctors, independent of their type, advised antibiotics plant protection products to farmers, i.e. in $2.8 \pm 18\%$ of advises (532 out of 20428 advises table 3, figure 4b).

Non-business plant doctors advised few, but slightly more antibiotics than business-connected plant doctors (3.5 ± 21 vs $2.2 \pm 16\%$, plant doctor & clinic session nested independent samples t-test, $t_{1; 4033} = 5.2, p < 0.0001$). Overall there was a slightly decreasing tendency of advising antibiotics (see 2014 vs. 2015 in table 3)

When splitting data into sub groups of plant doctors, it becomes clear that cooperative plant doctors without business connection advise most antibiotics ($4.5 \pm 23\%$), followed by private plant doctors with agri-businesses ($3.2 \pm 20\%$). In contrast, all other plant doctor types advise less than 1.5% antibiotics (figure 4b, $p < 0.05$ for Tukey post hoc test after multifactorial GLM: region: $F_{5; 4037} = 4, p = 0.0005$). As for those details in advises on antibiotics, it remains difficult to say which type of plant doctors advises most antibiotics (figure 4b). The geographic region and year did not influence advice of antibiotics (Multifactorial GLM: region: $F_{2; 4037} = 0.1, p = 0.9$; year: $F_{1; 4037} = 0.3, p = 0.56$).

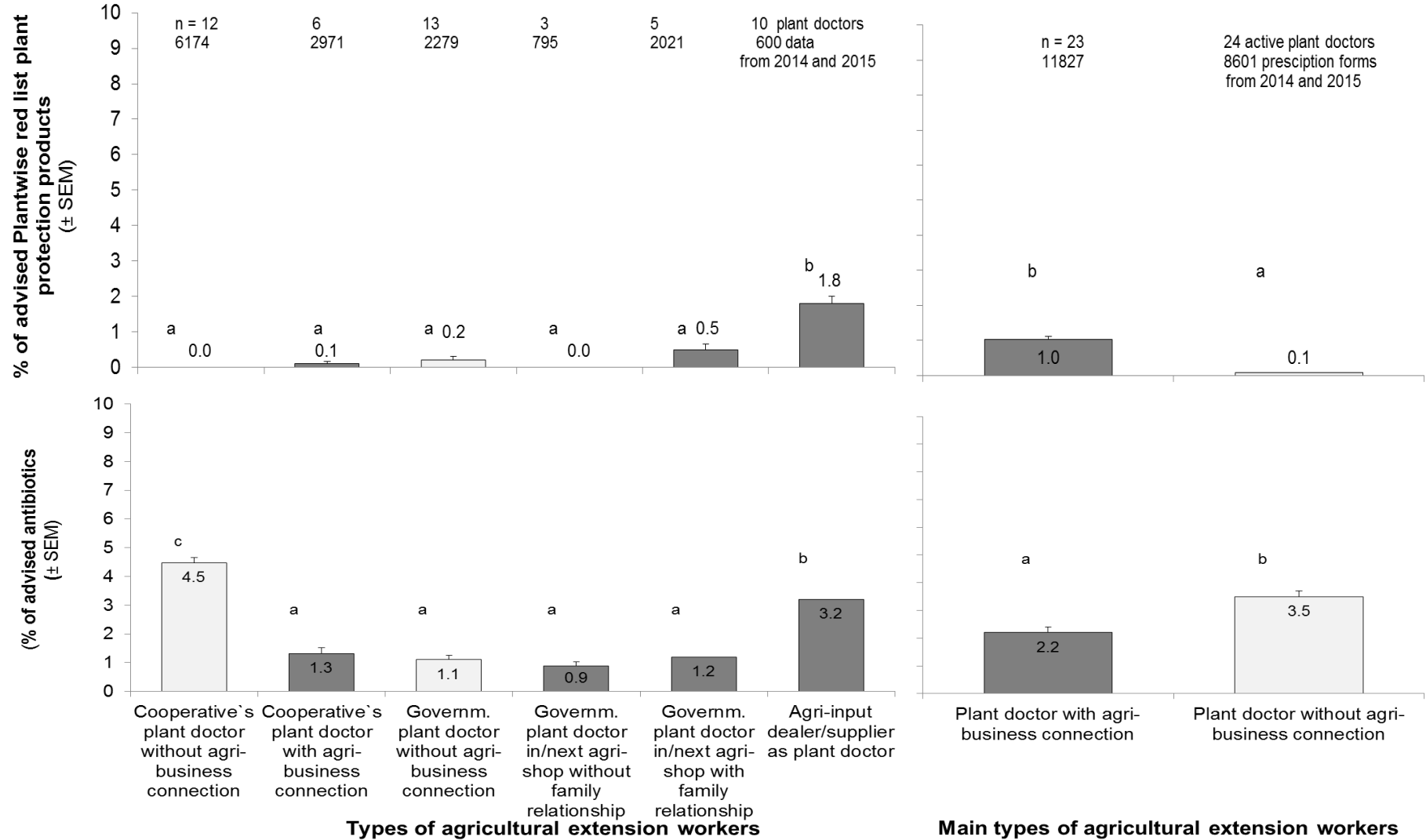


Figure 4. Non-IPM compatible plant protection products recommended to farmers by non-business and business-connected agricultural extension workers (here plant doctors) in plant clinics in Beijing, Sichuan, and Guangxi provinces of China in 2014 and 2015 (% red list products or % antibiotics as per issued prescriptions form ± SEM). Red list products as per Stockholm Convention, Rotterdam Convention, Montreal Protocol, WHO toxicity class 1a, 1b, (Plantwise, 2016). Dark grey bars = agri-business connected; White bars = without agri-business connection; only active plant clinics shown with more than 10 issued prescription forms per year (different letters on bars indicate differences according Tukey post hoc multiple comparison after GLM or two independent samples t- test at p < 0.05).

Table 3. Few non-IPM compatible plant protection agents recommended to farmers by non-business and business-connected agricultural extension workers (here plant doctors) in plant clinics in Beijing, Sichuan, and Guangxi provinces of China in 2014 and 2015 (% red list products or % antibiotics as per prescriptions form \pm SEM). Red list products as per Stockholm Convention, Rotterdam Convention, Montreal Protocol, WHO toxicity class 1a, 1b, (Plantwise, 2016).

Non-IPM products	214		2015	
	8152 recommendations		12276 recommendations	
	#	%	#	%
<i>Red list products</i>				
Cadusafos	3	0.04	0	0
Carbofuran +	44	0.54	4	0.03
Chlordimeform	2	0.03	0	0
Chlordecone *	0	0	3	0.02
Cyfluthrin or Beta-Cyfluthrin *	2	0.03	1	0.01
Dichlorvos, or DDVP *	20	0.25	22	0.18
Methamidophos	1	0.01	0	0
Methidathion +	2	0.03	1	0.01
Methomyl +	1	0.01	0	0.00
Monocrotophos	2	0.03	2	0.02
Nicotine *	1	0.01	0	0.00
Omethoate +	5	0.06	2	0.02
Oxydemeton-methyl, or Metilmerkaptophosoksid *	1	0.01	0	0
Parathion *	1	0.01	0	0
Triazotion, or Azinphos-ethyl *	5	0.06	2	0.02
Sum	90	1.10	37	0.30
<i>Antibiotics</i>				
Streptomycin	146	1.79	195	1.59
Zhongshengmycin	78	0.96	68	0.55
Other antibiotics	32	0.39	13	0.11
Sum	256	3.14	276	2.25

*Not yet totally banned in China by the end of 2015 (MoA, 2016), + Not yet banned in China by the end of 2015 but not allowed in most crops (MoA, 2016).

DISCUSSION

Due to the potential conflict of interest when agri-input dealers are involved in agri-advisory services (FAO, 2010; Bandara *et al.*, 2014; Danielson *et al.*, 2014), an effect of agri-business engagement on the quality of advice to farmers is often assumed, although evidence is generally lacking. It is hypothesized that agri-business interests may lead to unnecessary promotion of inputs in the recommendations provided to farmers (FAO, 2010; IRPRI, 2016), such that the plant doctor's focus is more on making profit than giving the farmers the advice that is best for them in terms of efficacy, price and safety. The current comparison of six types of plant doctors with different levels agri-business-connections in the diverse Chinese agri-extension system revealed that such effects exist, but are minor.

Diagnosis and pest management advice were found to be of high quality across all extension worker types (here synonym to plant doctor types) as well as across geographic regions. Moreover, no major differences were found in the advised proportions of preventive, monitoring and interventive IPM measures, including IPM-compatible synthetic pesticides. Moreover, the risk of advising highly hazardous pesticides was overall extremely low: less than 1% of all records. Thus, the large majority of extension workers, regardless of their affiliation with agri-business, appear to adhere to national regulations and IPM standards (Plantwise, 2016; Boller 1997, 2004). It remains to be seen whether the tiny but statistically significant difference in frequency of hazardous pesticide recommendations is socially and environmentally important or not. The data

set used in this study is very large – over 20,000 records of plant health problem diagnosis and pest management advice were analysed. Even when data were, due to some dependencies among them, nested for each plant doctor or for each plant clinic session, sufficient data still remained for analyses. Therefore, statistical analyses, particularly on levels of differences between plant doctors, are statistically powerful. Nevertheless, conclusions about the effects of agri-business engagement on quality of advice, and the extrapolation of those conclusions to other parts of China or other countries, must be made with caution.

First, there are only three provinces of China covered by this study. Although the investigated extension worker types, including different levels of agri-business involvement, exist in many other countries (IFPRI, 2016), countries are culturally, agriculturally and economically different. For instance, the level of intrinsic honesty and the prevalence of rule violations differ between societies (Gachter & Schulz, 2016).

Second, all the investigated extensions workers with different levels of agri-business connections went through a similar training programme from Plantwise to become plant doctors (Romney *et al.*, 2013; Bandara & Kulatunga, 2014). Furthermore, those plant doctors, regardless of being governmental, cooperative or private extension workers, had been selected by government plant protection institutions based on local reputation and professionalism. This may have reduced some of the differences that potentially exist between such different agri-extensions services.

Third, the current study is based entirely on records of the advice given to farmers, written by the extension worker. The oral communication between the extension worker and farmer was not assessed, but may be the subject of a follow-up study. Nevertheless, the here-presented study is statistically profound, covering questions of extension service outreach to farmers, as well as quality of diagnosis and recommendation. And taking all those into account, the study indeed suggests, to a small extent, differences between extension services provided by government or other independent institutions and private sectors.

As for outreach to farmers, it was found that the affiliation of the extension worker may be more relevant than their intensity of agri-business connection. For example, government extension workers, independent of their business connection,

reached fewer farmers per year than did cooperative or private extension workers. The main reason is that government extension workers held fewer plant clinic sessions per year than others. And this was especially evident for government extension workers without any connection to agri-input business. As for the cooperatives and private extension workers, the plant clinics are normally located where personnel are based for their daily duty, i.e. in their cooperative offices or input shops. In this way, it is likely much more convenient for them to hold clinic sessions than it is for the governmental extension workers. Moreover, cooperative offices and input shops are already familiar to farmers as points for advisory support, whereas plant clinics need to be effectively advertised to increase farmers' awareness of the clinics' existence and operating schedule (Alokit *et al.*, 2014; Danielson *et al.*, 2014). In addition, also the geographical (provincial) region slightly influenced extension service outreach. This is likely due to differences in the local plant clinic management, particularly regarding public awareness raising in the farming communities.

Gender analysis revealed that more than 80% of the government extension workers are males, which is a typical situation, with historic reasons, for frontline governmental services in China. Interestingly, the more intense the agri-business connection of extension workers, the higher the proportion of females, with fully private agri-input dealers having the highest rate of females, i.e. nearly 60%. The reason is that females in rural areas are often more available for full time employment within-agri-shop works than men, who are often responsible for other income resources, at least part time, especially from cash crop farming.

As for outreach to gender, about 2/3 of advised farmers were males on average across plant doctor types. Government extension workers running plant clinics in or next to agri-shops run by relatives reached the lowest proportion of female farmers. This result is largely due to geographical aspects. That is, this subgroup is mainly prevalent in Guangxi province, a region where more than 90% of advised farmers are usually males. The local partners in Guangxi province explained that this matches the local culture with men being responsible for making decisions on farming, including asking for help for crop health problems and purchasing inputs in the agri-shops. In contrast, female attendance at the plant clinics in the Beijing area and Sichuan province was

higher, i.e. about 35 to 40% in 2014 and 2015, also reflecting the local cultural situation.

In terms of extension service quality, all extension workers, regardless of their type, performed well; that is, the data validation process resulted in a high acceptance rate for both plant health problem diagnoses and pest management recommendations. The data validators (Chinese plant protection experts) found that over 98% of diagnoses and recommendations were valid. This is a high rate and reflects generally good skills of the extension workers. In some countries such high acceptance rates by validation teams are also found, such as in Zambia (S. Toepfer, pers. observation, 2015), but in other countries, acceptance rates can be much less, such as in Uganda (Danielsen *et al.*, 2014; Mur *et al.*, 2015). It may also be that the validation process is not entirely suitable in China for detection of imperfection or mistakes. Anyway, slight differences in the quality of recommendations appeared between the two major types of extension workers. Recommendations by business-connected extension workers were slightly less comprehensive (fewer management options) than those from non-business extension workers. This would match the assumption that business-connected extension workers may pay more attention to chemical control and ignore some additional IPM practices that are less interesting from a sales point of view. On the other hand, business-connected plant doctors provided more detailed recommendations (explained with more written text). This may be because those plant doctors tend to operate in their main location and have more information readily available, particularly on chemical pesticides (Danielson *et al.*, 2014). It is suspected that extension workers normally write less detail than what is actually spoken during the exchange with a farmer. Differences in the depth of information written on the prescription form may therefore be due to different opinions on what level of detail is required as well as different time pressures during the plant clinic session. An assessment of the specific information within each written recommendation would be informative; however, that level of analysis was, unfortunately, beyond the scope of the present study.

As mentioned above, the biggest concern of agri-business involvements in agricultural extension is the potentially more frequent advice for chemical pesticides and even non IPM-compatible highly hazardous chemicals (Bandara *et al.*, 2014). This can from our study, however,

only be partly confirmed. As stated above, a large majority of extension workers, regardless of their type, seem to stick to the agricultural regulations and IPM standards (Plantwise, 2016; Boller 1997, 2004). However, there seems to be a tiny higher risk of business-connected extension workers advising highly hazardous products more frequently than non-business extension workers (1% and 0.07 % of the more than 20,000 recommendations, respectively). It should be mentioned that most of the highly hazardous pesticides showing up in plant doctors' written prescriptions are not yet on the banned pesticide list of China (MoA, 2016) (Tab. 3); thus are legally allowed to be sold and used. Thus, those few extension workers, advising highly hazardous products are not doing anything illegal, but could have provided better i.e. safer and more IPM-compatible advice. Additional training could likely solve this problem.

As for antibiotics, non-business extension workers advised antibiotics more frequently than business-connected extension workers did (3.5 % and 2.2% of all recommendations, respectively). However, as with highly toxic pesticides, mentioning of antibiotics was still quite rare in the clinic data. Antibiotics in plant protection are a special case for China. Although antibiotics are considered IPM-incompatible in plant protection in many countries; in China, they are one of the permitted types of biopesticides and are even promoted for use according to Chinese agri-policies like the Green Control Policy (MoA, 2011). Because antibiotics are considered safe to the user, they are commonly used in vegetable production in China. Extension workers serving cooperatives, were particularly likely to advise antibiotics (4.5% of all recommendations). A comparable situation is found in fruit protection in the USA (Stockwell & Duffy 2013). This should, however, not downplay the concerns behind the use of antibiotics in plant protection (Kada *et al.*, 2014), as this can potentially lead to an additional uptake of antibiotics by humans through plant produce, i.e. in addition to the uptake through meat (Jorgensen and Wernli 2016), and through medication of human bacterial diseases (Cully, 2014). Increased exposure to antibiotics, in turn, raises the risk of potential resistance development of human pathogens. This is particularly crucial in plant protection as antibiotic residues on fruits and vegetables lead to a low dose scenario, which is particularly prone to lead to resistance development (Kada *et al.*, 2014).

In summary, the quality of extension services, regardless of their type and agri-business connection was generally high. The differences between agricultural extension (plant doctor) services with different levels of agri-business connection seem small in China. Therefore, it seems that human or environmental hazards created by pesticide use are less likely a result of advice quality by agricultural extension services to farmers than originally thought. Contamination scandals of agricultural produce and food may be due to structural reasons in the food chain, such as or making profits through using cheapest and therefore often hazardous options or the failure to implement food safety standards, rather than poor pest management advice by extension services. Furthermore, farmers' final decisions on which methods to use to manage crop problems and how to apply them may play a key role here, but this was not possible to assess with clinic data analysis alone.

CONCLUSION

Overall, it seems that different extension workers, regardless of employment type or agri-business linkage, can, if properly trained, make a correct diagnosis of plant health problems and provide good pest management recommendations to farmers. Differences between agricultural advisory services with different levels of agri-business-connection seem small; with a tiny higher risk of more hazardous products advised by business-connected services. The level of expression of this risk may be different between countries, and care should be taken when considering including the private sector in agricultural extension tasks.

It should also be remembered that human or environmental hazards by pesticides in food chains may have a number of reasons and not just being a result of advice quality to farmers. A need for training may be a recommendation to other Chinese provinces or countries when adjusting their plant health systems. In the end, it remains the responsibility of the countries and societies (Gachter & Schulz 2016) to analyse their own extension systems with regard to advisory service quality and the potential risks of involving the private sector in delivering such services.

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