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ANALYSIS OF ABSORPTIVE CAPACITY CONDITIONS BASED ON R&D PROJECTS

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ABSTRACT

Purpose: In this study, the notion of absorptive capacity (AC) and its configurations were adopted as a reference with the general goal of understanding the development stage of processes and routines of the acquisition, transformation and application of knowledge in the context of a public research company.

Originality/value: One of the mobilizing factors in the agricultural sector in Brazil is the generation of new products and processes. In this case, the Brazilian Agricultural Research Agency (Embrapa) has played a role, especially in the absorption, internalization and generation of agricultural knowledge and innovations. In its processes, it involves its decentralized units and scientific and technological partners through research and development (R&D) processes. Identifying and systematizing the most effective forms and configurations in processes and routines associated with the dynamic of knowledge appropriation in a diverse and dynamic environment such as Embrapa constitutes a major challenge for scholars. However, recent studies have highlighted the growing diffusion of the debate on the AC construct.

Design/methodology/approach: For this purpose, a case study was conducted involving Embrapa and three of its R&D projects. The study found evidence of intra-organizational and interorganizational alliances, as well as resulting important innovations.

Findings: The principal contribution was identifying, in a public research company, the presence of routines and processes similar to those observed in the configurations of AC analyzed in the literature and the consolidation of routines and processes of knowledge absorption at the intra-organizational and interorganizational levels.

KEYWORDS

Absorptive capacity. R&D projects. Intraorganizational and interorganizational alliances. Agricultural innovations. Knowledge.

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1. INTRODUCTION

The acquisition of external knowledge by the organization has proved to be increasingly important to the generation of innovations (Lane & Lubatkin, 1998; Lin, Su, & Higgins, 2016). However, acquiring external knowledge is not sufficient when it comes to mobilizing innovations, as this process involves a firm's absorptive capacity (AC), i.e., "a set of organizational routines and processes through which firms acquire, assimilate, transform and exploit knowledge" (Zahra & George, 2002, p. 186).

Studies conducted after the pioneering diffusion of this concept (Cohen & Levinthal, 1990) have revealed evidence of important relationships: the influence of AC on innovative performance (Cohen & Levinthal, 1990; Lane, Koka, & Pathak, 2006; Moilanen, Østbye, & Woll, 2014); the intra-organizational transfer of knowledge (Martinkenaite & Breunig, 2016); and the revision/recycling of internal knowledge through its interaction with external knowledge (Lewin, Massini, & Peeters, 2011).

On the other hand, the generation of innovations has required increasingly complex and diverse knowledge. Knowledge acquisition, especially for the development of innovations, occurs in different ways, such as strategic alliances, joint ventures, and mergers and acquisitions. Of these, strategic alliances stand out because they enable the acceleration of technological advances (Grant & Baden-Fuller, 1995; Costa & Porto, 2014; Shin, Kim, & Park, 2016).

By enabling the generation of new knowledge and innovations, AC has been confirmed as an important theme in the contemporary environment (Lane et al., 2006; Rodríguez-Serrano & Martín-Armario, 2017), meaning that the systematization of its configurations is an important task, especially in decisive economic sectors of the country and, above all, in the operations of public research companies. This is the case of the Brazilian agricultural sector, which is responsible for approximately 24% of gross domestic product (Brazilian Agricultural Research Agency [Embrapa], 2014), and its agricultural innovations are very often the outputs of the research and development (R&D) projects of public research companies (Crespi, Costa, Preusler, & Porto, 2019).

According to Ribeiro, Monteiro Salles-Filho, and Bin (2015), the evolution of public research companies (or public research institutes) at the global level can be divided into two phases. In the first one (from 1980 to 1990), the structural evolution of these companies was motivated by fiscal and financial crises, changes in the roles of the state (including financial constraints), the emergence of new fields of knowledge and technical and scientific trans-

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formations and, finally, by the most representative operations of new players, such as science parks, incubators and startups, which reorganized national innovation systems (Salles-Filho, 2000; Laredo & Mustar, 2004; Salles-Filho & Bonacelli, 2010; Moura, Madeira, Duarte, Carvalho, & Kahilana, 2019). The second phase (which began in the 2000s), in turn, was marked by a new wave of transformations (which are still ongoing), in which the professionalized management of public research companies is highlighted, as well as new possibilities for inclusion and knowledge sharing in national innovation systems, institutional governance, the complete planning cycle and the maintenance and expansion of human resources for innovation (Bin et al., 2013; Ribeiro et al., 2015; Moura et al., 2019).

Among the public research companies in the Brazilian agricultural sector, Embrapa has assumed an important role through strategic alliances with scientific and technological partners (universities, research institutes and firms) to conduct R&D projects (Crespi et al., 2019). One of the main goals of these alliances to conduct R&D projects is to deliver to the market a qualified supply of innovations in products and processes (Embrapa, 2016). According to Gulati (1998, p. 293), these alliances can be defined as "arrangements between firms involving exchange, sharing or co-development of products, technologies or services".

It should be emphasized that the performance of public research companies in emerging countries will depend increasingly on their capacity to access external knowledge and add it to the capacities of their geographically dispersed internal units (Santos, 2006). This construction will require considerable improvement in the ability to organize knowledge that is spread over decentralized units and in the hands of external technological partners (Cyrino & Barcellos, 2006).

It is precisely because of this magnitude that it is difficult to identify and systematize the most effective forms and configurations in the dynamic of appropriating knowledge in a diverse and comprehensive environment, such as the operations of public research companies in the Brazilian agricultural sector. Therefore, the general objective of this study was to understand the development stage of processes and routines involved in the acquisition, transformation and application of knowledge considering the context of a public research company.

To achieve this goal, the notion and dynamic of AC was used and served as a reference for analyzing the relational processes of Embrapa with the generation of knowledge. The scope and diversity of Embrapa's activities directed this analysis to R&D projects that represented the company's best,

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in terms of knowledge absorption processes capable of fulfilling the complete theoretical-empirical cycle, in other words, the acquisition of external knowledge to generate innovations, undergoing processes of external knowledge assimilation, internal transfer and application of this knowledge in different environments. Thus, three R&D projects that resulted in important innovations were selected: 1. Imidazolinone tolerant soybean cultivars (Embrapa Soja); 2. Co-inoculation (Embrapa Soja); 3. Carbon-Neutral Meat (Embrapa Gado de Corte), the development of which required strategic alliances with internal and external partners.

In this perspective, the study was conducted to answer the following research question:

- Can the R&D projects selected as an expression of the acquisition and transformation of knowledge and as mobilizers of the generation of innovations in a public research company be considered consolidated examples of the dynamic and construct addressed in the literature as AC?

The answer to this question lies in an analysis of the configuration of the processes related to knowledge absorption at Embrapa in light of the theoretical-empirical references of AC.

2. THEORETICAL BACKGROUND

In the seminal article of Cohen and Levinthal (1990, p. 128), the AC of a firm is addressed as its ability to "recognize the value of new external information, assimilate it and apply it to commercial ends". This indicates that abilities involving the evaluation and exploitation of external knowledge are fundamental to the creation of innovations.

Zahra and George (2002) address AC as a complex, diverse and significant organizational phenomenon that enables the reconfiguration of the resource base and its adaptation to the changeable environment in order to obtain a competitive advantage. From the viewpoint of dynamic capabilities, these authors reviewed the existing literature, i.e., the concepts of Cohen and Levinthal (1990), Mowery and Oxley (1995) and Kim (1998), and re-conceptualized this capacity, defining it as "a set of organizational routines and processes through which firms acquire, assimilate, transform and exploit knowledge in order to shape a dynamic organizational capability" (Zahra & George, 2002, p. 186).

Another important approach to the AC construct is the one that analyzes its dynamics and configuration, in other words, one that is indicative

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of the processes that underlie its structuring. Although there is not necessarily a consensus regarding these definitions, many of the studies point out that the dynamic of AC is structured based on internal and external relationships and interactions that are established in the routines and processes that focus on the acquisition, assimilation, internalization, transformation, recycling and application of external knowledge (Zahra & George, 2002; Lane et al., 2006; Todorova & Durisin, 2007; Volberda, Foss, & Lyles, 2010; Lewin et al., 2011; Patterson & Ambrosini, 2015; Ferreira & Ferreira, 2017).

In this processual approach, studies should also be highlighted that defend the formation and development of AC as dependent on the construction of a learning environment in organizations (Lane et al., 2006; Sun & Anderson, 2010; Gebauer, Worch, & Truffer, 2012), the mobilization and diffusion of this knowledge at different organizational levels (Coleman & MacNicol, 2016), and external articulations with technical and commercial partners and clients (Sáez, Arribas, & García, 2002).

In this study, the position presented by Apriliyanti and Alon (2017) is adopted as the result of a bibliometric analysis regarding production on AC, in which this notion appears as a multidimensional construction, involving different processes, routines and interactions. Apriliyanti and Alon (2017) also confirmed the limited consensus among the works that were examined regarding the composition, ordering or scope of these elements in the configuration of AC. Therefore, based on an analysis of the seminal literature on the theme, a decision was made to select a configuration of AC composed of three categories: 1. antecedents of AC; 2. central dynamic of AC; and 3. structural facilitators, whose theoretical foundation is presented below and summarized in Figure 2.1.

The first category (Figure 2.1), antecedents of AC (Cohen & Levinthal, 1990; Todorova & Durisin, 2007; Gebauer et al., 2012), adds the result of different organizational constructions, such as knowledge and experience accumulated over time (Zahra & George, 2002); cooperation networks in R&D and constructed innovations (Murovec & Prodan, 2009); the prior knowledge of professionals and managers (Jansen, Van Den Bosch, & Volberda, 2005); and the technical, scientific and experiential qualifications of professionals, also known as intellectual capital (Cassol, Gonçalo, & Ruas, 2016).

The antecedents of AC category are, thus, made up of a series of factors that mobilize organizations to prospect external knowledge, thereby constituting a base to support the development of the main stages of building AC.

The second category (Figure 2.1) specifically addresses the central dynamic of AC, i.e., the four dimensions of absorption (or capabilities of

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AC) of external knowledge in organizations and the dynamics: acquisition, assimilation, transformation and application of external knowledge (Zahra & George, 2002; Todorova & Durisin, 2007). Every one of these dimensions is structured by specific processes and routines, although some of them can be observed in more than one dimension in different forms. This category is referred to, in this study, as the central dynamic of AC because, in this space, the effective processes of external knowledge absorption are developed.

Regarding the first dimension of this category, acquisition, the literature identifies routines and processes associated with the development of projects and participation in networks with external partners (clients, suppliers, research institutions, associations etc.), visits to companies, attendance at fairs and technical and scientific events, technical missions to other centers and participation in public contests (Zahra & George, 2002; Lane et al., 2006; Todorova & Durisin, 2007; Gebauer et al., 2012; Ali, Musawir, & Ali, 2018; Bjorvatn & Wald, 2018).

Meanwhile, concerning routines and processes associated with the second dimension, assimilation, the literature highlights openness to new ideas, sharing knowledge, collective interpretation of acquired knowledge, review of routines, rotation of functions in the intra- and inter-sector environment, and participation in decisions on strategy and operations. These routines and processes mobilize the internalization of acquired knowledge through the analysis, processing, interpretation and classification of new knowledge (Cohen & Levinthal, 1990; Zahra & George, 2002; Sun & Anderson 2010; Gebauer et al., 2012; Patterson & Ambrosini, 2015).

As can be seen, the first two dimensions of AC, acquisition and assimilation, have a strong relationship with processes and routines associated with external relationships in networks, which enable the appropriation of knowledge.

The processes and routines related to the third dimension of the Central Dynamic of AC, transformation, focus on the adaptation and combination of external knowledge with knowledge that already exists in the firm, internally. This occurs through the regular review of routines, the search for knowledge required for new products and processes and future strategies, and the recycling of knowledge used by the firm (Zahra & George, 2002; Todorova & Durisin, 2007; Sun & Anderson, 2010; Gebauer et al., 2012).

Finally, the last dimension of this category, application, focuses on creating new processes, goods, services and knowledge, and is witnessed through routines and processes of launching innovations, redefining market position, awards for performance, applications for patents and others (Cohen

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& Levinthal, 1990; Lane et al., 2006; Todorova & Durisin, 2007; Gebauer et al., 2012).

The third and last category (Figure 2.1) involves structural facilitators, i.e., social interactions and processes that occur within organizations and originate from the structural and institutional conditions of each organization. This category is referred to in a number of ways in different studies on the theme: social integration mechanisms (Zahra & George, 2002; Todorova & Durisin, 2007); learning relationships (Lane et al., 2006); combinatory capabilities (Gebauer et al., 2012); and intellectual capital (Cassol et al., 2016).

Considering that these elements mobilize the consolidation of the four dimensions of AC (acquisition, assimilation, transformation and application) and, therefore, the effective absorption of external knowledge, they can be considered structural facilitators of AC.

The exchange of knowledge between the parties involved in R&D projects should also be considered, given that each phase of the lifecycle of these projects has specific routines and characteristics, as they occur in each of the dimensions of AC (Lewin et al., 2011; Rocha, 2014), the routines of acquisition and assimilation (Potential absorptive capacity – Pacap), and the routines of transformation and exploitation (Realized absorptive capacity – Racap) (Zahra & George, 2002), including the scoping, specification of the project, planning, implementation and conclusion with delivery and post-project evaluation (Mikulskienė, 2014; Ali et al., 2018; Bjorvatn & Wald, 2018).

Thus, organizations that are efficient in the generation of innovations have routines for each dimension of AC (Zahra & George, 2002), which in turn are interrelated with the phases of the lifecycle of R&D projects (Mikulskienė, 2014; Project Management Institute [PMI], 2013; Ali et al., 2018; Bjorvatn & Wald, 2018), composing a broad set of organizational processes. These, when systematized, can confer the stage of development (Guedes, Ziviani, Paiva, Ferreira, & Herzog, 2017) of the AC (potential, achieved or scalable), i.e., the capacity to absorb knowledge and promote innovations (new products, processes and services). In short, among the different possibilities of characterizing the configuration of AC, it is understood that it is possible to classify it briefly into the categories detailed below (Figure 2.1).

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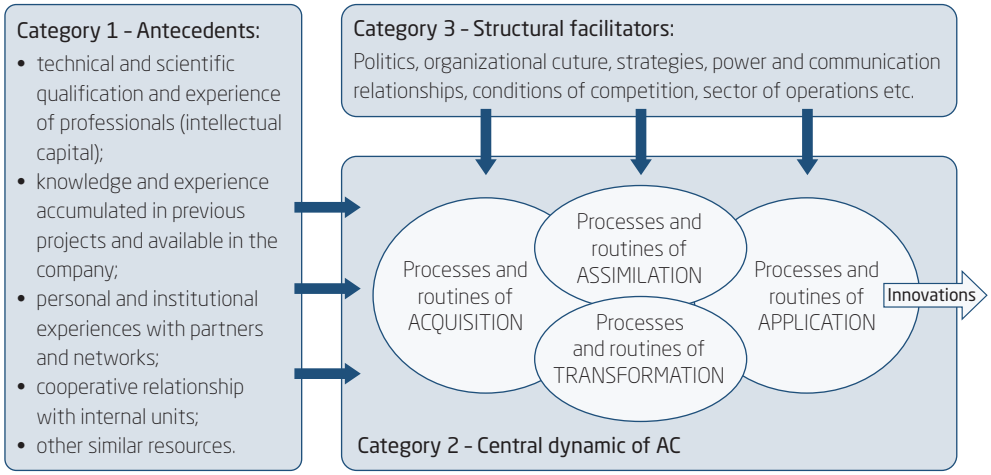
Figure 2.1

CONFIGURATION OF ABSORPTIVE CAPACITY



Source: Adapted by the authors based on Zahra and George (2002), Jansen et al. (2005), Lane et al. (2006), Todorova and Durisin (2007), Murovec and Prodan (2009), and Gebauer et al. (2012).

- *Category 1 – antecedents of AC*: related to the elements capable of recognizing external knowledge and mobilizing a search for it to streamline the flow of input into the organization and aid its assimilation and transformation within the organization, whose main forms are previous knowledge, experience accumulated over time, networks of cooperation in R&D, intellectual capital etc.
- *Category 2 – central dynamic of AC*: based on the processes and routines that specifically focus on the acquisition of knowledge from outside the organization and its assimilation, transformation and application to support innovations. This category has to do with the consolidation of AC and its associations with the life cycles of R&D projects.
- *Category 3 – structural facilitators*: elements associated with the institutional characteristics of each firm and the context in which they operate (structure, politics, organizational culture, strategies, power relationships and communication relationships, competitiveness of the sector etc.) and which will define the organization's internal and external forms of social interaction.

From this configuration of AC, the characteristics of the external knowledge process at Embrapa were analyzed, represented by the three selected R&D projects.

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3. METHODOLOGICAL PROCEDURES

The study was qualitative, in nature (Creswell, 2017), with a descriptive approach (Godoy, 1995). The case study method was used to investigate Embrapa, a public research company that has played a fundamental role in Brazilian agricultural development (Embrapa, 2016), with the method being used (Eisenhardt & Graebner, 2007) to analyze three R&D projects that involved inter- and intra-organizational alliances.

In the first stage of the field research, interviews were held with the advisor to Embrapa's R&D board, at the company headquarters, in Brasília (Brazil) and members of the central units of the Strategic Business Secretariat (SNE) and the Department of Technology Transfer (DTT).

At this point, the agricultural innovations generated from collaborative R&D projects with the formation of inter-organizational and intra-organizational alliances over the previous five years (2013-2017) were mapped.

The mapped alliances were classified as intra-organizational or interorganizational: the former involving internal relationships formed between units/branches of the same company, and the latter, external relationships formed with partners, such as universities and private companies.

Finally, the three projects selected for this study involving inter-organizational and intra-organizational alliances were validated by the interviewees in the first phase and then investigated in the second phase of the field research.

In the second stage, semi-structured interviews were conducted, fundamental sources of evidence for a cases study (Zamberlan, Rasia, Souza, Grison, Gagliardi, & Teixeira, 2014), involving researchers, heads of technology transfer and heads of R&D of the three projects selected in the previous stage. It should be highlighted that 14 interviews were held, recorded, transcribed and interpreted with regard to the analysis categories described above: antecedents of AC, central dynamic of AC and structural facilitators.

Complementary data were also obtained and kept on observation sheets, with notes on the analysis categories. Furthermore, secondary documents of the projects were analyzed (notices for project selection, strategic documents and guidelines and reports on the projects). The data collection was deemed concluded when the information was sufficiently confirmed and the emergence of new data became rare, indicating an information saturation point (Zamberlan et al., 2014).

The data were analyzed in three stages (Zamberlan et al., 2014): reduction, presentation and conclusion. The reduction involved selecting, focusing,

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simplifying, abstracting and transforming the data, organizing them according to the themes or research goals. The presentation was based on these data and enabled a systematic analysis, observing similarities, differences and interrelationship. The conclusion included a review and consideration of the meanings of the data, which were validated, i.e., it was confirmed that the conclusion derived from them was plausible and credible (Miles & Huberman, 1994).

Triangulation (Zamberlan et al., 2014) and content analysis (Marconi & Lakatos, 2007) procedures were also used. In the triangulation process, the various sources of data that were considered (interviews, documents and observation) were systematized in comparative matrices, resulting in more convincing and accurate discoveries and conclusions for the case study. Meanwhile, the content analysis, which focused on ideas rather than the words themselves (Marconi & Lakatos, 2007), comprised the following phases: 1. pre-analysis, which involved organizing the material; 2. exploration of the material for coding, classification and establishment of analysis categories; and, finally, 3. treatment of the results, inference and interpretation, which were obtained through the condensation and relevance of the information for analysis (Bardin, 2010; Zamberlan et al., 2014).

4. RESULTS AND ANALYSES

The systematization of the characteristics of the three projects in question is shown in Figure 4.1, based on the field research (interviews and observation) and the surveyed documents.

Figure 4.1

DESCRIPTIVE ELEMENTS OF R&D PROJECTS

Descriptive elements of the R&D projects	Project A (Imidazolinone tolerant soy)	Project B (Co-inoculation)	Project C (Carbon-neutral meat)
Responsible unit	Embrapa Soja	Embrapa Soja	Embrapa Gado de Corte
Project goal	To indicate new soy cultivars with the potential to maintain annual genetic gains in productivity.	To establish innovative lines of research, both basic and applied, with nitrogen-fixing bacteria and promoters of the growth of plants.	To validate the Carbon-Neutral Meat (CNM) Protocol in different regions of Brazil for the implementation of the concept of the CNM brand.

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Figure 4.1 (conclusion)

DESCRIPTIVE ELEMENTS OF R&D PROJECTS

Descriptive elements of the R&D projects	Project A (Imidazolinone tolerant soy)	Project B (Co-inoculation)	Project C (Carbon-neutral meat)
Duration of project	Five years	Four years	Forecast for three years
Main internal partners	Embrapa West Agriculture, Amapá, Temperate Climate, Mid North, Tabuleiros Costeiros, Rondônia, Roraima and others.	Embrapa West Agriculture, Tabuleiros Costeiros and Cerrados.	Embrapa Corn and Sorghum, Embrapa Southeast Farming, Embrapa Milk Cattle, Embrapa East Amazon, Embrapa Fish Aquaculture and others.
Main external partners	Basf, Meridional Foundation, Cerrados Foundation, West Bahia R&D Support Foundation and others.	Total Biotecnologia, Meridional Foundation, Londrina State University and the Federal University of Paraná.	Federal University of Minas Gerais, Federal University of Mato Grosso do Sul, Federal University of Goiás, meat lockers and certification agency.
Resulting innovations	Soy cultivars tolerant to Imidazolinone herbicide.	AzoTotal Max Product.	CNM brand.
Patents and registration of cultivars	Cultivars BRS 397 CV, BRS 8482 CV and BRS 8082 CV	Registration of AzoTotal Max product.	National Industrial Property Institute (Inpi) under processes no. 907078982, 907079156 and 907079270.

Source: Elaborated by the authors.

The following section is dedicated to the life cycle of the three R&D projects in question (Figure 4.1). According to Pillai, Joshi, and Rao (2002), PMI (2013), and Mikulskienė (2014), there are seven phases to an R&D project: 1. initial scoping; 2. project specification; 3. detailed planning; 4. evaluation; 5. implementation via actions and review; 6. completion; and 7. post-project evaluation.

In the following analysis, evidence is presented of the presence in each of these seven phases of the three R&D projects under the study of the categories: antecedents of CA, central dynamic of AC, and structural facilitators.

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4.1 Phases 1, 2, 3, and 4 of the R&D projects: conception, planning, and preparation

The initial activities of the new R&D projects in phase 1, initial scoping, have a strong mobilizing element in the search for external knowledge. It is from this process that some of the main directives originate for project development, such as technical and market requirements and technological impasses, brand registration etc. At the same time, it is in this search for knowledge that the building (or rebuilding) of partnerships occurs with private local and multinational companies and consultancies, relationships with Ministry of Agriculture, Livestock, and Food Supply (Mapa) and Virtual Laboratories Abroad (Labex), research institutes and universities etc. (Dingler & Enkel, 2016).

An important resource in this phase is the bibliographic database of the portal of the Coordination for the Improvement of Higher Education Personnel (Capes), and a substantial part of the external knowledge that is explored, which originates in networks that have already been constructed and developed by the company in the recent past (Dingler & Enkel, 2016).

Continuing with the initial scoping, the search for information and knowledge in the internal environment of Embrapa also plays an important role. Indeed, the systematized knowledge available in central agencies of the company, such as the Embrapa's Strategic Intelligence System (Agropensa) or the Embrapa's Programming Management System (Ideare), enables a review of recent projects, portfolios, research and macro programs, harboring a potential contribution to projects that are being conceived, especially in terms of operational alternatives. Furthermore, internal partnerships, involving specific knowledge that originated in company units operating in different regions of Brazil, constitute a valuable resource in this stage of conception.

Phase 1 also involves individual initiatives of researchers and technicians in search of external knowledge through exchanges of researchers, research in databases, contacts with external partners, attending conferences, courses and technical meetings and other modalities at which the availability of researchers, their external professional relationships and access to the database play a fundamental role. According to Mikulskienė (2014), in the initial scoping phase, constructions are more flexible, which gives value to autonomy and creativity in researchers' actions.

Phase 2 of R&D projects, specification, involves the systematization of the knowledge gathered in the previous phase to minimize generalities,

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seek greater focus and articulate the initial scoping to reality. This stage includes the preparation of bulletins with a view to connecting the preliminary ideas to the arrangements and portfolios that precede the drafting of the project, such as an analysis of the relationship between the resources envisaged in the conception and the resources that are available/necessary. Thus, previous experiences with partnerships and alliances help to define alternatives and criteria for selecting external partners and forming alliances in new projects.

Therefore, the mentors of the three R&D projects made special use of Embrapa's Ideare and the company's core units, where knowledge is available on the management of projects conducted in recent years, for the systematization of projects.

Phase 3, detailed planning, is when the elements developed in the previous phases must be stated in the form of specific planning, especially with regard to goals, actions, deadlines, necessary resources, human resources and respective competencies. This is the time for projecting agreements and practices for forming closer ties with companies, research institutes and graduate programs (the formation of inter- and intra-organizational alliances). This phase also includes preliminary negotiations and debates on industrial property.

In phase 3, it is already possible to observe important specific details in each of the three projects in question: while the detailed planning of project B is marked by the acquisition of knowledge that stemmed from clients, in C, this search occurs in the Integration Network of Farming, Livestock and Forests (ILPF Network).

Phase 3 includes knowledge sharing processes, applied: 1. in conventional practices, such as research meetings, aided by a partnership with companies or associated graduate programs; 2. at interactive events, such as "field days", activities with different interlocutors (technicians and researchers from various fields, representatives of agriculture companies and consultancies, individual farmers etc.; and 3. at events focusing on the applied perspective of Embrapa's technology and processes.

Phase 4, evaluation, finalizes the conception and planning of R&D projects and the intention is to select proposals received from possible internal and external partners, evaluate the notices for tenders and their results (Pillai et al., 2002), and approve the plans that have been made.

Ideare is the tool used to manage the information by the Internal Technical Committee (CTI) and the Macro Program Technical Committees (CTMP). Therefore, the evaluation phase can also be viewed as an internal

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diffusion process of the content, norms and perspectives for partnerships and alliances. To a certain extent, the planning of R&D projects is evaluated and enabled by those who will directly or indirectly participate in them as they progress.

4.2 Phases 5, 6 and 7 dos R&D projects: implementation, completion, and developments

The implementation (phase 5) of R&D projects involves executing project activities, based on the knowledge that originally supports the implementation process, stemming from the previous phases, in other words, from external, technical and market knowledge through interorganizational partnerships, and specific internal knowledge through partnerships formed at Embrapa's units. Nevertheless, the requirements of interactivity and recursion in the implementation of research generate new dynamics, as one of the core elements is constituted by the new cycles of the acquisition of external knowledge and the recycling of internal knowledge. This is done to adapt the planning of the research to the challenges of reality through the practice of approximation and/or exchanges of knowledge, and/or negotiations with companies and other institutions. This involves meetings, field days and training programs, routines that are induced by the social articulation within the research (Dingler & Enkel, 2016).

Evidence of this dynamic can be seen in project A, as the scope of external knowledge sources (chemical industry) and internal sources (units in different regions of Brazil) required solutions that depended on intense knowledge and information sharing process. It can also be found in project C, whose implementation required the formalization of new alliances and, thus, new cycles of information and knowledge exchange to handle the scope of the project. These new cycles of external knowledge acquisition and internal knowledge recycling are supported by activities, such as meetings, field days, workshops, technical visits and actions that multiply information and knowledge.

Phase 6, completion, culminates with a final report in which the achievement of the proposed goals and targets of the project is evaluated (Mikulskienė, 2014). In this phase, the application of acquired and recycled knowledge can be seen in project A through the exploitation of the cultivars that were generated. It can be seen in project B, through the commercial application of the newly acquired knowledge (Lane & Lubatkin, 1998). It is evident in project C, through the registration of a concept brand, which

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is exploited through its implementation in already validated themes and in different biomes. Therefore, this constitutes a compilation of competencies through knowledge acquired and transformed during operations (Zahra & George, 2002).

The final phase of R&D projects, post-project, involves analyzing the results obtained (Mikulskienė, 2014), with this phase characterized by exploration of technology transfer actions (field days, divulging the technology with publicity and at conferences etc.), which also involves knowledge acquisition through contact with clients and other companies, aiding new projects and, thus, representing the cyclical process of AC, through which the results provide feedback for the innovation system, as proposed by Lane et al. (2006).

As examples expressed in the three projects in question, incremental innovations deserve to be highlighted, generating new cultivars with different agronomical characteristics, and new formulations of inoculants and the validation of Carbon-Neutral Meat for new biomes.

Another results to be highlighted, in phase 7, the post-project phase, is the formation of new alliances or the reuse of previous ones, as the role of alliances, especially the major ones and those with international experience, has a strong positive impact on the adaptation of innovations in the form of processes and products focused on markets in other countries.

4.3 Presentation of the relationships between the phases of Embrapa's projects and the categories that constitute the configuration of AC

Although the three R&D projects analyzed here address different issues, themes and purposes, their trajectories follow the same seven phases, which include relatively similar activities, processes and routines. Therefore, to concentrate the focus of the analysis on what is of interest to the study, the relationship of the main activities, processes and routines in each project with the structural configuration of the notion of AC, expressed in the three categories presented in section "Theoretical background", it is summarized in Figure 4.3.1.

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Figure 4.3.1

RELATIONSHIPS BETWEEN THE PHASES OF EMBRAPA'S PROJECTS AND THE CATEGORIES THAT CONSTITUTE THE CONFIGURATION OF ABSORPTIVE CAPACITY

Category 1 – most relevant antecedents	Project phases	Category 2 – central dynamic of AC	Category 3 – structural facilitators
• Behavior of company professionals when seeking alternatives and solutions. • Previous systematized knowledge and experiences (e.g., Agropensa). • Technical and scientific training and experience of professionals. • Relationship between the company's internal units formed in previous projects.	Initial scoping	• Acquisition of external knowledge through participation in R&D networks, projects associated with third parties, technical missions, talks and meetings with the production sector, farmers, technicians and industry. • Seeking and selecting internal knowledge in the company and in routines of reviewing projects and debates between different areas of the company. • Individual attitudes associated with external knowledge acquisition, in which individuals are the protagonists, as in searches of databases, technical meetings, and attending conferences and courses.	• Condition of public company impacts the players in the field, stimulating cooperation, partnerships and alliances. • Organizational culture of Embrapa: valuing the experience and knowledge of professionals.
	Project specification	• Seeking and selecting internal knowledge in the company archives and in routines of reviewing projects and debates between different areas of the company.	• Availability of information on projects already undertaken in Embrapa's system.
	Detailed planning	• Adaption and classification of the proposals and goals of new projects to the effective conditions of the company and its partners, and to the norms and limits of action. • Interpretation and collective classification of the knowledge and processes to be developed on field trips (field days). • Review of routines for new projects (including actions with partners). • Preliminary negotiations regarding industrial property.	• Stimulus for the ongoing training and development of researchers and technicians.

(continue)

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Figure 4.3.1 (conclusion)

RELATIONSHIPS BETWEEN THE PHASES OF EMBRAPA'S PROJECTS AND THE CATEGORIES THAT CONSTITUTE THE CONFIGURATION OF ABSORPTIVE CAPACITY

Category 1 – most relevant antecedents	Project phases	Category 2 – central dynamic of AC	Category 3 – structural facilitators
• Relationships with institutional partners and companies formed in previous projects. • Researchers' personal relationships with institutions and national and international networks.	Implementation	• Implementation of projects with the participation of respective partners from inter- and intra-organizational alliances. • New knowledge acquisition cycles stemming from partners' conditions and demands.	• Embrapa's internal communication policy: encouraging sharing among areas and professionals. • Policy of participating in research decisions, encouraging researchers to assume responsibility.
	Evaluation	• Analysis, evaluation and approval of the main elements of the planning, involving areas of the company that will work on projects, which implies the diffusion and collective interpretation of new knowledge. • Internal diffusion for analyzing new knowledge. • Adaptation of new knowledge to existing knowledge.	
	Completion	• Drafting reports, using tools to assess the results of projects or their commercial application, using procedures to register brands or patents, identifying competencies to be exploited etc. • Application of the results of R&D projects.	
	Post-project	• Experimental field trips to present the results of the projects, specific talks with clients and users, preparing and diffusing advertising, attending conferences and other initiatives to divulge results. • As underlying effects of these initiatives, Embrapa's professionals receive feedback at these events, ongoing demands, and suggestions for new projects etc. • Reports with analysis of the impacts of applying the results of the projects.	

Source: Elaborated by the authors.

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4.4 Analysis of the relationships between the phases of Embrapa's projects and the categories that constitute the configuration of absorptive capacity

This section focuses on identifying and systematizing evidence of the presence of elements associated with the configuration of AC, especially the three categories and the dimensions of acquisition, assimilation, transformation and application of external knowledge to Embrapa's R&D projects investigated in this study.

According to Mikulskienė (2014), the exploitation of external knowledge is one of the mobilizing processes of the concept of a new project, as it is from this that comes the perspective of meeting new demands, becoming familiar with emerging technologies or new production techniques and making higher-value products generally stems. Therefore, external knowledge is decisive when it comes to identifying gaps, setting clear and achievable goals and defining the scope, planning and partnerships required for a project.

This condition was no different in the case of the three Embrapa's R&D projects, as in this case, external knowledge played an important goal from the outset to the implementation of the projects, including the appropriation of new knowledge acquisition cycles in these stages. Furthermore, if the exploitation of external knowledge is a preliminary condition for the presence of AC in the projects in question, it can be concluded that this condition was met.

The exploitation of external knowledge means a major concentration on the category known as Central Dynamic of AC and the processes and routines that constitute the dimensions of acquisition, assimilation, transformation and application of external knowledge. Therefore, the analysis begins with this category, as referenced in Figure 4.3.1.

First, it should be observed that the dimension of external knowledge acquisition is found in all seven phases of the projects, but obviously in different levels of intensity. However, the processes and routines associated with this acquisition play a more important role in the initial scoping phase, as it is here that these issues related to market demands, technological gaps, needs to register a brand, etc. are addressed, and all of them possibly already present before the project is begun, but reaffirmed from other interactions. This confirms the importance of external knowledge in this phase. In the detailed planning phase, in which the external knowledge, although highly relevant, are more of the operational kind involving knowledge of norms or arrangements and alliances necessary to make the project happen. In the

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implementation phase, external knowledge stems mostly from interactions with partners in trials, meetings, talks and field days, including new knowledge acquisition cycles. Finally, in the post-project stage, when the results of projects are analyzed, it stems from information on these results in different environments.

The most important processes and routines of the acquisition dimension in the phases highlighted above are: 1. contacts and consultations with partners (companies, research institutions, universities, government agencies etc.); 2. participation in national and international R&D networks; 3. participation in technical missions, exchanges between researchers in talks and at meetings and specific activities, such as field days and practical meetings to diffuse new technologies and techniques; and 4. participation in training programs with the production sector such as farmers, technicians and professionals from industry.

The assimilation dimension, which is present in some form in every stage of the project, plays a more important role in the phases of project specification, detailed planning and evaluation, which comprise conception and planning, as this is when all the appropriation of external knowledge needs to be adapted to consolidated protocols and norms and the potential requirements of the company's knowledge. Meanwhile, during the implementation phase, in which external knowledge is incorporated in new cycles, it needs to be assimilated to the knowledge being constructed in the project.

The most important processes and routines in the assimilation dimension in the phases highlighted above are: 1. interpretation and collective classification of knowledge and processes to be developed on field trips (field days) and in activities such as trials; 2. review of routines for new projects (including operations with partners); 3. preliminary negotiations regarding industrial property; and 4. participation of the areas involved in the projects in decisions concerning the use of new knowledge in routines and processes.

The transformation dimension plays a decisive role in the project specification phase, in that it aids adaptation to external demands – new products, processes, technological developments etc. – and to the knowledge and interests of partners to Embrapa. It aids detailed planning, in which this adaptation is focused on directives, norms, protocols and procedures regarding project management to draft notices and announcements to trigger projects. It aids the implementation phase, which is marked by interactive and recursive processes, encompassing knowledge acquired through interorganizational alliances (e.g., technical and market knowledge) and intra-organiza-

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tional alliances (specific knowledge). It also aids the completion phase, the exploitation and application of the results of projects in productive activities, including adapting the results of projects to other situations and circumstances, together with local or international partners.

The most important processes and routines of the transformation dimension are: 1. reviews of routines and processes owing to new knowledge; 2. research meetings and field days with professionals from firms, graduate programs and internal Embrapa units to share and adapt knowledge; and 3. drafting assessment reports on the application of the results of projects, their commercial application or with regard to registering brands and patents etc.

Finally, the application dimension is revealed in greater detail during the implementation phase, when new knowledge is experimented in practice in trials, with the participation of diverse partners. In the completion phase, it emerges during the evaluation of results and their application to different situations. In the post-project phase, which includes an analysis of the results, it appears in initiatives to diffuse technology to other environments and in the analysis of feedback from clients and partners after the results are put into practice, with the possibility of aiding new projects.

The most important processes and routines in the application dimension are: 1. meetings, trials, talks and field days to demonstrate new products and new and/or recycled technologies and techniques to internal and external partners; 2. evaluation of project outcomes involving adequate assessment tools and identifying the competencies necessary for their use; 3. systematization of feedback from partners on the use of the project results, defining new external knowledge acquisition cycles, addressing adaptation to new environments and conditions; and, finally, 4. prior analysis, revealing strong evidence of the acquisition, assimilation, transformation and application dimensions, as well as the processes and routines that support them, which mobilize the central dynamic category of AC.

In the case of Embrapa, the term central dynamic of AC appears to make sense, because it was found that the exploitation of external knowledge constitutes an important capability of the company. According to this analysis, the exploitation of external knowledge is a resource found in every phase of the projects in question, generating new cycles of external knowledge appropriation, even in the completion phases of these projects.

However, it was also found that the absorption capacity of external knowledge at Embrapa cannot be done without mediating interventions involving the use of internal knowledge. Indeed, it is the recovery of internal

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knowledge that enables the identification, selection, valuing and, especially, the adaptation of external knowledge to the resources of the organization.

Among the principal mediating interventions that employ internal knowledge in the conception, planning, implementation and evaluation of the projects, the following deserve to be mentioned: 1. use of knowledge available in internal networks and from the company's professionals to systematize the proposals and external demands in light of the effective conditions of the company (resources and competencies); 2. use of information and knowledge from previous alliances and their respective arrangements to identify and pre-select the most appropriate internal and external partners with a view to the planning of the projects; 3. use of norms, procedures and directives to complete projects at Embrapa, in order to define the main specific directives of new projects (objectives, goals, principal results, deadlines, main partners, indicators for assessing processes and results etc.); 4. appropriation of the knowledge and experience of the company's technicians and researchers, deployed in evaluation committees to analyze and adjust the results of the planning (directives, proposals for announcements and alliances in the early stage of the projects and, at the end, to evaluate the results in terms of new products, technologies, techniques, registration of brands etc.).

These forms of intervention require from a company's resources and capabilities a consistent and available base of knowledge and experiences. This is the case of Embrapa, which has at its disposal: 1. knowledge from previous projects and research, systematized in its strategic agencies, such as the Ideare or Agropensa; 2. experiences shared in networks, such as the Embrapa's unit network, located in various regions of the country, or the Integration Network of Farming, Livestock and Forests (ILPF Network); and, finally, but also very important 3. the qualifications, knowledge and experiences of the company's professionals, i.e., its intellectual capital, which is constantly a target for new learning, a force that can be activated whenever necessary.

By highlighting the mediating role of internal knowledge in the successful experience of exploiting external knowledge at Embrapa, this analysis is linked to the category of antecedents of AC. According to the literature, this category includes different formats (Cohen & Levinthal, 1990; Zahra & George, 2002; Jansen et al., 2005; Todorova & Durisin, 2007; Murovec & Prodan, 2009; Gebauer et al., 2012), most of which are found in the case of Embrapa: previous knowledge and experiences, systematized and made available to strategic agencies (Ideare and Agropensa); consolidated research

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alliances and networks, both external and internal, which can be relied on continuously; wide-ranging and consistent intellectual capital of company professionals, whose individual initiatives are recognized as important in the development of projects.

The aforementioned findings confirm that the R&D projects under study, with the intention being to demonstrate what usually occurs in an external knowledge absorption process at Embrapa, show strong evidence of the elements that comprise the antecedents category, a fundamental component of the configuration of AC.

Finally, regarding the third category of the configuration of AC, structural facilitators, although they are addressed in different ways in studies of AC – social integration mechanisms (Zahra & George, 2002; Todorova & Durisin, 2007); learning relationships (Lane et al., 2006); combinatory capabilities (Gebauer et al., 2012); intellectual capital (Cassol et al., 2016), they show a reasonable convergence with regard to their origin. In other words, they stem from the structural and institutional conditions of each organization and the sector in which they operate, such as the nature of the business, culture, politics, strategy and power relationships. Considering that these elements mobilize and modify the four dimensions of AC (acquisition, assimilation, transformation, and application), and, thus the effective absorption of external knowledge, they can be considered structural facilitators of AC. Evidently, these elements can have a positive or negative effect, i.e., facilitate or hinder the exploitation of external knowledge.

In the case of Embrapa, as a public company whose scientific and technological production does not have a competitive purpose, this reinforces the adoption of R&D strategies sustained in national and international alliances and partnerships, involving a wide range of actors, ranging from private multinational companies to graduate programs and research institutions. This situation enables access to a large number of sources of information and external knowledge, and, according to reports, this resource has been frequently used by the company. The condition of public company is a highly important facilitating factor with regard to its openness to national and international partnerships and its capacity to exploit external knowledge.

Another facilitating factor of structural origin stems from the organizational culture of valuing the experience and knowledge appropriated by the company's professionals. In addition to stimulating the continuous qualification and development of its researchers and technicians, the company has systematized and organized the knowledge and results of its projects. In this respect, it is necessary to highlight the knowledge accumulated and made

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available through Agropensa or Ideare, or, as a resource, through networks, the ILPF.

The company's management strategy also makes important contributions: first, in the policy of participation and horizontalization of research decisions; and second, by encouraging the sharing of information among the company's areas and professionals. The combination of these two policies appears to mobilize researchers to assume more responsibilities on the progress and outcomes of projects.

Evidently, the same characteristics that determine conditions that facilitate can also lead to difficulties. This is the case of Embrapa as a public company, involving such factors as budgetary constraints.

In any case, in the analysis, it was observed that the structural facilitators have resulted in more positive contributions to the exploitation of external knowledge than difficulties.

At the end of this analysis are the considerations regarding the elements that comprise the antecedents category. They were found, at the time of the field research, to be consistent and capable of handling different situations of external knowledge appropriation. As for the central dynamic of AC category, an examination of the role of the dimensions of acquisition, assimilation, transformation and application, and their respective processes and routines that define the quality of the processes of exploiting external knowledge in the company revealed intensity, flexibility and recursion. This was mainly evidenced by the dynamism of these processes and the successful emergence of new cycles of external knowledge acquisition during all the phases of the projects in question. Finally, it is necessary to reaffirm the positive contribution of the elements that constitute the structural facilitator category in the exploitation of external knowledge.

Thus, the evidence related to each of the three categories that constitute the configuration of AC within the R&D projects in question makes it possible to consider the strong possibility that the company in which these projects were conducted has a consolidated and consistent absorption capacity for external knowledge.

5. FINAL CONSIDERATIONS

This study indicates that new knowledge is constantly acquired, assimilated and transformed during the implementation of R&D projects, demonstrating the interactive nature of this phase, in which projects can be adjusted and adapted. As the routines and processes of acquisition, assimilation,

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transformation and exploitation were systematized and interrelated with the stages of the life cycle of the R&D projects, resulting in active and recursive absorption of knowledge and the generation of agricultural innovations, Embrapa achieved a successful consolidation with regard to the systematization and adaptation of AC processes.

By addressing organizational processes related to the absorption of knowledge into R&D projects, this study contributes to the advance of scientific knowledge in response to the call from Lane et al. (2006), especially by providing a deeper understanding of these processes in strategic intra- and interorganizational alliances. Thus, the study also complements the works of Volberda et al. (2010), providing a better understanding of: 1. how AC processes occur in R&D projects established through strategic alliances, both intra-organizational and inter-organizational; 2. how AC is systematized and how the contribution of each of its dimensions occurs in the phases of the life cycle of projects; and 3. how R&D alliances can spur the AC of the projects under study, generating knowledge, and the registration of cultivars and products.

In short, the main contribution of the study was that it gauged the presence, in a public research company, of routines and processes similar to those observed in the configurations of AC analyzed in the literature and confirmed the consolidation of routines and processes of knowledge absorption at the intra- and interorganizational levels.

Regarding its practical contributions, this study can provide orientation for managers of R&D institutions in the agricultural sector (other Embrapa units, state research institutions etc.) and diverse fields, as it contains important considerations on the development of AC in research institutions, such as: promoting the formation of strategic alliances to seek knowledge and create the potential for AC; stimulating the training of technical staff; encouraging contact with clients as a source of knowledge acquisition; promoting a favorable environment for sharing information; autonomy in the execution of R&D; use of reward systems; and seeking the scalability of AC through the formation of alliances with leading R&D companies with experience in knowledge acquisition. The development of routines for acquisition, assimilation transformation and exploitation of knowledge consolidates AC processes, which can result in numerous advantages for institutions.

However, this study has some limitations, as the evidence of AC that was analyzed was obtained only from the projects studied and conducted by Embrapa units: imidazolinone tolerant soybean cultivars – project A; co-inoculation – project B; and carbon-neutral meat – project C, through

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interviews, non-participant observation and the analysis of secondary documents, and the contributions of the study cannot be generalized.

The study of scalable AC and the data collection from the partners could promote interest in future studies and reveal new and important clarifications, such as the partner's perception of scalable AC, how scalable AC contributes to the maturity of organizational AC, whether the formation of alliances initially means interest in this scalability and how scalable AC contributes to the partner's innovative performance. Furthermore, it is necessary to study market knowledge that stems from inter-organizational alliances more deeply to investigate a possible differentiation between public and private partners.

Future studies could also investigate the scalability of AC in partners that have developed an R&D project through the formation of strategic alliances with Embrapa and, at a broader level, validate the proposed scalability model through a quantitative study. Research of external partners could reveal whether academic institutions, such as universities, which have initiatives of entrepreneurship and innovation, are also capable of developing AC and market expertise, or whether this is unique to research institutes and companies. Finally, this study, due to the importance of its theme and the points raised, could help to motivate numerous other studies that could contribute further still to theoretical advances and the practical purposes of understanding and using AC.

ANÁLISE DAS CONDIÇÕES DA CAPACIDADE ABSORTIVA COM BASE EM PROJETOS DE P&D

RESUMO

Objetivo: Adotaram-se, neste estudo, a noção de capacidade absortiva (CA) e suas configurações como referência, com o objetivo geral de compreender o estágio de desenvolvimento dos processos e das rotinas de aquisição, transformação e aplicação do conhecimento, considerando o contexto de uma empresa pública de pesquisa.

Originalidade/valor: Um dos fatores mobilizadores do setor agropecuário no Brasil tem sido a geração de novos produtos e processos. Nesse movimento, a Empresa Brasileira de Pesquisa Agropecuária (Embrapa) tem assumido um papel de protagonista, especialmente na absorção,

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internalização e geração de conhecimentos e inovações agropecuárias, envolvendo nesses processos suas unidades descentralizadas e parceiros científicos e tecnológicos, por meio de projetos de pesquisa e desenvolvimento (P&D). Identificar e sistematizar as formas e configurações mais efetivas nos processos e nas rotinas associados à dinâmica de apropriação de conhecimento, em um ambiente diverso e dinâmico como o da Embrapa, são ações desafiadoras para os estudiosos do tema. Contudo, estudos recentes têm destacado a difusão crescente do debate acerca do construto CA.

Design/metodologia/abordagem: Com esse intuito, foi realizado um estudo de caso que considera a Embrapa e três projetos de P&D, os quais apresentam evidências de alianças intraorganizacionais e interorganizacionais, bem como importantes inovações como resultado.

Resultados: A principal contribuição foi verificar a presença, em empresa pública de pesquisa, de rotinas e processos semelhantes àqueles observados nas configurações de CA analisados na literatura, além de afirmar a consolidação de rotinas e processos de absorção de conhecimento nos níveis intraorganizacional e interorganizacional.

PALAVRAS-CHAVE

Capacidade absortiva. Projetos de P&D. Alianças intraorganizacionais e interorganizacionais. Inovações agropecuárias. Conhecimento.

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