TRENDS IN KNOWLEDGE PRODUCTION AND GENERATION IN THE AGRICULTURAL SECTOR: PERSPECTIVES OF NIGERIAN AGRICULTURAL RESEARCH INSTITUTES

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ABSTRACT

This article is based on a study that investigated the phenomenon of knowledge production and generation in the agricultural sector, with particular focus on Nigerian agricultural research institutes (ARIs). Qualitative and quantitative approaches known as mixed methods research were used through a survey design to collect data from the population of research scientists and directors of the ARIs. The findings showed that the knowledge produced by the institutes included: genetic improvement of varieties of crops; crop production, breeding, weed control, value-addition techniques, fertility of soil and mechanisation; crop improvement and management practices; generation of agricultural technologies and management practices; pest management, agronomic practices and improved seeds; and fish production and management practices. The study found that generation of explicit knowledge and tacit knowledge was

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high in the institutes. The research implications of the study are to stimulate Nigeria to become self-sufficient in feeding its own people by investing in the agricultural knowledge production to drive research and innovation in the sector since knowledge production is a critical tool in innovation, and research and development (R&D). The social implications of the study are to provide a deeper understanding of various phenomena pertaining to knowledge production and generation in the agricultural sector which could serve as a basis for re-evaluation, re-strategising and re-focusing knowledge management practices in the institutes. The originality of the study lies in its ability to investigate how concepts and variables from various theories/models played out in the context of Nigerian ARIs. The study contributes to policy, theory, practice and society.

Keywords: knowledge management, knowledge production, agricultural research institutes, agriculture, Nigeria

1. INTRODUCTION

The knowledge economy is driven by knowledge capital. As today's economy becomes more knowledge and information driven, so does the necessity for effective information and knowledge management strategies in all human endeavours. During the 1950s, 1960s and early 1970s, agriculture was the mainstay of the Nigerian economy and contributed to over 94 per cent of government revenue and 60–70 per cent of total exports (Daramola et al. 2008). Since the discovery of Nigerian oil in the 1970s, the significance of agriculture has declined, and oil now totals 95 per cent of exports and 40 per cent of government revenues (EIA 2012), while agriculture only accounts for 0.2 per cent of exports (Daramola et al. 2008).

Declining agricultural production has relegated the role played by the agricultural sector in innovation development and knowledge discovery which is now characterised by a myriad of problems. This is evident in the nation's agricultural sector contribution to the gross domestic product (GDP), which was down to 30.9 per cent in 2013, in contrast to the industrial sector, which contributed 43 per cent (CIA 2014). Nigeria is therefore increasingly becoming dependent on food imports to feed the rapidly growing population of 174 507 537 million people (CIA 2014). According to Shehu (2013) Nigeria spends 16.7 per cent of GDP (N1.3 trillion) on food imports and this trend is not sustainable. Nigeria must become self-sufficient in feeding its own people by investing in agricultural sector. The agricultural research institutes (ARIs) in this regard are vital to drive innovation, and research and development (R&D) in agriculture. Knowledge production is a critical tool in innovation and R&D. The resultant effect of these problems in the context of this study is: (i) poor agricultural R&D in the country; (ii) low productivity and income in the sector; (iii) inadequate farmers' skills and innovations for enhanced output;

(iv) declined government revenue and impeded national development; and (v) high importation of food and other agricultural products.

2. OBJECTIVES OF THE STUDY

The objectives of the study were to:

- identify the types of knowledge generated in the five agricultural research institutes;
- determine the modes of knowledge production in the agricultural research institutes.

3. LITERATURE REVIEW

Agricultural researchers (ARIs, universities, NGOs, private companies and farmers) are engaged in developing technologies and finding new ways of improving agricultural production and the value of agricultural products. Research helps to solve specific scientific problems and provides policy-makers with methods and tools that help to formulate policies. Research provides assessments of farming practices and policies and points out necessary reforms. Making their contribution, Röling and Wagemakers (1998) have indicated that farmers are expected to become experts in external wisdom and technologies and are not just adopters of technology. They make the point that farmers need to adapt the new practices to suit their local situation. This implies that farmers, too, need to experiment and be part of the process to enhance their farming systems. This point is supported by the literature reviewed, which points out that farmers have been experimenting and innovating on their farms for many years (Shrestha 1996).

Knowledge is not static and changes continuously (Riley 1998). The old knowledge equation was: 'knowledge is power, so collect it'. This has been replaced by: 'knowledge is power, so share it in order for it to multiply' (Allee 1997). This means that people and organisations should continuously renew and create more knowledge (Allee 1997). Knowledge creation is defined by Argote, McEvily and Reagans (2003) as new knowledge that is generated within an organisation. They stress that knowledge could be generated at each level of analysis:

- job/individual;
- team;
- organisation; and
- industry.

Knowledge is a vital resource that can be managed for the improvement of agriculture (Engel 1997; Salomon and Engel 1997). Knowledge and skills are essential resources for farming. Studies concerning ways in which farmers obtain and share knowledge are invaluable to farming systems research and extension, and in informing policy (ETC East Africa 2000). The World Bank (1998) links knowledge to light and argues that it is weightless and intangible, yet it travels easily round the world and enlightens people. Knowledge is deemed to be the most important factor influencing livelihoods, by bringing to light preferences, informing markets and illuminating economic transactions (World Bank 1998). It has been described as a primary source of competitive advantage (Awad and Ghaziri 2004; Von Krogh, Ichijo and Nonaka 2000); a catalyst for development (Chapman and Slaymaker 2002); an accelerator of development; and a resource for addressing poverty (Mchombu 2007).

Shan, Zhao and Hua (2013), drawing from Nonaka and Takeuchi's (1995) theory of organisational knowledge creation, studied the impact of quality management practices on the knowledge creation process in the Chinese aviation industry, using a comprehensive literature review and field survey. The results showed that employee training, employee involvement, product design, benchmarking and vision statement have a significant direct impact on the knowledge creation process, while other quality management practices – such as top management support, customer focus, supplier quality management, quality information and recognition and rewards – do not have a direct impact on knowledge creation. The findings further stated that the use of cross-functional teams enables employees to share ideas in light of their experience and promote the sharing of tacit knowledge. Zakaria and Nagata (2010), in a study informed by the success and sustainability of Japanese agriculture, examined the preferences and roles played by extension advisors in relation to knowledge creation and sharing among advisors, farmers and other stakeholders using interviews with 11 principal and senior extension advisors and consultants from different prefectures and organisations, as well as questionnaires from 135 extension advisors in the Ibaraki Prefecture, Japan. The results showed that the Japanese agricultural agencies are actively involved in facilitating integrated knowledge creation and sharing initiatives within their organisations. The extension advisors, as intermediaries and catalysts, are the key links between farmers and the relevant agencies in terms of providing personalised and need-based information for decision-making by all parties concerned.

In assessing agricultural knowledge production from farmers' perspectives, Koutsouris and Papadopoulos (1998) stipulate that local knowledge is a requirement for understanding the complex farming systems of farmers. Although rural people's knowledge was, in the past, perceived to be primitive, unscientific and wrong, Scoones and Thompson (1993) and Warren (1991) feel that local knowledge is necessary for solving local problems. Supporting this argument, Oettie and Koelle (2003) point out that rural communities have

a great strength – their local knowledge. They know about medicinal plants, environmental management and sustainable traditional agricultural practices. As observed by Hoffmann, Probst and Christinck (2007), farmers have been developing agricultural practices and innovations without the contributions of modern science. It is indeed acknowledged that farmers' local knowledge is gaining importance (De Villiers 1996; McDowell 2004; Von Liebenstein 2000).

The World Bank (2010) points out some good practices, such as zero tillage and biochar, which are beneficial to farmers and the environment and which tap on both local knowledge and external information. To concretise these arguments, in a study of regional development through knowledge creation in the organic agriculture of Mexico, Galindo (2007) illustrated how organic agriculture standards and the attractiveness of the market changed the rural setting by promoting knowledge creation and application in the field. The results of such knowledge generation are endogenous growth practices for people who otherwise would abandon agriculture as a means of living. Learning, innovating and networking are requirements and outcomes of following and utilising organic standards.

4. THEORETICAL FRAMEWORK

The study was underpinned by Nonaka and Takeuchi's (1995) theory of organisational knowledge creation; complemented by Boisot's (1987) knowledge category model; Grant's (1996) knowledge-based theory of the firm; and Teece, Pisano and Shuen's (1997) dynamic capabilities perspective model.

The reasons for adopting Nonaka and Takeuchi's (1995) theory are twofold: firstly, the theory is widely used in various research work similar to the current one, such as studies by Chang, Hsu and Yen (2012); Martin de Castro, Lopez Saez and Novas Lopez (2008); Aybuke, Daneshga and Ward (2008); Mellor (2011); Boisot (1998); Gourlay (2006); Lwoga (2011); and Lwoga, Ngulube and Stilwell (2010).

Secondly, as far as possible, the theory covers all the variables of the study and provides a broad explanation and a theoretical lens or perspective for the study. The theory in particular, emphasises knowledge identification, acquisition, development, sharing, preservation and application of knowledge. The theory describes the existence of two types of knowledge, namely, tacit (based on intuition, experience, skills, belief, mental model), and explicit (codified knowledge found in documents, databases/repositories).

Furthermore, Nonaka and Takeuchi's (1995) theory espouses two dimensions of knowledge creation, namely, the epistemological dimension, and the ontological dimension. The epistemological dimension deals with the four modes of knowledge conversion, namely, socialisation (tacit to tacit) that creates synthesised knowledge;

and externalisation (tacit to explicit) that creates conceptual knowledge; combination (explicit to explicit) that creates systematic knowledge; and internalisation (explicit to tacit) that creates operational knowledge. All these modes of knowledge creation are not independent, but interact to create a knowledge spiral which produce new products and innovation. The ontological dimension deals with the level at which these knowledge management processes of knowledge identification, acquisition, development, sharing, preservation and application of knowledge take place.

Boisot's (1987) model supports Nonaka and Takeuchi's (1995) theory by classifying knowledge based on the ease of transmission and the readiness to share. Boisot's (1987) model regards knowledge as either codified or uncodified, and as either diffused or undiffused. The central feature of Grant's (1996) theory is the notion of 'tacitness'. The theory posits that tacit knowledge is the only potential source of competitive advantage (Grant 1996). Based on this view, the idea of knowledge that can be articulated and documented (explicit) is not recognised as a source of organisational efficiency, productivity and innovation development.

Teece et al.'s (1997) model asserts that competencies are dynamic capabilities in the exploitation of existing internal and external firm-specific competencies to address changing environments. This model emphasises exploitation of the firm-specific existing knowledge as against the creation of new knowledge to enhance productivity and development. According to the theory, knowledge capabilities include expertise, knowledge documents, lessons learned, policy and procedures, data.

5. METHODOLOGY

The main methodologies or research approaches in social research include the quantitative, the qualitative (Babbie and Mouton 2001; Creswell 2003; Durrheim 2006; Sheppard 2004) and mixed methods research (Creswell 2003; Creswell and Plano Clark 2007; Greene 2008; Teddlie and Tashakkori 2009). In the present study, the methodology consisted of qualitative and quantitative methods of data collection known as mixed methods. A mixed methods research design is a procedure for collecting, analysing and 'mixing' qualitative and quantitative research and methods in a single study to understand a research problem (Creswell and Plano Clark 2007).

There are 17 ARIs in Nigeria, of which five were purposively chosen from the five geopolitical zones. Each zone has one major agro-based research institute (ARCN 2008). The five ARIs covered by the study serve as zonal agricultural research coordinating institutes for all the states within the zones. The ARIs include (ARCN 2008):

1. National Root Crops Research Institute (NRCRI), Umudike, Abia State (South-East) covering Abia, Akwa Ibom, Anambra, Bayelsa, Cross-Rivers, Ebonyi, Enugu, Imo and Rivers States.

2. Institute for Agricultural Research and Training (IAR&T) Ibadan, Oyo State (South-West) covering Ogun, Oyo, Osun, Ondo, Ekiti, Edo and Delta States.
3. National Cereals Research Institute (NCRI) Badeggi, Niger State (North-Central) covering Niger, Abuja FCT, Kwara, Kogi and Benue States.
4. Institute for Agricultural Research (IAR) Zaria, Kaduna State (North-West) covering Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto and Zamfara States.
5. Lake Chad Research Institute (LCRI), Maiduguri, Borno State (North-East) covering Gombe, Bauchi, Taraba, Yobe and Borno States.

The population of the five institutes stood at 1 363. According to Israel (2012), if the population is 1 363 at ± 5 per cent precision, the sample should be 286 at the 95 per cent confidence level. In this regard, 214 research scientists were randomly selected and to administer the questionnaire, while one director each was purposively selected from the five ARIs and interviewed. The sample for researchers was distributed proportionately among the five ARIs institutes, using a formula recommended by Krejcie and Morgan (1970) represented below:

$$\frac{N \times S}{TP}$$

Where:
N = Number (i.e. population of each institute)
S = Sample
T = Total sample size
P = Population

Based on this formula, the distribution of samples across the five ARIs was:

IAR Zaria	$\frac{274}{1\,363} \times 286 = 58$
IAR & T Ibadan	$\frac{292}{1\,363} \times 286 = 61$
LCRI Maiduguri	$\frac{267}{1\,363} \times 286 = 56$
NCRI Badeggi	$\frac{262}{1\,363} \times 286 = 55$
NRCRI Umudike	$\frac{268}{1\,363} \times 286 = 56$

Generally, the interview questions covered themes, such as: type of knowledge generated and managed; generation of explicit knowledge versus tacit knowledge; extent of knowledge production; and knowledge sharing and dissemination. The questionnaire was organised in sections A–C, covering questions 1–20, with the following themes: knowledge generation; knowledge sharing among researchers;

explicit knowledge generation versus tacit knowledge generation; knowledge management activities performed; and knowledge creation/production processes.

6. RESULTS AND DISCUSSION

6.1. Respondents' profiles

This section presents the total number of returns *vis-à-vis* the total number of questionnaires administered to the population of research scientists in the five ARIs, as depicted in Table 1.

Table 1: Response rate from the five ARIs

Institute	Expected respondents (N = 276)	Actual respondents (N = 214)	% of actual respondents
IAR Zaria	56	47	83.10
IAR&T Ibadan	59	42	71.18
NRCRI Umudike	54	44	81.48
NCRI Badeggi	53	41	77.35
LCRI Maiduguri	54	40	74.07
Total	**276**	**214**	**77.6**

The results in Table 1 showed that 214 (77.6%) questionnaires were completed and returned out of the total 276 that were administered. In this regard, 47 (83.10%) were returned from IAR Zaria; 42 (71.18%) from IAR&T Ibadan; 44 (81.48%) from NRCRI Umudike; 41 (77.35%) from NCRI Badeggi; and 40 (74.07%) from LCRI Maiduguri. From these results, it is evident the highest returns were recorded at IAR Zaria (83.10%), followed by NRCRI Umudike (81.48%). Further demographic analysis was conducted to determine the respondents' department/unit/programme, educational status, gender, age, years of working experience and position/rank.

The findings revealed that the number of respondents working in the various departments/units/programmes were as follows: 18 (8.4%) in the Agric Econs and Extension Programme; 29 (13.6%) in the farming system; while 26 (12.1%) were working in the Biotechnology Department. The findings further revealed that 38 (17.8%) of the respondents were working in the product development programme and 24 (11.2%) in the research outreach departments of the institutes, while the majority 79 (36.9%) of the respondents were working in other departments/programmes, which included the cassava programme, yam programme, sweet potato, cocoyam, ginger, post-harvest, technology, maize, banana, kenaf and jute, cereals, trypanotolerant

livestock, grain legumes, land and water resource management, cowpea, groundnut, cotton, confectioneries, castor and tomato programmes.

According to Alene et al. (2007), agricultural research is now principally carried out by 17 NARIs. Six of these deal with arable crops; three with forestry and tree crops; three with livestock; two with fisheries; and one each with extension, processing and storage. Each has a national mandate for specific major commodities in each agro-ecological zone. IITA, in partnership with NARIs and other collaborative institutions, has developed and released, to Nigerian and other farmers in Sub-Saharan Africa (SSA), numerous improved varieties of cassava, yam, maize, cowpea, plantain and banana and soybean. Nigeria is now the world's largest producer of cassava, yam and cowpea (Manyong et al. 2005).

The findings also revealed that the majority of the respondents were males 151 (70.6%), while females stood at 57 (26.6%). Furthermore, the data showed that most of the respondents were in the age bracket of 29–49, with educational qualifications ranging from 62 (29.0%) with a master's degree to 62 (29.0%) with a PhD, at the rank of Research Officer I & II. Despite the availability of high calibre manpower, Nigeria's agricultural research faces the challenge of responding to the new demands to contribute to poverty reduction, in the face of declining national research budgets. In 2000, for instance, although Nigeria employed the highest total number of full-time equivalent researchers in SSA (11%), its share of spending was only 7 per cent of the total US$1.5 billion (US$10.5 million) (Beintema and Stads 2004). The International Institute for Tropical Agriculture (IITA) has been supplying improved germplasm to NARIs and has strengthened their research capacity, mainly through collaborative research, short courses and long-term training of their staff at MSc and PhD levels.

6.2. Knowledge generated by the Nigerian ARIs

Based on Nonaka and Takeuchi's (1995) theory, knowledge generation refers to the capability of an organisation as a whole to create new knowledge, disseminate it throughout the organisation, and embody it in products, services and systems. They stress that organisational knowledge creation is fundamental to the distinctive ways through which organisations create innovations. Knowledge creation and generation take place through continuous interactions between the epistemological and ontological dimensions of knowledge (Nonaka 1994; Nonaka and Takeuchi 1995), whether tacit or explicit (Nonaka and Konno 1998; Nonaka and Takeuchi 1995).

The study revealed that the ARIs generated knowledge in the following areas: genetic improvement of varieties of cereals, crops, roots, tubers, barley; wheat, rice, soybeans, sugarcane, beniseed, millet; crop production, breeding, weed control, value-addition techniques, fertility of soil and mechanisation; crop improvement and management practices; generation of agricultural technologies and management

practices; pest management, agronomic practices and improved seeds; fish production and management practices. These findings showed that knowledge generation and creation in the five ARIs were within their core mandates of conducting research in major categories of agricultural crops, products, equipment and services, such as: cereal research; grain legumes and soil seed; cotton research; biotechnology research; agricultural mechanization; farming systems; and product development research for agricultural development in the country. Joshi, Suresh and Pratap (2001), in a similar study on the impact of Indian agricultural research, found that the Indian ARIs generated knowledge in the areas of: yield enhancement of sugarcane, hybrid rice, wheat and potato; pigeon pea, genetic enhancement of crops and tubers; resource management in agriculture; integrated pest management techniques; agricultural implements and versitol technology; social welfare and conservation of natural resources. The similarity in the results of the current study and that of Joshi et al. 2001 may be attributed to the fact that both India and Nigeria are developing economies, hence the need to generate agricultural knowledge that could add value to their quest for food security. Revenue enhancement and overall development of the agricultural sector of the two nations is of paramount importance.

A study by Hahn et al. (2006) on knowledge generation and organisational innovation in wetland landscape on small, flexible municipal organisations in southern Sweden, identified the following knowledge that was generated: scientific and local knowledge on ecosystem and landscape management; adaptive governance; adaptive management; and resilience in social-ecological system techniques. Even though the locations of the organisations/institutes studied differed, the similarity in the findings of the present study and that of Hahn et al. (2006) could be due to the fact that both organisations are focused on generating knowledge that could improve practices, products and services and, most importantly, meet up with their statutory responsibilities and obligations. Both studies used semi-structured interviews to collect data. Kaniki and Mphahlele (2002) posit that local knowledge emanates from research conducted in areas unique to a given culture or society and is based on innovation and practical experimentation.

Addom (2010), in a study to understand the phenomenon of knowledge creation and sharing within the agricultural innovation system of Ghana using interviews and focus group discussion techniques, found two sources of knowledge generation (local and scientific), such as: indigenous traditional irrigation practices; knowledge on weather forecasting; biological control of diseases and pests in soybean; production of new pesticide formulations; and use of different plants and roots for soil fertility improvement. These findings were similar to results obtained from the semi-structured interviews about the types of knowledge generated in the ARIs in the current study, which showed that the knowledge generated was mostly scientific data, knowledge on agriculture; information on science and nature; findings from scientific investigations; results of experiments aimed at addressing the needs of

farmers and other stakeholders; and technological packages for optimum productivity in agriculture. Interviewees noted that:

> Research in to genetic improvement of root and tuber crops; agric extension services in liaison with states and federal agencies; provide technical/vocational training to farmers, students and other stakeholders; farming systems based research for south eastern Nigeria … National genetic mandate on nine crops; cotton, cowpea, ground nut, maize, sorghum, artemisia, jetropha, castor; dissemination of agricultural research-based information to stakeholders.

6.2.1. Generation of explicit versus tacit knowledge in the institutes

Based on Nonaka and Takeuchi's (1995) theory, there are two types of knowledge, namely, explicit knowledge and tacit knowledge. Explicit knowledge is knowledge that can be expressed in words and numbers and easily communicated and shared in the form of hard data, scientific formulae, codified procedures, or universal principles. The knowledge is synonymous with a computer code, a chemical formula, or a set of general rules normally found in documented form. Tacit knowledge has two dimensions: the first is the technical dimension, which encompasses the kind of informal and hard-to-pin-down skills or craft captured in the term 'know-how'; the second is the cognitive dimension, which consists of schemata, mental models, beliefs and perceptions. Though they cannot be articulated very easily, these implicit models shape the way people perceive the world around them. Boisot's (1987) model supports Nonaka Takeuchi's (1995) model by classifying knowledge based on the ease of transmission and readiness to share. Boisot's (1987) model regards knowledge as either codified or uncodified and either diffused or undiffused.

Table 2: Generation of explicit knowledge versus tacit knowledge

Explicit knowledge (N = 206)				
Responses	**Frequency**	**%**	**Valid %**	**Cumulative %**
Very low	5	2.3	2.4	2.4
Low	45	21.0	21.8	24.3
High	102	47.7	49.5	73.8
Very high	54	25.2	26.2	100.0
Missing value	8	3.7		
Total	214	100.0	100.0	

Tacit knowledge (N = 207)				
Responses	**Frequency**	**%**	**Valid %**	**Cumulative %**
Very low	8	3.7	3.9	3.9
Low	48	22.4	23.2	27.1
High	99	46.3	47.8	74.9
Very high	52	24.3	25.1	100.0
Missing value	7	3.3		
Total	**214**	**100.0**	**100.0**	

The findings in Table 2 revealed a high generation of explicit knowledge in the five ARIs. One hundred and two (47.7%) of the respondents viewed the generation as high, while 54 (25.2%) thought it was very high. The perception for the high generation of explicit knowledge may largely be due to constant R&D activities, seminars, workshops and conferences taking place in the institutes and documentation of findings and knowledge generated in the form of research reports, seminar papers, manuals and other research guides and protocols. In a sharp contrast to the findings of the present study, Nunes et al. (2006) examined knowledge management issues in knowledge-intensive SMEs, in two knowledge-intensive SMEs in the South Yorkshire region, United Kingdom. Using interpretive paradigm and interviews as data collection instruments, they found that both small and medium companies collected and stored explicit knowledge in the form of training materials, newsletters, databases and company's websites, they did not seem to make active use of them as a source of knowledge.

Furthermore, the findings from the present study showed that the generation of tacit knowledge by the five institutes was high, considering that 99 (46.3%) of the researchers opined that it was high, while 52 (24.3%) said the generation was very high. These findings conformed to Nonaka and Takeuchi's (1995) theory, which showed that organisations cannot create knowledge on their own without the initiative of the individuals and the interaction that takes place within a group. Knowledge can be amplified or crystalised at the group level through dialogue, discussion, experience sharing and observation. According to Nonaka (1991), knowledge sharing amongst employees contributes to the creation of new knowledge in the organisation, which is a critical activity that contributes to the success of the organisation, as new knowledge becomes available for everyone in the organisation to take advantage of. This may lead to innovative initiatives within the organisation, giving the company an advantage in the competitive world. This thinking is consistent with Grant's (1996) theory, which postulates that practices and routine interactions between and among employees produce tacit knowledge in organisations (e.g. Inkpen and Dinur 1998; Lam 2000; Malan and Kriger 1998; Robertson and Swan 1998).

Mudege (2005) has established that agricultural knowledge is primarily social and its production is a social process; thus, gender dynamics, politics, power, conflicts, resistance, religious beliefs and government policies determine the production and socialisation of knowledge production in Zimbabwe. Shan et al. (2013), drawing from Nonaka and Takeuchi's (1995) theory, studied the impact of quality management practices on knowledge creation process in the Chinese aviation industry using a comprehensive literature review and field survey. The findings revealed that the use of cross-functional teams enabled employees to share ideas in light of their experience and promote the sharing of tacit knowledge. High generation of tacit knowledge by the institutes makes more sense to Grant's (1996) theory, because its central feature is the notion of 'tacitness', as tacit knowledge is a potential source of competitive advantage due to its limited transferability.

Generally, the findings of the present study revealed that both explicit knowledge and tacit knowledge were generated in high proportion through R&D activities, seminars, workshops, conferences and sharing of experience, ideas and expertise, which became a norm in the institutes. To further elucidate the generation of the two types of knowledge in the institutes, the findings from the semi-structured interviews revealed that the ARIs generated both types of knowledge. Knowledge generated through regular interaction between scientists and management was documented. By and large, the two types of knowledge were found to be interwoven and complementary. In a related study, Herman (2013) used a knowledge-based view. The study aimed at developing a typology of knowledge that could be fruitful in facilitating research in a knowledge-based production environment. The findings showed that differences between the tacit, codified and encapsulated shapes of knowledge carried strategic implications for the firm along six important dimensions, which included: a locus or knowledge substrate; transferability; expression; acquisition process; source of economic value; and observability. The findings revealed that different types of knowledge resources required different corporate strategies to maximise their value. Both Herman's (2013) and the present study recognise the importance of the two types of knowledge, which are pertinent in the organisations' quest for attaining competitive advantage. In this regard, an interviewee noted that:

> Both types of knowledge are generated by my institute. Knowledge generated by regular interaction between scientists and management are documented. Documented knowledge is disseminated among scientists sometimes through interaction. The two types of knowledge are interwoven and complimentary.

In the same vein, another interviewee stated the following:

> Mostly scientific data, knowledge in agriculture; Information on science and nature; Research findings from scientific investigations; National and international information in agriculture … Results of experiments aimed at addressing the needs of farmers and other stakeholders; technological packages for optimum productivity.

6.3. Modes of knowledge production in the institutes

According to Bagshaw (2000), knowledge workers are valuable in organisations because they look for innovation which increases choices and thereby increase the organisations' knowledge asset.

The findings of the present study revealed that knowledge in the ARIs was produced through: formal and informal interactions; mentoring; research, teaching and experiments; workshops, seminars and conferences; training and re-training; annual review meetings; adaptive research; cropping scheme meetings. The findings seemed to suggest that knowledge production was largely achieved through interaction, learning by doing and knowledge sharing in the five ARIs. The knowledge production process seemed to start with tacit knowledge and subsequently converted into explicit knowledge production. This confirmed the earlier findings about explicit knowledge and tacit knowledge generation, which was high in the five ARIs.

The findings were consistent with Nonaka and Takeuchi's (1995) epistemological dimension of knowledge production, in which knowledge creation starts when tacit and explicit knowledge interact with each other in what is referred to as epistemological dimension/knowledge conversion. Knowledge conversion is made up of four modes, namely: socialisation (tacit to tacit), a process by which knowledge is synthesized; externalisation (tacit to explicit), a process where conceptual knowledge is created; combination (explicit to explicit), where systematic knowledge is created; and internalisation (explicit to tacit), where operational knowledge is created. All these modes of knowledge creation are not independent, but interact to create a knowledge spiral, which produces new products and innovations.

Ha, Okigbo and Igboaka (2008), seeking to determine knowledge creation and dissemination in SSA, used a free broadband service knowledge centre in the Ihiala village of southern Nigeria. The findings of the study revealed that farmers used broadband technology, especially when it was available to them for free. The farmers evaluated positively the postings on the centre's web space. Ha et al. (2008) demonstrated the influence of interaction and social networking (both online and offline) on knowledge production, creation and dissemination. Yang, Fang and Lin (2009), in a study of organisational knowledge-creation strategies, guided by knowledge-based theory and knowledge creation theory, proposed four modes of knowledge creation strategies, encapsulated in the EICE model – exploration, institutional entrepreneurship, combination and exploitation. It is a strategy through which an organisation increases its intellectual capital, by creating its unique private knowledge within its organisational boundaries (Ichijo 2002).

The institutional entrepreneurship strategy is concerned with articulating private knowledge into public knowledge. The combination strategy is concerned with converting public knowledge (i.e. knowledge not unique to any one firm but also exists in the outside environment) into more complex and advanced sets of public knowledge. It focuses on the synthesis and application of current and acquired

public knowledge (Kogut and Zander 1992; Nahapiet and Ghoshal 1998). The exploitation strategy focuses on transforming public knowledge into firm-specific private knowledge. It is also concerned with enhancing the intellectual capital of a firm with existing public knowledge (Ichijo, 2002). The variation in the findings of the two studies, with regard to the modes of knowledge production, may be as a result of the different approaches used in the two studies. While the present study used a mixed methods approach to obtain empirical data, the Yang et al.'s (2009) study was based on conceptual framework and literature review.

6.3.1. Frequency of knowledge production in the ARIs

According to Grant's (1996) theory, continuous knowledge production in organisations is the only way to the successful attainment of competitive advantage. In this regard, the respondents were asked to indicate the frequency of knowledge production in the ARIs. The results are shown in Table 3.

Table 3: Frequency of knowledge production in the ARIs

Responses	Frequency	%	Valid %	Cumulative %
Rarely	1	0.5	0.5	0.5
Occasionally	5	2.3	2.4	2.8
Frequently	110	51.4	51.9	54.7
Very frequently	96	44.9	45.3	100.0
Missing value	2	0.9		
Total	**214**	**100.0**	**100.0**	

The distribution on the basis of the frequency of knowledge production in the ARIs was that 110 (51.4%) respondents believed that knowledge production was frequent, while 96 (44.9%) thought knowledge production was very frequent. These findings suggest that knowledge production was a common practice in the ARIs.

Related to the findings of the present study, Zehrer (2011) studied knowledge management in Australian tourism organisations, based on Grant's (2005) theory. The study found that knowledge production was frequent in the organisations through knowledge-sharing and the documentation of knowledge.

The convergence in the findings of the present study and that of Zehrer (2011) may be attributed to the fact that ARIs and tourism organisations are regarded as knowledge-intensive organisations (Hjalager 2002; Knight and Harland 2005). Also consistent with the findings of the present study were those of Assefa et al. (2011), who assessed the agricultural knowledge management in dairy production improvement in the Amhara region of Ethiopia using semi-structured questionnaires

and a literature review. The study found frequent knowledge production through experience sharing sessions, on-farm demonstration, learning by doing, listening to the radio and farm visits by officials of the Woreda Agricultural and Rural Development Office (WARDO). In line with Teece et al.'s (1997) model, R&D capability of organisations enables them to invent new technology, as well as to convert existing technology to develop new products and services. R&D capability help firms to develop new technical knowledge and use this knowledge to design superior products and services (Teece et al. 1997). An interviewee commented on the mode of knowledge production thus:

> Knowledge is produced on regular basis through research and results are documented on a regular basis through annual reports published by the institute and through journals published by scientists.

6.3.2. Activities of knowledge production in the institutes

Nonaka and Takeuchi's (1995) theory asserts that knowledge production in organisations starts with knowledge sharing among employees and continuous R&D activities. In line with Nonaka and Takeuchi's theory, the present study investigated activities that generate knowledge production and sharing in the ARIs. These activities included: interpersonal discussion with colleagues; workshops, seminars and conferences; research and consultancy; memos, reports and files; magazines and newsletters; online and offline databases.

The results identified the activities that led to the production of knowledge in the ARIs. Based on the activities, interpersonal discussion with colleagues was cited by 65 (30.4%) as very frequently, while 115 (53.7%) said frequently, 29 (13.6%) occasionally, and four (1.9%) sometimes; workshops, seminars and conferences 67 (31.3%) very frequently, 104 (48.6%) frequently, 39 (18.2%) occasionally and one (0.5%) sometimes; research and consultancy 107 (50.0%) very frequently, 83 (38.8%) frequently, 18 (8.4%) occasionally, and two (0.9%) sometimes; memos, reports and files 55 (25.7%) very frequently, 84 (39.3%) frequently, 18 (8.4%) occasionally, and two (0.9%) sometimes; publications such as magazines, newsletters, bulletins etc. 42 (19.6%) very frequently, 81 (37.9%) frequently, 67 (31.3%) occasionally, and 21 (9.8%) sometimes, while 1 (0.5%) responded never; online and offline database search 40 (18.7%) very frequently, 85 (39.7%) frequently, 56 (26.2%) occasionally, 25 (11.7%), while tow (0.9%) opined that it never happened.

The results showed that all the activities that led to knowledge production were performed frequently, especially interpersonal discussion with colleagues, workshops, seminars and conferences, research and consultancy and memos, reports and files management. These findings corroborated the findings of the semi-structured interviews, where most of the respondents confirmed the performance of these activities that led to the production and sharing of knowledge in their institutes.

The researcher established that performance of such activities helped to generate the production of tacit and explicit knowledge in the various institutes and these findings corroborated the findings obtained through semi-structured interviews in which respondents claimed that knowledge was produced on a regular basis through knowledge sharing, R&D, annual reports and journal articles published by scientists. Related to these findings, a study of 431 United States and European companies by Metaxiotis and Psarras (2003) found that companies were engaged in new knowledge generation by accessing knowledge from outside sources (Singh 2010). As one interviewee put it:

> Knowledge is produced through participatory approach with the stakeholders and management by all our scientists through knowledge sharing in both formal and informal for a…Through seminars, workshops, monthly meetings with ADPs in south west agro-ecological zone; Annual Workshop of Agricultural Research Extension Farmer Input Linkage Services (REFILS); Annual in-house review of programs in the institute.

7. CONCLUSION AND RECOMMENDATIONS

Today's economy is becoming more knowledge and information driven, hence the necessity for effective information and knowledge production in all organisations. The present study discovered that knowledge production was frequent and high in Nigerian ARIs through interpersonal discussion with colleagues; workshops, seminars and conferences; research and consultancy; memos, reports and files; magazines and newsletters; online and offline databases; formal and informal interactions; mentoring; research, teaching and experiments; holding workshops, seminars and conferences; training and re-training; annual review meetings; adaptive research; and cropping scheme meetings.

These activities led to production of knowledge in diverse areas, including: (i) genetic improvement of varieties of cereals, crops, roots, tubers, barley (such as wheat), rice, soybeans, sugarcane, beniseed and millet; (ii) crop production, breeding, weed control, value-addition techniques, fertility of soil and mechanisation; (iii) crop improvement and management practices; (iv) generation of agricultural technologies and management practices; (iv) pest management, agronomic practices and improved seeds; and (v) fish production and management practices. Based on the findings, the study recommends that:

1. Even though knowledge production and generation was high in the ARIs, the impact has not been visible in Nigeria, considering the dwindling fortune of the agricultural sector in the country; hence, there is a need to carry out agricultural research and knowledge impact assessment.
2. The establishment of a co-ordinated programme for the development of a National Information Infrastructure (NII), State Information Infrastructure (SII)

and Local Information Infrastructure (LII), by using emerging technologies, such as satellites, including VSAT, fibre optic networks, high-speed gateways and broad-band/multimedia technologies to facilitate information and knowledge transfer among the ARIs and stakeholders/end-users.

3. An enabling environment should be created through appropriate policies to facilitate access to knowledge generated in the ARIs. A national agricultural research database/databank should be established to enhance awareness, documentation, access and utilisation of agricultural information and knowledge for overall national development.

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