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Participatory appraisal of institutional and political constraints and opportunities for innovation to address parasitic weeds in rice

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ABSTRACT

Parasitic weeds in smallholder rice production systems, of which *Striga asiatica*, *Striga hermonthica* and *Rhamphicarpa fistulosa* are the main representatives, form an increasing problem for food and income security in sub-Saharan Africa (SSA). The objective of this paper is to identify institutional and political constraints and opportunities for innovation to address parasitic weed problems in rice. Constraints and opportunities for innovation were studied across three nested systems: the parasitic weed control system, the crop protection system, and the agricultural system.

Multi-stakeholder workshops, interviews and surveys were held to gather data on key constraints faced by different stakeholder groups across three parasitic weed infested study sites in both Tanzania and Benin. The results demonstrate that in both countries, the majority of institutional and political constraints relate to the functioning of the broader crop protection and agricultural systems and not specifically to parasitic weeds. Although differences were observed between the two countries and the different stakeholder groups, the majority of constraints perceived by the stakeholders were caused by a lack of capabilities and resources and a limited access to credit. Awareness raising of parasitic weed problems among farmers, extension and crop protection officers at the local level, combined with improved input and service supply and enhanced agricultural education and training curricula at the national level, were identified as important elements for improvement. More structural collaboration between key stakeholder groups is expected to contribute to a better recognition of agricultural problems, like that of parasitic weeds in rice, and a more timely identification of feasible solutions.

1. Introduction

Parasitic weeds in cereal production systems form a growing threat to local and regional food security and income generation for smallholders in sub-Saharan Africa (SSA) (Parker, 2012; Rodenburg et al., 2010; Scholes and Press, 2008). Parasitic weeds are increasingly encountered in rice (Rodenburg et al., 2015), which is the fastest growing cereal commodity in SSA (Seck et al., 2010). Yield reductions between 40 and 100% in parasitic weed infested rice fields have been reported (Gbèhounou and Assigbé, 2003; Rodenburg et al., 2011c). The weeds are wide spread in SSA and while accurate and precise figures on their economic importance are lacking, a recent desk-top study estimate the combined annual damage for rice production in SSA to range from 60 to 700 million US dollars (Rodenburg et al., 2014). Despite this threat, there is limited attention for, and awareness of, parasitic weed problems in rice as compared to other cereal crops such as maize or sorghum, both in the scientific literature (Rodenburg et al., 2010), as well as among practitioners in some of the countries where parasitic weeds are eminent (e.g. Schut et al., 2015b). For rice, *Striga hermonthica* and *Striga aspera* dominate in West Africa, *S. hermonthica* is the most important in east and central Africa (around lake

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Victoria), while *Striga asiatica* is the dominant species in southern parts of East Africa (Rodenburg et al., 2010). *Rhamphicarpa fistulosa* is found across sub-Saharan Africa (Rodenburg et al., 2015).

Parasitic weeds can be considered a complex agricultural problem. Complex agricultural problems are defined as problems that have multiple dimensions (e.g. biophysical, technological, social-cultural, economic, institutional and political) that are embedded in interactions across different integration levels (international, national, regional, district, village, farm, field). Furthermore, complex agricultural problems are characterised by uncertainty, and affect a multitude of stakeholders and organisations (Schut et al., 2014c). To support integrated analyses of complex crop protection problems, and to explore innovations to address them, systems approaches have been proposed (e.g. Birch et al., 2011; Kropff et al., 2001; Savary et al., 2012). A recent systematic review of systems approaches to innovation in crop protection concluded that: (1) there is little attention for the institutional and political[1] dimensions of innovation in crop protection systems, and (2) the active involvement of stakeholder groups in research that explores systems approaches to crop protection innovation is limited (Schut et al., 2014b). The above findings resonate with the existing body of scientific literature on parasitic weeds in rice, that mainly focuses on understanding the biology, ecology and distribution of parasitic weeds, and on the development, testing, adoption and impact of technologies for parasitic weed management at farm level (Rodenburg et al., 2010). To a lesser extent, the socio-cultural dimension (e.g. Vissoh et al., 2007) and economic impact of parasitic weeds (De Groote, 2007; Debrah, 1994; N'cho et al., 2014) are addressed. The institutional and political dimensions of parasitic weeds and innovations to address them do not receive structural attention. While farmers frequently participate in parasitic weeds research on rice and other crops (Abang et al., 2007; Emechebe et al., 2004; Kamara et al., 2008; Schulz et al., 2003), above-farm level actors such as the private sector, civil society organisations, and government are less often involved. The objective of this paper is to identify institutional and political constraints and opportunities for innovation to address parasitic weed problems in rice as perceived by different stakeholder groups. As parasitic weed affected areas are expected and reported to increase (Rodenburg et al., 2011a, 2015), identifying and addressing institutional and political constraints that hinder innovation is essential for the development of integrated and coherent research, development and policy strategies for parasitic weed control in SSA.

2. Concepts and methods

2.1. Key-concepts

Innovation is defined as a co-evolving process of technological (e.g. cultivars, fertilizer, agronomic practices) and socio-organisational (e.g. land tenure arrangements and stakeholder collaboration) changes (Hall and Clark, 2010; Hounkonnou et al., 2012; Leeuwis, 2004). Such changes occur across different levels, and are shaped by interactions between stakeholders and organisations inside and outside the agricultural sector (Kilelu et al., 2013; Klerkx et al., 2010). In this study, constraints and opportunities for innovation are studied across three nested systems: the parasitic weeds control system, the crop protection system, and the agricultural system. The parasitic weed control system is embedded in the crop protection system, which, in turn, forms part of the larger agricultural system. We use a definition by Spedding (1988) to delineate these systems as the operational units including all actors and organisations involved in parasitic weed control, crop protection and broader agricultural production, processing and commercialization activities. The institutional dimension of problems or innovations comprises the formal (e.g. policies) and informal (e.g. values) 'rules of the game' (Hounkonnou et al., 2012). The political dimension includes the mutual dependencies and power dynamics between individual stakeholders or stakeholder groups and their collaboration in terms of tackling problems. Stakeholders are those actors or actor groups with a stake in the problem or in the innovations that can lead to their resolution (McNie, 2007).

2.2. Study sites

Data for this study were gathered in Tanzania and Benin. Tanzania and Benin were selected as case study countries for a number of reasons. First, in both countries rice is predominantly grown under rainfed conditions (Table 1) – either upland or lowland – by smallholder farmers, i.e. conditions where parasitic weed problems are most eminent (Rodenburg et al., 2010). Second, Tanzania and Benin represent different institutional and political contexts in terms of how parasitic weed control, crop protection, and the broader agricultural systems are structured. In Tanzania, for example, there is a policy on parasitic weeds ('*Striga* Rules' that form part of Tanzania's Crop Protection Act), whereas such a specific policy is absent in Benin. Third, the choice for an East African and a West African country allows us to capture some degree of within-country and between-country heterogeneity that can provide a starting point to explore more generic parasitic weed management strategies across SSA.

For both Tanzania and Benin, three study sites in rice producing regions with known parasitic weed problems were identified. In Tanzania, Kyela (Mbeya region), Songea Rural (Ruvuma region) and Morogoro Rural (Morogoro region) districts were selected. These regions represent 34% of the total rice area planted and 37% of the domestic production in Tanzania (United Republic of Tanzania, 2012). In Benin, Dassa-Zoumè (Collines region), Kandi (Alibori region) and Tanguiéta (Atacora region) districts were selected (Fig. 1). These regions account for 80% of the rice area and 85% of domestic rice production in Benin (DPP/MAEP, 2009; N'cho et al., 2014).

2.3. Data collection

Data were collected between April and November 2012 in Tanzania, and between July and August 2013 in Benin. To gather and analyse data in collaboration with different stakeholder groups, a participatory diagnostic tool for the Rapid Appraisal of Agricultural Innovation Systems (RAAIS) was used (Schut et al., 2015a). At the core of RAAIS are multi-stakeholder workshops that each took one day, and were held at the six study sites. Starting point of the workshops was for each individual participant to identify five constraints that could be specifically related to parasitic weeds, or to crop protection or agriculture in a more general sense. A subsequent step was to develop a stakeholder group top 5 that was used throughout the rest of the workshop. The stakeholder group top 5 was based on stakeholder group consensus on the five most important constraints faced by that group. Two types of constraints were identified and prioritised by stakeholder groups: (1) constraints experienced by the specific group that directly influence their ability to achieve their objectives, and (2) constraints faced by other stakeholder groups that indirectly influence their ability to

[1] In this paper the term 'political' refers to the power-play between different stakeholders or stakeholder groups. This includes politics related to the governance and public affairs of a country, but can also include organizational politics, or household politics.

Table 1
Characteristics of the rice production in Tanzania and Benin.

	Tanzania	Benin
Total area under rice production (ha) in 2012	799,361	65,729
Percentage under rainfed production (% of total area under rice production)	93%	88%
Average rice yields between 1992 and 2012 (t/ha)	1.8	2.3
Average annual rice yield increase between 1992 and 2012	1.7%	4.5%
Key constraints for rice farmers	Diseases, pests and weeds; poor soil fertility; lack of irrigation; poor seed distribution; labour and land shortage; unavailability of fertilizers; unfavourable weather	Access to credits and inputs; poor infrastructure; weeds; drought; low soil fertility; diseases
Source(s)	(FAOSTAT, 2012; Mghase et al., 2010; Raes et al., 2007; United Republic of Tanzania, 2012)	(Diagne et al., 2013; FAOSTAT, 2012; Totin et al., 2012)

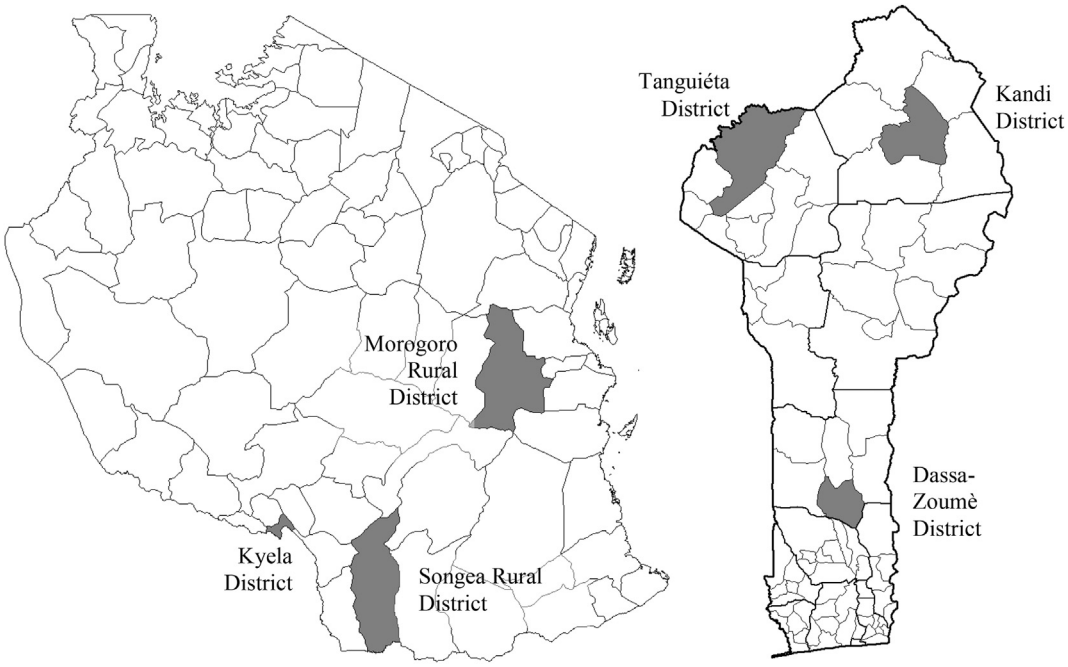

Fig. 1. Study sites in Tanzania (left) and Benin (right).

achieve their objectives (e.g. low literacy levels among farmers complicating the work of NGOs and development organisations). Each workshop could accommodate a maximum of 25 participants, which determined the sample size (Table 2). A facilitation and note taking protocol guided consistent execution and recording of the workshops.

Semi-structured interviews provided more insights in the root-causes of parasitic weed control, crop protection and broader agricultural systems constraints identified during the workshops. Other than the workshops, which took place at district level,

Table 2
Overview of methods of data collection, their key objectives, sampling strategy, the type of analysis conducted, the stakeholder groups that were targeted and the sample size.

Method of data collection	Key objective	Sampling strategy	Country	Stakeholder groups targeted (sample size)					
				Farmers	NGO/civil society	Private sector	Government	Research and training	Total
Multi-stakeholder workshops	Participatory analysis of constraints and opportunities for innovation	Stratified snowball sampling	Tanzania	16	13	10	16	13	68
			Benin	13	16	11	16	10	66
Semi-structured interviews	Insights in stakeholder constraints and opportunities identified during the workshops	Stratified snowball sampling	Tanzania	4	4	2	22	10	42
			Benin	5	10	4	26	20	65
Survey	Identify opportunities and constraints to innovation in the country's public extension system	Stratified random sampling	Tanzania	120			30		150

Table 3
Analytical framework.

Analytical dimensions	Categories
A: Types of institutional and political constraints	Policy (e.g. crop protection policies); research (e.g. natural and social science related to weeds and rice); education and training (e.g. of extension officers or at universities); extension (e.g. how service delivery is organised); markets (e.g. rice prices, input prices); politics (e.g. multi-stakeholder power-play)
B: Embedding of constraints in different systems	Parasitic weed control system; crop protection system; agricultural system; beyond agricultural system
C: Structural conditions that can cause constraints to innovation	Physical and knowledge infrastructure and assets; institutions such as policies and regulatory frameworks; interaction and collaboration between stakeholders; capabilities and access to resources
D: Value chain segments	Credit; inputs and services (I&S); production; post-harvest; trade; transport; marketing; retail; consumption; export
E: Integration levels	International; national; regional; district; ward; village; household

interviewees also represented regional and national level, which explains the relative strong presence of government and research and training representatives. Total sample size was based on the concept of 'saturation'; the point at which no new information or themes are observed in the interview data (Guest et al., 2006). Several of the interviewees also participated in the workshops. In Tanzania, a farmer and extensionist survey was held across the three study sites. The survey captured institutional and political constraints and opportunities for innovation in the country's public extension system, including, amongst others, frequency and quality of interaction between farmers and extension officers, and backstopping of extension officers (see: Daniel, 2013). Complementary information was gathered from secondary data that included revision of national agricultural policies, regional research priorities, agricultural education and training curricula, and extension guides from Tanzania and Benin.

2.4. Data analysis

We follow an analytical framework composed of 5 dimensions (Table 3) to analyse the workshop and interview data: (A) we subdivide between six institutional and political subcategories, and (B) analyse how different constraints and opportunities experienced by stakeholders are embedded in three nested systems. Subsequently, (C) causes for stakeholder constraints are analysed using structural conditions for innovation as identified by Klein Woolthuis et al. (2005). Moreover, we analyse how (D) constraints and opportunities are related to different segments of agricultural value chains following Thitinunsomboon et al. (2008) and (E) different integration levels following Douthwaite et al. (2003).

Quantitative workshop data were analysed for constraints and opportunities across the two countries, study sites and stakeholder groups. Microsoft Excel® software supported descriptive statistical analysis that was guided by the analytical dimensions of Table 3. A similar approach was used to analyse the farmer and extensionist survey, although the focus here was on revealing similarities and differences across the Tanzania study sites. Qualitative interviews data were transcribed and analysed electronically in Adobe Acrobat™ using keywords (e.g. parasitic weeds, extension, policy, etc.). In the analysis, we focussed on identifying root causes and explanations of constraints identified in the workshops. Furthermore, the analysis of the qualitative interview data provided insight in sensitive political issues that were more freely discussed in the individual interviews as compared to the multi-stakeholder workshop setting. Secondary data were analysed on their relevance to parasitic weeds or crop protection problems, or agricultural innovation more generally.

3. Results

Following the objectives of this paper, we first present results per stakeholder group (Section 3.1). Analytical dimensions A, B, C and D are visualised in figures, and E is described in the text. This is followed by results that show the interrelatedness of constraints faced by different stakeholder groups (Section 3.2). Subsequently opportunities for innovations are explored (Section 3.3).

3.1. Constraints of different stakeholder groups

3.1.1. Farmers

Farmer workshop participants across the study sites in Tanzania and Benin indicated that a substantial proportion of their constraints are extension-related (23% and 30%, resp.) (Fig. 2A). In both countries, they mentioned insufficient support from extension services to address crop protection problems and the untimely supply of agricultural inputs (e.g. provision of seed and fertilizer through a government voucher system). Interviews and secondary data revealed that in Tanzania and Benin the number of extension officers has increased over the past years. Survey results showed however that this did not directly benefit the frequency of interaction between farmers and extensionists. For example, Songea has a higher number of extension officers per agricultural household (1:470) as compared to Kyela and Morogoro (1:617 and 1:1320, resp.). However, the average contact between extension officers and farmers was much lower in Songea (2.4 times per year) than in Kyela and Morogoro (3.7 and 3.6 times per year, resp.). Interviews with extension officers demonstrated that capacity development of extensionist is lacking, resulting in inefficiencies in terms of providing support to farmers. Only farmers from Tanzania identified constraints directly linked to parasitic weed control (18%). Between 13 and 18% of the farmers' constraints were related to crop protection problems in Benin and Tanzania respectively, although the vast majority were related to broader challenges in the agricultural system (Fig. 2B). Constraints identified by farmers in Tanzania were principally related to the lack or poorly functioning of institutions (31%) (Fig. 2C). As example, interviewed farmer representatives mentioned the government's input voucher system. Vouchers to purchase inputs arrive too late and inputs are insufficient to fulfil farmers' needs. In Benin, constraints are mainly caused by a lack of capabilities and resources (47%), such as access to equipment, knowledge on water and weed management, and credits. The majority of constraints of farmers in both Tanzania and Benin (60% and 31% resp.) are related to production (Fig. 2D). According to farmers in both countries, addressing their constraints mainly requires interventions at the district level (22% in Tanzania, 47% in Benin).

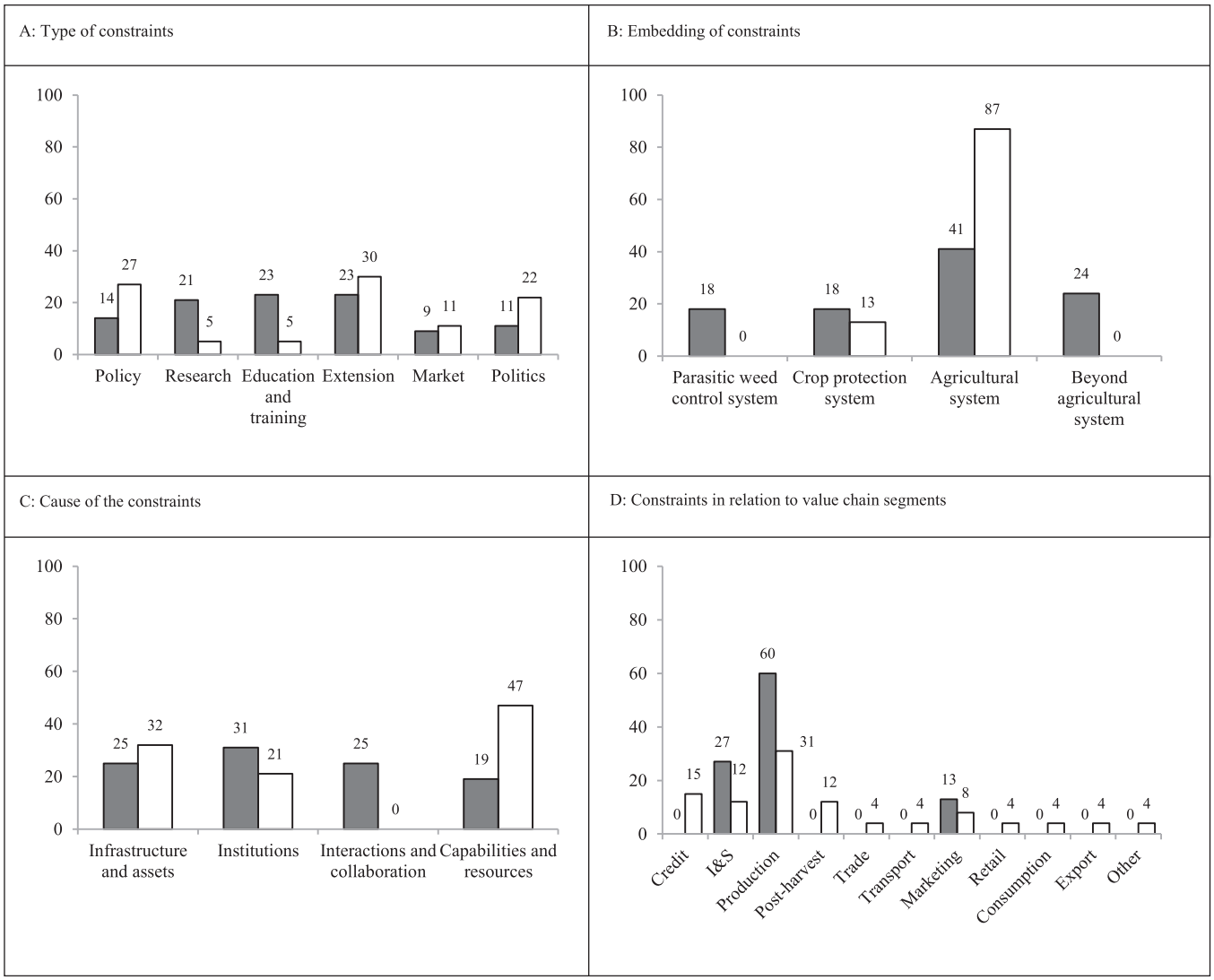

Fig. 2. Percentage of type of constraints (A), embedding of constraints (B), cause of constraints (C), and how constraints related to different segments of the value chain (D) mentioned by farmer workshop participants in Tanzania (grey bars) and Benin (white bars).

3.1.2. *NGOs and civil society organisations*

For both countries, NGO and civil society stakeholders perceive the majority of their constraints related to education and training (24% in Tanzania, 21% in Benin) (Fig. 3A). Concrete examples include low literacy levels among farmers, difficult collaboration with farmers or other project beneficiaries, and poor agribusiness skills of farmers. Constraints are not related to parasitic weeds specifically, although in both countries 13% were related to more generic crop protection problems (Fig 3B). The majority of constraints, however, are associated with broader challenges in the agricultural system. A lack of capabilities and resources available (42% in Tanzania) or lack of interaction and collaboration between stakeholders in the agricultural sector (30% in Benin) form the largest category of constraint causes (Fig. 3C). In Tanzania, the lack of continuity in project implementation and capacity building for farmers was mentioned. Interviewees in Benin expressed limited coordinated action between stakeholders in the agricultural sector and difficult collaboration with the government. Furthermore, they stressed that collaboration is mainly *ad-hoc* and project-based, rather than structural and ongoing. Looking at the value chain, NGO and civil society perceived constraints appear to be mainly related to input and services (e.g. access to seed, fertiliser and knowledge; henceforth abbreviated as I&S) (Fig. 3D). According to the stakeholder group, addressing these constraints would mainly require interventions at the national level (20% in Tanzania, 33% in Benin).

3.1.3. *Private sector*

In both countries, a large proportion of constraints perceived by the private sector are related to policy, closely followed by education and training in Tanzania, and politics in Benin (Fig. 4A). Interviews revealed how the absence or malfunctioning of institutions for quality control of agricultural inputs lead to a situation where adulterated or low quality inputs dominate the formal and informal markets in Tanzania and Benin. The largest proportion of constraints is related to broader problems in the agricultural system (53% in Tanzania, 100% in Benin). Constraints related to crop protection were only mentioned by private sector in Tanzania, although none of the constraints were specifically related to parasitic weeds (Fig. 4B). Categorization of constraints demonstrates that workshop participants consider a lack of capabilities and resources as a major cause (e.g. lack of access to stable sources of electricity) (Fig. 4C). The distribution along the value chain shows that, in Tanzania, the largest share of private sector constraints is

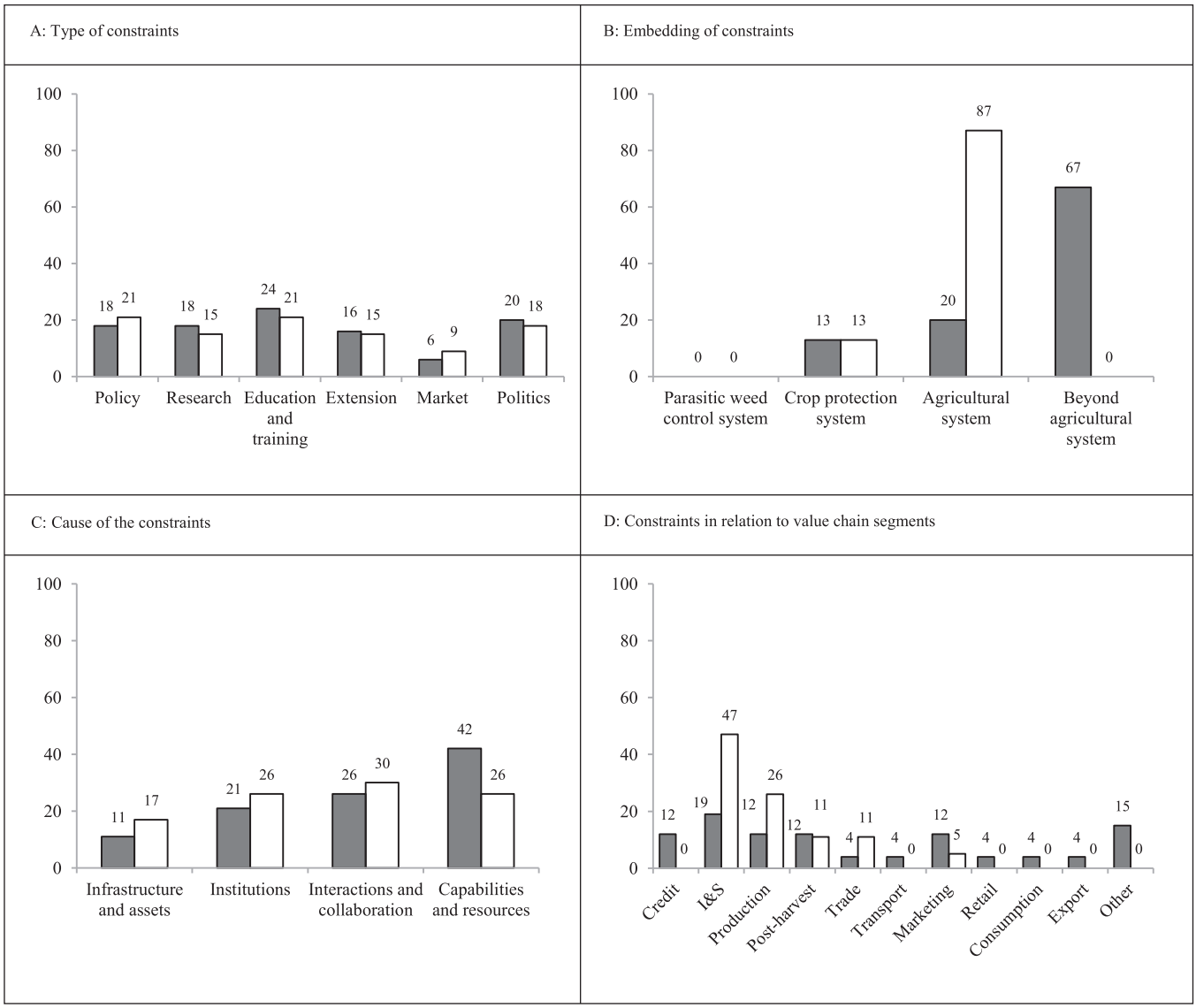

Fig. 3. Percentage of type of constraints (A), embedding of constraints (B), cause of constraints (C), and how constraints related to different segments of the value chain (D) mentioned by civil society and NGO workshop participants in Tanzania (grey bars) and Benin (white bars).

associated with input and service supply (47%) (Fig. 4D). In Benin, constraints are mainly related to lack of post-harvest process and storage equipment (31%) and access to credit for themselves as well as for farmers (25%). According the private sector, addressing their constraints would mainly require interventions at the national level (32% in Tanzania, 80% in Benin).

3.1.4. Government

In both countries the majority of constraints identified by government representatives were related to policy (24% in Tanzania, 32% in Benin) (Fig. 5A). Examples include poor implementation of national agricultural policies (Benin) and frequent policy changes (Tanzania). The majority of constraints are associated with broader problems in the agricultural system. Crop protection problems reflect 38% of the constraints perceived by government officials in Tanzania and 7% in Benin (Fig 5B). Government representatives did not explicitly mention parasitic weeds. Interviews revealed that government crop protection is curative (rather than preventive) with a strong focus on chemical pest and disease control. The poor functioning of institutions, or even absence of them, and limited capabilities and resources to implement agricultural programmes cause a large share of government constraints in Tanzania and Benin (Fig. 5C). Examples are insufficient number of agricultural (extension) officers and their low level of technical expertise and backstopping. Of surveyed government extension officers in Songea (Tanzania), 30% indicated to have no means of transport to visit farmers. Tanzania's national rules for *Striga* control, that form part of the country's Crop Protection Act, were not implemented due to limited resources to sensitise regional and district extension officers and farmers. Interviews confirmed that extension officers in both Tanzania and Benin have a very limited awareness of (problems related to) parasitic weeds in rice. In Tanzania, for example, none of the regional government officials, responsible for crop protection in the three study sites, had ever heard of *R. fistulosa*. In terms of value chain segments, constraints are mainly associated with post-harvest in Tanzania (29%) and input and service supply in Benin (22%) (Fig. 5D). Addressing the majority of government constraints require interventions at the national level (27% in Tanzania, 53% in Benin).

3.1.5. Researchers and trainers

The biggest proportion of constraints faced by researchers and

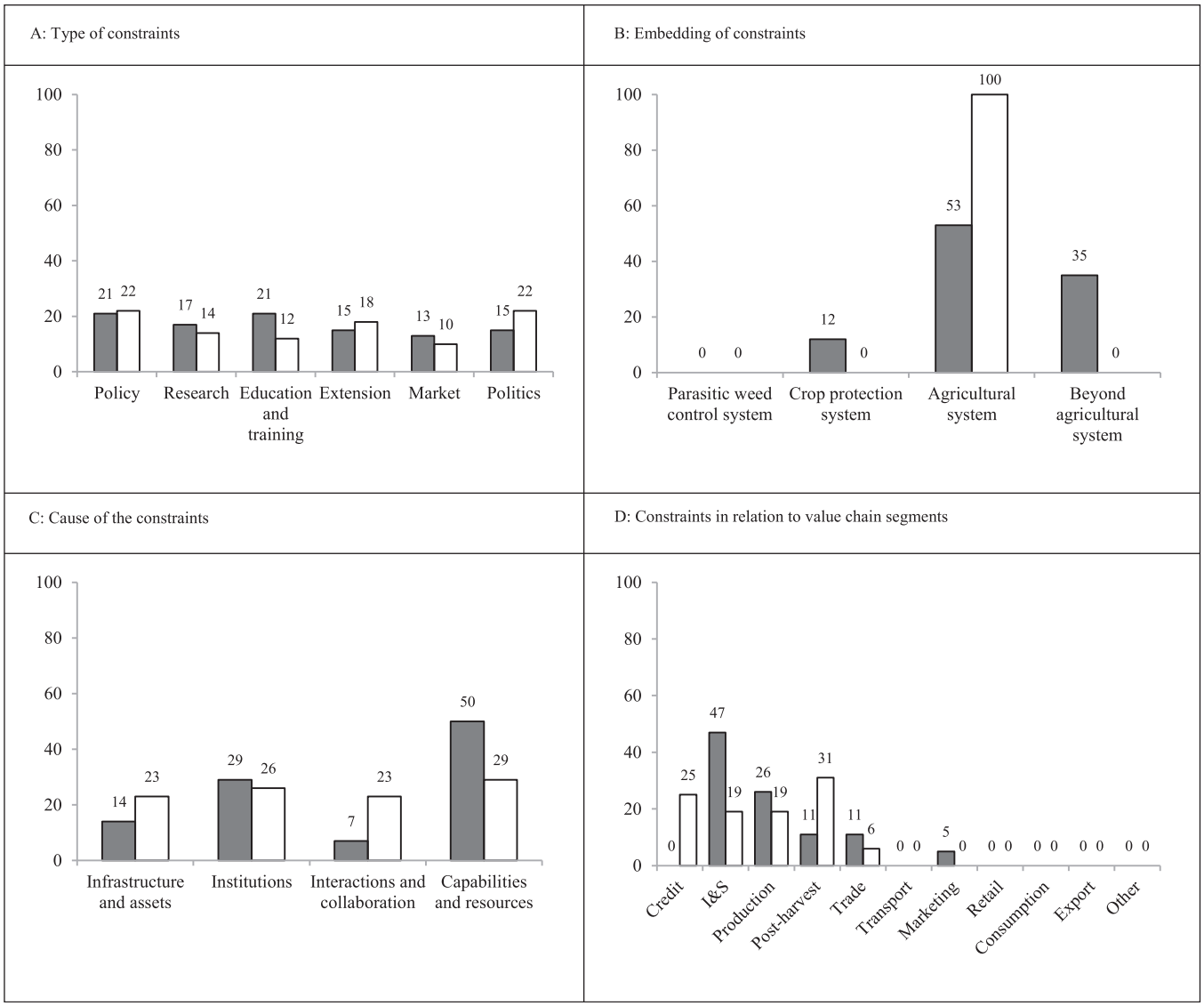

Fig. 4. Percentage of type of constraints (A), embedding of constraints (B), cause of constraints (C), and how constraints related to different segments of the value chain (D) mentioned by private sector workshop participants in Tanzania (grey bars) and Benin (white bars).

trainers are policy-related (31% in Tanzania and 39% in Benin) (Fig. 6A). The absence of policies to facilitate coordination between researchers, trainers, extension officers and farmers were mentioned during the workshops and interviews. The vast majority of constraints for this stakeholder group relate to broader problems in the agricultural sector, rather than to crop protection or parasitic weed problems specifically (Fig. 6B). A large proportion of the constraints faced by researchers and trainers is related to insufficient capabilities and resources to attain a high standard of research, education and training (Fig. 6C). Interviews demonstrated that in both countries the number of weed researchers in the national agricultural research and education systems is limited. Weeds in general and parasitic weed in particular receive little attention in research, education and training. Secondary data analysis showed that, in Tanzania, weed control activities are not prioritised in the National and Zonal Agricultural Research Priorities for the sites included in this study. In Benin, guides for pest and disease control in food and cash crops are available, but an equivalent for weed control does not exist. Interviews showed that in both countries, parasitic weeds are addressed in research and teaching at agricultural universities. However, limited interaction between research and training institutes forms an obstacle for translating research findings into training materials according to interview respondents. Evaluated across different segments of the value chain, researchers and trainers felt that the biggest proportion of constraints is related to production (26% in Tanzania, 18% in Benin) (Fig. 6D). Alleviating constraints would mainly require interventions at the national level (27% in Tanzania, 53% in Benin).

3.2. Direct and indirect relations between constraints of different stakeholder groups

During the workshops, stakeholder groups identified relations between their constraints and those faced by other stakeholder groups (Table 4).

Farmers' constraints are mainly related to government's constraints (e.g. inability to respond to regular pest infestations) and private sector constraints (e.g. quality control problems of inputs) in Tanzania, and to NGO/civil society (e.g. no credit for agriculture) and private sector constraints (e.g. no storage facilities) in Benin. NGOs and civil society organisations' constraints are mainly related to private sector constraints (e.g. poorly developed infrastructure)

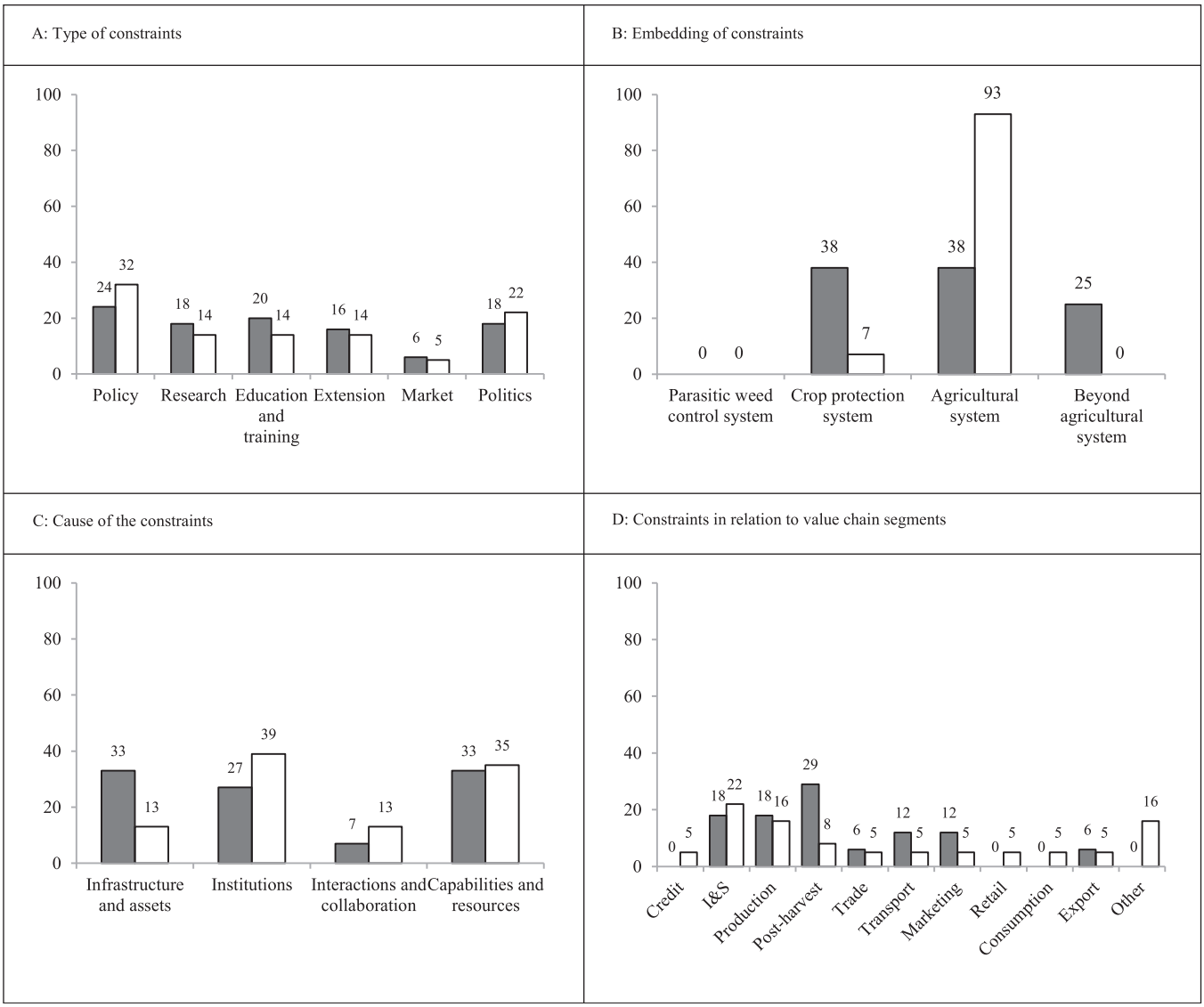

Fig. 5. Percentage of type of constraints (A), embedding of constraints (B), cause of constraints (C), and how constraints related to different segments of the value chain (D) mentioned by government workshop participants in Tanzania (grey bars) and Benin (white bars).

in Tanzania, and farmer constraints (e.g. insufficient agricultural equipment) and government constraints (e.g. absence of a stakeholder platform for agriculture) in Benin. Private sector constraints are mainly associated with constraints faced by farmers in both countries. 'Access to inputs to improve soil fertility', for example, were directly related to farmer constraints such as 'no timely arrival of inputs' and 'problems with managing weeds'. Constraints faced by government officials are mainly linked to farmer constraints in Tanzania and researcher and trainer constraints in Benin. Across both countries, the majority of constraints faced by researchers and trainers are related to government constraints although the differences between categories were less pronounced for Tanzania, compared to Benin.

As for the more indirect relationships between stakeholder constraints, the workshops revealed interesting results. Farmers' weed problems, for example, relate to numerous constraints faced by other stakeholder groups. These include the lack of physical infrastructure for input supply, poor collaboration between stakeholders in the agricultural system, inadequate education on modern agricultural practices and political interference in agricultural programmes (Fig. 7). Consequently, addressing farmer constraints needs to be complemented by addressing interrelated constraints faced by other stakeholder groups.

Interviewees from both countries mentioned a lack of coordination and collaboration between government, development projects, and (international) research institutes in addressing their interrelated problems. According to several respondents this results in the spread of contradictory messages to farmers. One specific example that was mentioned in Tanzania was conflict of interest between a government cocoa project that promoted the use of inputs, and a donor cocoa project that promoted conservation agriculture. The later had negative advice on the use of fertilisers that led to farmers abandoning the use of fertiliser, also in other cropping systems than just cocoa.

3.3. Opportunities for innovation perceived by different stakeholder groups

During each multi-stakeholder workshop in Tanzania and Benin, participants identified the five constraints with highest priority. A number of crosscutting themes were identified among the prioritised constraints (Table 5).

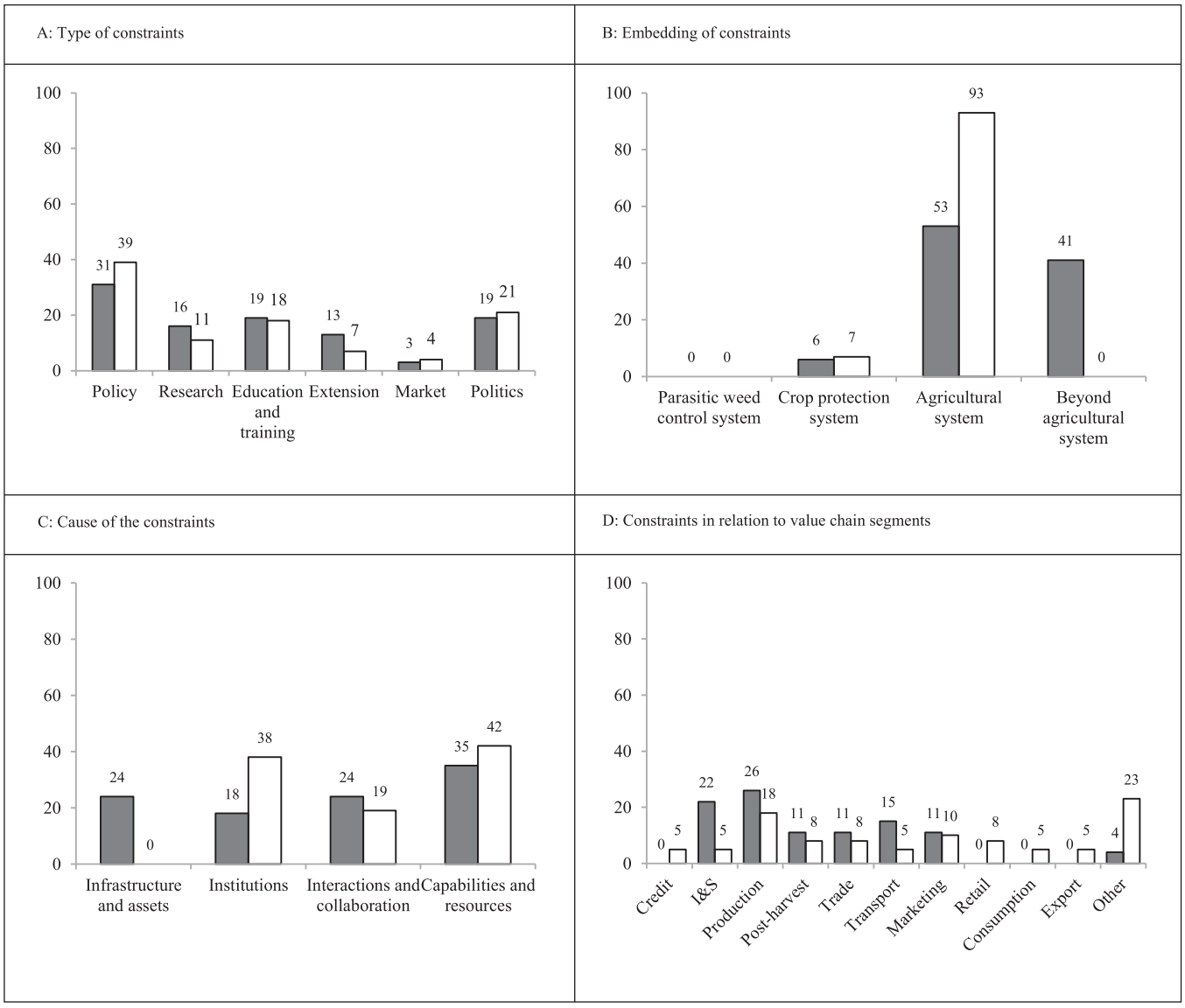

Fig. 6. Percentage of type of constraints (A), embedding of constraints (B), cause of constraints (C), and how constraints related to different segments of the value chain (D) mentioned by research and training workshop participants in Tanzania (grey bars) and Benin (white bars).

Table 4
Relative proportion of direct relations between constraints faced by different stakeholder groups in Tanzania and Benin.[a]

Country	Stakeholder group	Farmers	NGO/civil society	Private sector	Government	Researchers and trainers	Total
Tanzania	Farmers	X	12	32	35	22	100
	NGO/civil society	17	X	33	26	24	100
	Private sector	32	24	X	25	19	100
	Government	34	18	24	X	24	100
	Researchers and trainers	27	20	22	31	X	100
Benin	Farmers	X	37	33	23	7	100
	NGO/civil society	44	X	14	36	6	100
	Private sector	48	17	X	31	3	100
	Government	20	26	18	X	36	100
	Researchers and trainers	13	8	4	75	X	100

[a] Table should be read horizontally. For example, in Tanzania, 12% of constraints identified by farmer representatives relate directly to constraints identified by NGO/civil society representatives.

The largest number of priorities is related to agricultural education, training and extension. Examples of opportunities for innovation identified by workshop participants include (a) updating the agricultural education and training curricula to the reality of the field, (b) capacity development of technical and communication competences for extension officers, (c) more attention for the development of agribusiness skills, and (d) farmer participatory technology development for, for example, weed management. The

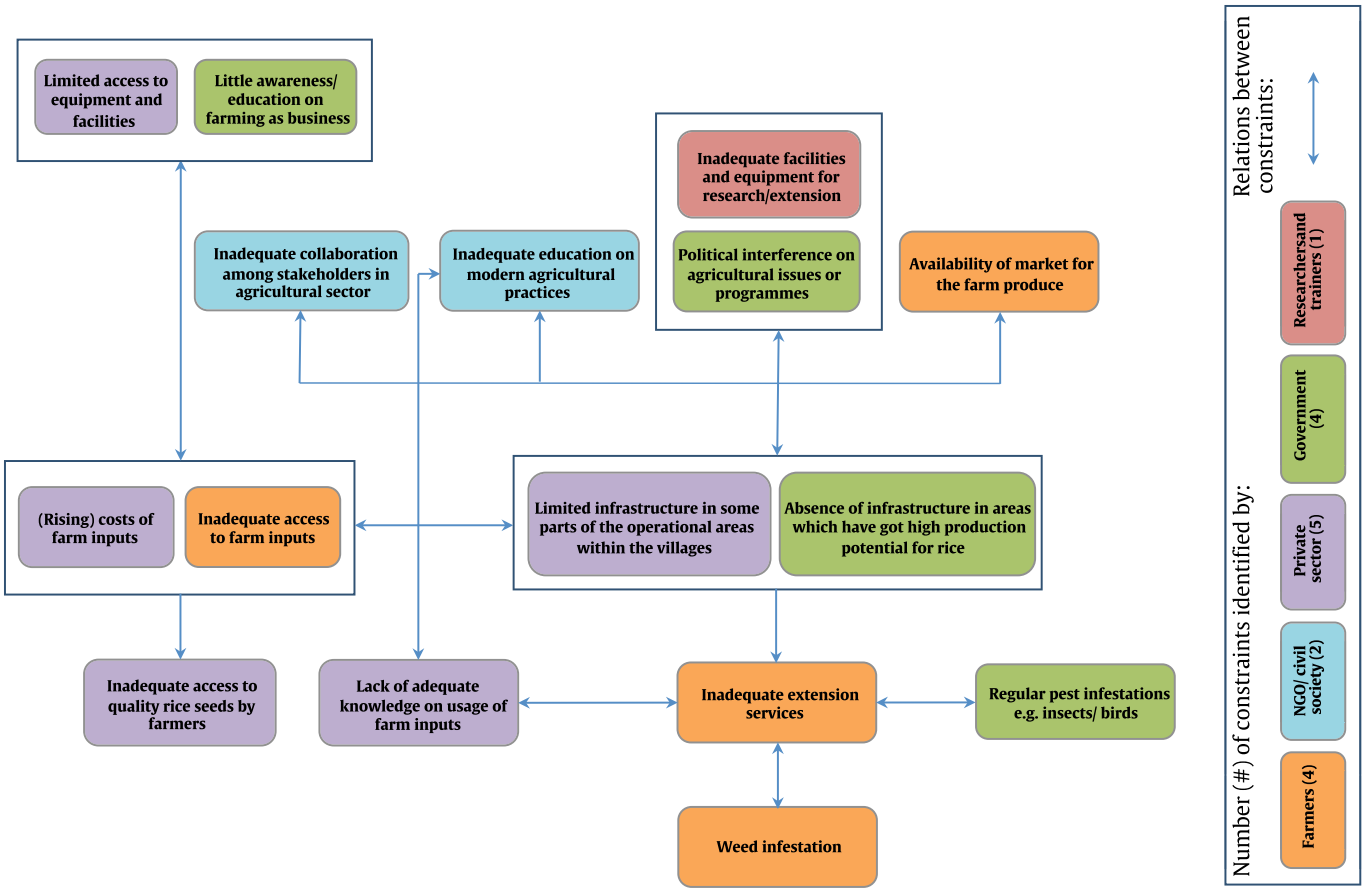

Fig. 7. Schematic representation of direct and indirect linkages between constraints associated with 'weed infestation' as experienced by stakeholders in Songea, Tanzania. Constraints that are in the same rectangle box, were identified by workshop participants as overlapping. Arrows were drawn by workshop participants and indicate linkages between constraints, not necessary causal relationships.

Table 5
Crosscutting themes reflecting the prioritisation of constraints, and opportunities for innovation identified by workshop participants in Tanzania and Benin.

Crosscutting themes	Number of constraints prioritised per country and (percentage of) total			Opportunities for innovation as identified by workshop participants in Tanzania and Benin
	Tanzania	Benin	Total (%)-	
Training, education and extension	3	6	9 (30%)	- Updating of education and training curricula - Capacity development for extension officers - Development of agribusiness skills - Farmer participatory technology development
Stakeholders collaboration	2	2	4 (13%)	- Establish and institutionalise multi-stakeholder platforms
Access to credit	1	3	4 (13%)	- Support to farmer organisations in managing funds/credits/subsidies - Timely access to credit - Assessment of the real financial needs for agricultural research and training - Committed donors
Value chain linkages/market access	2	1	3 (10%)	- Policies that enhance domestic market access for farmers - Improved farmers' bargaining power
Policy implementation	1	1	2 (7%)	- Harmonisation of government and donor activities - Government commitment to implement and enforce agricultural policies
Timely access to quality inputs	1	1	2 (7%)	- Support farmers in assessing required farm inputs - Ensuring that inputs are timely and sufficiently available - Private sector development
Climate change	2	0	2 (7%)	- Identify early maturing and drought tolerant varieties
Other	3	1	4 (12%)	N/a

second largest groups of priorities were related to stakeholder collaboration and access to credit (both 13%). Opportunities for improved stakeholder collaboration include the development and institutionalisation of multi-stakeholder platforms for the key value chains, including rice. According to workshop participants, better access to credit and financial resources would result from (a) support to farmer organisations in managing funds/credits/subsidies, (b) an improved business environment to timely access credit, (c) an objective assessment of the real financial needs for agricultural research and training, and (d) identification of a committed donor to support that. Constraints related to improved value chain linkages and market access accounted for 10% of the

priorities. In this respect, opportunities identified are (a) the development of policies to strengthen the domestic markets, and (b) improved farmers' bargaining power to access these markets. Opportunities for improved policy implementation and supervision (7%), and timely access to high quality agricultural inputs (7%) were prioritised in both countries. Examples provided by workshop participants regarding the former include (a) improved harmonisation of government and donor activities in the agricultural sector to reduce the spread of contradictory messages by different types of public and private service providers, and (b) enhanced government commitment to implement and enforce agricultural policies. With regard to the latter, workshop participants proposed (a) improved support to farmers in making a proper estimate of required farm inputs, (b) ensuring that subsidised inputs are available for farmers in a timely manner and in sufficient quantity and quality, and (c) private sector development. Climate change was identified across two study sites in Tanzania as an increasingly important problem. It was concluded that researchers should invest more resources in identifying early maturing varieties and drought tolerant varieties to support farmers in coping with the impacts of climate change.

In terms of addressing constraints, farmers perceived themselves as the most dependent stakeholder group. Farmers in Tanzania and Benin indicated that for resolving respectively 87% and 100% of their constraints, actions by other stakeholder groups would be required. Government and researchers and trainers perceived themselves as the least dependent stakeholder group, although addressing respectively 67% and 70% of their constraints would still require actions by other stakeholder groups.

4. Discussion

4.1. Institutional and political constraints and opportunities in nested parasitic weed control, crop protection and agricultural systems

Our results show that the limited attention for the institutional and political constraints and opportunities for innovation in parasitic weeds and crop protection research is not justified. Many of the constraints and opportunities for innovation identified by different stakeholder groups are of institutional or political nature, and are directly or indirectly related to parasitic weed problems. The vast majority of constraints identified by stakeholders were generic and related to the functioning of the crop protection or agricultural systems, rather than to the functioning of the parasitic weed control system specifically (see Figs. 2B–6B). Nevertheless, these systems are nested, which means that generic constraints in crop protection or agricultural systems are often directly or indirectly related to specific constraints in the parasitic weed control system. Hence, addressing specific constraints related to parasitic weed control is unlikely to be successful, as long as related generic bottlenecks in the crop protection and agricultural systems are not addressed simultaneously. This points at the importance of analysing specific complex agricultural problems in the context of the broader, generic system(s) in which they are embedded (see also: Hall and Clark, 2010; Hounkonnou et al., 2012; Spielman et al., 2008). Our data contain various examples to illustrate this. In both countries, crop protection is curative, with a focus on chemical control of pest and disease outbreaks, rather than on weed prevention. Prevention strategies are particularly important for parasitic weed management, because once the weeds are introduced in a particular environment, they are difficult to eradicate as also indicated by Eplee (1992) and Parker (2012). Furthermore, there is relative limited attention for weeds, and parasitic weeds in particular, in agricultural research, policy and training, which explains the low awareness among extension and crop protection officers of parasitic weeds in rice, in particular with respect to *R. fistulosa*. With the spread and impact of parasitic weeds in rainfed rice farming becoming increasingly clear (Rodenburg et al., 2015), this requires immediate action. Another example of the relation between constraints in the broader agricultural system and parasitic weed control is provided by N'cho et al. (2014). They demonstrated that the adoption of control or prevention strategies for parasitic weeds is strongly correlated with farmers' access to credit, information and training; the same constraints that were prioritised by stakeholders in this study. Additionally, there is broad-based evidence showing that parasitic weed problems are a direct consequence of poor soil fertility (Kabiri et al., 2015; Parker, 2009), which directly relates to constraints such as untimely access to high quality inputs identified in this study. Following Klerkx et al. (2012), addressing such generic constraints is likely to have a spill-over effect on dealing with complex agricultural problems other than parasitic weeds.

Clearly, stakeholders did not mention a number of institutional and political constraints. Land tenure agreements, for instance, were not explicitly singled-out as a constraint while they form an institutional dimension related to parasitic weed problems. Parasitic weeds are particularly problematic on land characterised by poor soil fertility and water management (Kabiri et al., 2015). Such marginal land is often allocated to socio-economically disadvantaged groups such as women. Consequently, rice fields managed by women farmers may show a higher parasitic weed infestation rate or severity (N'cho et al., 2014). Stakeholder groups also seem to have limited attention for constraints at the international level. Climate change related constraints formed the exception to this, as they were identified across sites in Tanzania. This corroborates with expectations and reports on possible direct and indirect effects of climate variability on parasitic weed affected areas (Rodenburg et al., 2011a, 2015). Other international constraints of parasitic weeds, such as possible trade and export limitations, were not mentioned. This is particularly remarkable for stakeholders in affected areas in Tanzania, growing or trading local varieties that are highly valued and demanded at markets in surrounding regions and countries. We have clear indications that parasitic weeds negatively affect important grain quality characteristics that may have implications on the market and trade value of the rice. Consequently, exploring opportunities for innovations at supranational level should be explored further.

Acknowledging the importance of the institutional and political dimensions directly or indirectly related to parasitic weed problems has several implications. First, addressing the majority of the institutional and political constraints raised by stakeholders in this study requires interventions beyond the farm level. It shows that weed problems at plant or field level, cannot be solved in a durable way if at higher integration levels the enabling environment for that weed problem, or a disabling environment for its control, is not changed simultaneously (Rodenburg et al., under review). This finding highlights the importance of understanding multi-level interactions for fostering coherent agricultural innovation strategies, which is increasingly recognised in the agricultural innovation literature (Hounkonnou et al., 2012). Second, it requires a redefinition of crop protection innovation. Crop protection innovation is often described as the successful development and transfer of (chemical) crop protection technologies from researchers to farmers (Schut et al., 2014b). However, the success of such technological innovations is strongly correlated with institutional and political innovations, such as improved farmers' access to credit, inputs, information and training, as also shown elsewhere (Amankwah et al., 2012; Totin et al., 2012).

4.2. Stakeholder perceptions, dependencies and collaboration in exploring parasitic weed control innovations

Different groups of stakeholders experience different types of constraints related to parasitic weed control, crop protection and the generic functioning of the agricultural system. Nevertheless, our analysis demonstrates that stakeholder constraints are interrelated (see Table 4 and Fig. 7). Participatory research efforts on parasitic weeds, crop protection, and agricultural innovation in general have mainly focussed on involving farmers, and to some extent extension officers as key stakeholders (Neef and Neubert, 2011; Rodenburg et al., 2010; Schut et al., 2014b). The emphasis on farmer participation may explain the focus on productivity-oriented research at the farm level. It can also explain the continued focus on strengthening the agricultural extension systems to support farmer decision making to tackle crop protection issues (reflecting the characteristics of constraints identified by farmers in this study in Fig. 2) despite the many reforms that extension systems have already undergone (Rivera and Sulaiman, 2009). Although addressing productivity- and extension-related constraints is important, research, development and policy strategies should pay similar attention to how these relate to institutional and political constraints at higher system levels, where the majority of challenges faced by other stakeholder groups are situated.

To address complex agricultural problems, continuous stakeholder participation in describing and explaining problems, and exploring, designing and implementing solutions has been proposed (Douthwaite et al., 2009; Neef and Neubert, 2011). Involvement of stakeholders is essential for three reasons. First, different stakeholder groups provide insights about the technological, institutional and political dimensions of the problem across different levels, and what type of solutions are economically and institutionally viable, and social-culturally and politically acceptable (Schut et al., 2014c). Similar to biophysical diversity of parasitic weeds and the need to adapt management strategies and technologies accordingly (Kabiri et al., 2015), success of socio-organisational innovations that address institutional and political constraints depends on the specific context and the needs and interests of different stakeholders involved (e.g. Hounkonnou et al., 2012; Sumberg, 2005). Second, stakeholder groups become aware of their fundamental interdependencies and the need for concerted action to address their constraints and reach their objectives (Leeuwis, 2000). Third, stakeholder groups are more likely to support specific solutions when they have been part of the decision-making or innovation process (Faysse, 2006). The institutionalisation of multi-stakeholder collaboration, for example in multi-stakeholder platforms, as was suggested by workshop participants in both Tanzania and Benin, provides an interesting and promising entry point for continuous stakeholder interaction, collaboration and collective action (e.g. Kilelu et al., 2013; Schut et al., 2014a). Whether platforms or other kinds of stakeholder collaborations should be set up specifically around parasitic weeds is questionable, because awareness and perceived importance of parasitic weed problems for different stakeholder groups is rather low. It could be more effective to address parasitic weed problems as part of a broader focus on innovation in the crop protection system, as this appears to link more strongly to needs and interests of different stakeholder groups (e.g. Togbé et al., 2012).

5. Conclusions

This study demonstrates that the majority of institutional and political constraints for innovation to address parasitic weeds are related to the functioning of the broader crop protection system and agricultural system, rather than to parasitic weeds control system specifically. However, many of these more generic constraints (e.g. timely access to high quality inputs, access to credit, information and training) relate directly or indirectly to parasitic weed problems, and consequently form a bottleneck for developing effective parasitic weed prevention and control strategies. Such insights can provide a basis for the development of innovations for parasitic weed prevention and control strategies that are integrated (i.e. that address both technological and socio-organisational dimensions), coherent (i.e. coordinated interventions across different levels), and acceptable for different types of stakeholder groups. Such strategies should be tailored to the institutional and political realities of regions and countries where parasitic weeds in rice are causing problems.

Stakeholders experience different types of constraints related to the general functioning of the parasitic weed control, crop protection and agricultural systems. Overall, the majority of constraints are related to policy (e.g. poor harmonisation of donor and government policies), associated with a lack of capabilities and resources (and limited access to credit), and require interventions at the national level geared towards improved input and service supply and crop productivity. Despite the differences across different stakeholder groups, there exists a high degree of awareness of direct and indirect relations between their constraints, and a notion that addressing them effectively would require collaboration.

Opportunities for innovation that were identified by stakeholders include awareness raising of parasitic weed problems in rice among farmers, and extension and crop protection officers at the local level. Such efforts need to be accompanied by more structural interventions in terms of frequent updates of the agricultural training curricula, and implementation and enforcement of crop protection policies at higher systems levels in order to achieve long term and structural impacts. Improved and continuous collaboration between key stakeholder groups across different levels can contribute to a better understanding of problems and feasible solutions for parasitic weed control, as well as for other complex agricultural problems.

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References

Abang, M.M., Bayaa, B., Abu-Irmaileh, B., Yahyaui, A., 2007. A participatory farming system approach for sustainable broomrape (Orobanche spp.) management in the Near East and North Africa. Crop Prot. 26, 1723–1732.

Amankwah, K., Klerkx, L., Oosting, S.J., Sakyi-Dawson, O., van der Zijpp, A.J., Millar, D., 2012. Diagnosing constraints to market participation of small ruminant producers in northern Ghana: an innovation systems analysis. NJAS Wagening. J. Life Sci. 60–63, 37–47.

Birch, A.N.E., Begg, G.S., Squire, G.R., 2011. How agro-ecological research helps to address food security issues under new IPM and pesticide reduction policies for global crop production systems. J. Exp. Bot. 62, 3251–3261.

Daniel, E., 2013. Assessment of Agricultural Extension Services in Tanzania. A Case Study of Kyela, Songea Rural, and Morogoro Rural Districts. Wageningen University and Research Centre/Africa Rice Center, Wageningen, the Netherlands/Dar es Salaam, Tanzania, p. 45.
Diagne, A., Amovin-Assagba, E., Futakuchi, K., Wopereis, M.C.S., 2013. Estimation of cultivated area, number of farming households and yield for major rice-growing environments in Africa. In: Wopereis, M.C.S., Johnson, D.E., Ahmadi, N., Tollens, E., Jalloh, A. (Eds.), Realizing Africa's Rice Promise. CABI, Wallingford, Oxfordshire, UK, pp. 35–45.
De Groote, H., 2007. Striga economics. In: Ejeta, G., Gressel, J. (Eds.), Integrating New Technologies for Striga Control – towards Ending the Witch-hunt. World Scientific, Singapore, pp. 265–280.
Debrah, S.K., 1994. Socio-economic constraints to the adoption of weed control techniques: the case of Striga control in the West African Semi-Arid Tropics. Int. J. Pest Manag. 40, 153–158.
Douthwaite, B., Beaulieu, N., Lundy, M., Peters, D., 2009. Understanding how participatory approaches foster innovation. Int. J. Agric. Sustain. 7, 42–60.
Douthwaite, B., Kuby, T., van de Fliert, E., Schulz, S., 2003. Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. Agr. Syst. 78, 243–265.
DPP/MAEP, 2009. Evolution de réalisations des principales cultures par commune (Période: 1998-2008). Unpublished data base of the Direction de la Programmation et de la Prospective du Ministère de l'Agriculture, de l'Elevage et de la Pèche (DPP/MAEP).
Emechebe, A.M., Ellis Jones, J., Schulz, S., Chikoye, D., Douthwaite, B., Kureh, I., Tarawali, G., Hussaini, M.A., Kormawa, P., Sanni, A., 2004. Farmers' perception of the Striga problem and its control in Northern Nigeria. Exp. Agric. 40, 215–232.
Eplee, R.E., 1992. Witchweed (*Striga asiatica*): an overview of management strategies in the USA. Crop Prot. 11, 3–7.
FAOSTAT, 2012. Food and Agriculture Organisation of the United Nations Statistical Databases. Online database. http://faostat.fao.org/ (accessed March 2014).
Faysse, N., 2006. Troubles on the way: an analysis of the challenges faced by multi-stakeholder platforms. Nat. Resour. Forum 30, 219–229.
Gbèhounou, G., Assigbé, P., 2003. *Rhamphicarpa fistulosa* (Hochst.) Benth. (Scrophulariaceae): new pest on lowland rice in Benin. Results of a survey and immediate control possibilities. Ann. Des. Sci. Agron. Bénin 4, 89–103.
Guest, G., Bunce, A., Johnson, L., 2006. How Many interviews are Enough? An Experiment with data saturation and variability. Field Methods 18, 59–82.
Hall, A., Clark, N., 2010. What do complex adaptive systems look like and what are the implications for innovation policy? J. Int. Dev. 22, 308–324.
Hounkonnou, D., Kossou, D., Kuyper, T.W., Leeuwis, C., Nederlof, E.S., Röling, N., Sakyi-Dawson, O., Traoré, M., Van Huis, A., 2012. An innovation systems approach to institutional change: smallholder development in West Africa. Agric. Syst. 108, 74–83.
Kabiri, S., Rodenburg, J., Kayeke, J., Ast, A.v., Makokha, D.W., Msangi, S.H., Irakiza, R., Bastiaans, L., 2015. Can the parasitic weeds *Striga asiatica* and *Rhamphicarpa fistulosa* co-occur in rain-fed rice. Weed Res. 55, 145–154.
Kamara, A.Y., Ellis-Jones, J., Amaza, P., Omoigui, L.O., Helsen, J., Dugje, I.Y., Kamai, N., Menkir, A., White, R.W., 2008. A participatory approach to increasing productivity of maize through *Striga hermonthica* control in northeast Nigeria. Exp. Agric. 44, 349–364.
Kilelu, C.W., Klerkx, L., Leeuwis, C., 2013. Unravelling the role of innovation platforms in supporting co-evolution of innovation: contributions and tensions in a smallholder dairy development programme. Agric. Syst. 118, 65–77.
Klein Woolthuis, R., Lankhuizen, M., Gilsing, V., 2005. A system failure framework for innovation policy design. Technovation 25, 609–619.
Klerkx, L., Aarts, N., Leeuwis, C., 2010. Adaptive management in agricultural innovation systems: the interactions between innovation networks and their environment. Agric. Syst. 103, 390–400.
Klerkx, L., van Mierlo, B., Leeuwis, C., 2012. Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In: Darnhofer, I., Gibbon, D., Dedieu, B. (Eds.), Farming Systems Research into the 21st Century: the New Dynamic. Springer, Dordrecht, pp. 457–483.
Kropff, M.J., Bouma, J., Jones, J.W., 2001. Systems approaches for the design of sustainable agro-ecosystems. Agr. Syst. 70, 369–393.
Leeuwis, C., 2000. Reconceptualizing participation for sustainable rural development: towards a negotiation approach. Dev. Change 31, 931–959.
Leeuwis, C., 2004. Communication for Rural Innovation. Rethinking Agricultural Extension (With Contributions of Anne van den Ban). Blackwell Science, Oxford.
McNie, E.C., 2007. Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. Environ. Sci. Policy 10, 17–38.
Mghase, J.J., Shiwachi, H., Nakasone, K., Takahashi, H., 2010. Agronomic and socio-economic constraints to high yield of upland rice in Tanzania. Afr. J. Agric. Res. 5, 150–158.
N'cho, S.A., Mourits, M., Rodenburg, J., Demont, M., Oude Lansink, A., 2014. Determinants of parasitic weed infestation in rainfed lowland rice in Benin. Agr. Syst. 130, 105–115.
Neef, A., Neubert, D., 2011. Stakeholder participation in agricultural research projects: a conceptual framework for reflection and decision-making. Agric. Hum. Values 28, 179–194.
Parker, C., 2009. Observations on the current status of Orobanche and Striga problems worldwide. Pest Manag. Sci. 65, 453–459.
Parker, C., 2012. Parasitic weeds: a World Challenge. Weed Sci. 60, 269–276.
Raes, D., Kafiriti, E.M., Wellens, J., Deckers, J., Maertens, A., Mugogo, S., Dondeyne, S., Descheemaeker, K., 2007. Can soil bunds increase the production of rain-fed lowland rice in south eastern Tanzania? Agric. Water Manag. 89, 229–235.
Rivera, W.M., Sulaiman, V.R., 2009. Extension: object of reform, engine for innovation. Outlook Agric. 38, 267–273.
Rodenburg, J., Demont, M., Zwart, S.J., Cissoko, M., Bastiaans, L., 2014. The importance of parasitic weeds in Rice in Africa. In: Proceedings of the 4th International Rice Congress, 2014, Bangkok, Thailand.
Rodenburg, J., Meinke, H., Johnson, D.E., 2011a. Challenges for weed management in African rice systems in a changing climate. J. Agric. Sci. 149, 427–435.
Rodenburg, J., Morawetz, J.J., Bastiaans, L., 2015. *Rhamphicarpa fistulosa*, a widespread facultative hemi-parasitic weed, threatening rice production in Africa. Weed Res. 55, 118–131.
Rodenburg, J., Riches, C.R., Kayeke, J.M., 2010. Addressing current and future problems of parasitic weeds in rice. Crop Prot. 29, 210–221.
Rodenburg, J., Schut, M., Demont, M., Klerkx, L., Gbehounou, G., Oude Lansink, A., Mourits, M., Rotteveel, T., Kayeke, J.M., van Ast, A., Cissoko, M., Akanvou, L., Bastiaans, L., 2015. Systems approaches to innovation in crop protection; reflections and lessons learned from an integrated research programme on parasitic weeds in rice. Int. J. Pest Manag. (under review).
Rodenburg, J., Zossou-Kouderin, N., Gbehounou, G., Ahanchede, A., Toure, A., Kyalo, G., Kiepe, P., 2011c. *Rhamphicarpa fistulosa*, a parasitic weed threatening rain-fed lowland rice production in sub-Saharan Africa - a case study from Benin. Crop Prot. 30, 1306–1314.
Savary, S., Horgan, F., Willocquet, L., Heong, K.L., 2012. A review of principles for sustainable pest management in rice. Crop Prot. 32, 54–63.
Scholes, J.D., Press, M.C., 2008. Striga infestation of cereal crops - an unsolved problem in resource limited agriculture. Curr. Opin. Plant Biol. 11, 180–186.
Schulz, S., Hussaini, M.A., Kling, J.G., Berner, D.K., Ikie, F.O., 2003. Evaluation of integrated *Striga hermonthica* control technologies under farmer management. Exp. Agric. 39, 99–108.
Schut, M., Cunha Soares, N., van de Ven, G.W.J., Slingerland, M., 2014a. Multi-actor governance of sustainable biofuels in developing countries: the case of Mozambique. Energ. Policy 65, 631–643.
Schut, M., Klerkx, L., Rodenburg, J., Kayeke, J., Raboanarielina, C., Hinnou, L.C., Adegbola, P.Y., van Ast, A., Bastiaans, L., 2015a. RAAIS: rapid appraisal of agricultural innovation systems (part I). A diagnostic tool for integrated analysis of complex problems and innovation capacity. Agr. Syst. 132, 1–11.
Schut, M., Rodenburg, J., Klerkx, L., Kayeke, J., van Ast, A., Bastiaans, L., 2015b. RAAIS: rapid appraisal of agricultural innovation systems (part II). Integrated analysis of parasitic weed problems in rice in Tanzania. Agr. Syst. 132, 12–24.
Schut, M., Rodenburg, J., Klerkx, L., van Ast, A., Bastiaans, L., 2014b. Systems approaches to innovation in crop protection. A systematic literature review. Crop Prot. 56, 98–108.
Schut, M., van Paassen, A., Leeuwis, C., Klerkx, L., 2014c. Towards dynamic research configurations. A framework for reflection on the contribution of research to policy and innovation processes. Sci. Publ. Policy 41, 207–218.
Seck, P.A., Tollens, E., Wopereis, M.C.S., Diagne, A., Bamba, I., 2010. Rising trends and variability of rice prices: Threats and opportunities for sub-Saharan Africa. Food Policy 35, 403–411.
Spedding, C.R.W., 1988. An Introduction to Agricultural Systems, second ed. Elsevier Applied Science Publishers, New York.
Spielman, D.J., Ekboir, J., Davis, K., Ochieng, C.M.O., 2008. An innovation systems perspective on strengthening agricultural education and training in sub-Saharan Africa. Agr. Syst. 98, 1–9.
Sumberg, J., 2005. Systems of innovation theory and the changing architecture of agricultural research in Africa. Food Policy 30, 21–41.
Thitinunsomboon, S., Chairatana, P.A., Keeratipibul, S., 2008. Sectoral innovation systems in agriculture: the case of Rice in Thailand. Asian J. Technol. Innov. 16, 83–100.
Togbé, C.E., Zannou, E.T., Vodouhè, S.D., Haagsma, R., Gbèhounou, G., Kossou, D.K., van Huis, A., 2012. Technical and institutional constraints of a cotton pest management strategy in Benin. NJAS Wagening. J. Life Sci. 60–63, 67–78.
Totin, E., van Mierlo, B., Saïdou, A., Mongbo, R., Agbossou, E., Stroosnijder, L., Leeuwis, C., 2012. Barriers and opportunities for innovation in rice production in the inland valleys of Benin. NJAS Wagening. J. Life Sci. 60–63, 57–66.
United Republic of Tanzania, 2012. National Sample Census of Agriculture Smallholder Agriculture 2007-2008. Crop Sector - National Report. In: Ministry of Agriculture, Food Security and Cooperatives, Ministry of Livestock Development and Fisheries, Ministry of Water and Irrigation, Ministry of Agriculture, Livestock and Environment, Zanzibar, Prime Minister's Office, Regional Administration and Local Governments, Ministry of Industries, Trade and Marketing, The National Bureau of Statistics and the Office of the Chief Government Statistician, Zanzibar., Dar es Salaam, Tanzania, vol. II, p. 512.
Vissoh, P.V., Mongbo, R., Gbehounou, G., Hounkonnou, D., Ahanchédé, A., Röling, N., Kuyper, T.W., 2007. The social construction of weeds: different reactions to an emergent problem by farmers, officials and researchers. Int. J. Agric. Sustain. 5, 161–175.