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Redesigning the Production of the Bacillus thuringiensis Bio-Pesticide within the Context of Subsistence Agriculture in Andhra Pradesh, India

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Abstract: Biotechnologies are social constructions. The way in which biotechnology is designed, developed and deployed depends on the actors involved in these processes and the strategies and choices employed by these actors. This article assesses the re-designing process of the production of a biopesticide based on the extracts of the soil bacterium Bacillus thuringiensis (Bt) by local networks. The new Bt product attempts to address the Castor-Semilooper management problems of resource poor farmers in the rain-fed agriculture systems of Mahaboobnagar and Nalgonda in the state of Andhra Pradesh, India. It is argued that the development of biotechnologies in a local self-organized environment and the incorporation of certain social issues in the new products could lead to technologies attuned to the local potentialities and constrains. During the redesigning process the new Bt product has acquired a new material form and political social content.

Keywords : *Bt Bio-Pesticide, sociology, Subsistance Agriculture, Andhra Pradesh*

Introduction

Next to the efforts of private and public institutions to relate the development of biotechnologies[1] to the narrow framework of an increased industrialization of agriculture, there are also initiatives of

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multi-stakeholder networks to tailor biotechnologies to local sustainable developments.[2] Both types of initiatives are characterised by making different technological choices to manage biotic stresses, resulting in different techniques of pest management.

This article assesses the ongoing experience of the Andhra Pradesh Netherlands Biotechnology Programme (APNLBP)[3] to redesign the production of biopesticides[4] based on extracts of the soil bacterium *Bacillus thuringiensis* (Bt) in order to strengthen the development perspectives of small scale agrarian systems in the dry-land districts of Mahaboobnagar and Nalgonda of Andhra Pradesh, India. The new Bt product is applied to control the Semilooper (*Achea janata*) pest on the Castor crop. Therefore, by relating the technology's development to the context of the village economy it is claimed that a significantly different Bt bio-pesticide is emerging which is unlike the Bt-resistant plants and sprays delivered by multinationals. The Bt product is characterised by the following two core elements.

First, the techniques are designed to facilitate an organization of the Bt production process based on primarily (though not exclusively) *locally available resources*, such as local (informal and formal) knowledge, local strains of Bt effective against the local pests, and local labour-force.

Second, the *political control* over the development of the Bt technology has been reorganised towards an increased involvement of multi-stakeholders platforms in the design, production and deployment of the new Bt product. Consequently, it will be shown that the bottom-up technological development together with the conquered space for negotiations by farmers and civil society organisations on the design of the Bt product are reinforcing each other in such a way that the biopolitical dimensions of the Bt product are reshaping the social agrarian landscape of Andhra Pradesh.

By reflecting on the design, development and deployment of the Bt bio-pesticide, this article attempts to illustrate how the development of biotechnologies in a concrete self-organising social environment and by incorporation of certain social issues in the technological developments, could lead to new products which could address the needs of resource poor farmers. Furthermore, it is the intention of the paper to add empirical data to the debate in the social sciences about the possibilities to reorient the developments of biotechnologies from an exogenous development dominated by large agro-industrial corporations to a process in which specific social issues can be introduced in the design of new biotechnologies and products.

The article is structured in four sections; following this introductory paragraph, the second section addresses the social relevance of Bt-products both for large-scale and small-scale farming systems in Andhra Pradesh, India. The third section tackles the reorganization of the local available resources for the production of the Bt product. The fourth section deals with the political issues raised by the redesigning process. Therefore, the article argues how the design, development, and deployment of the Bt bio-pesticide related to the developmental perspectives of village economies have also changed the Bt product itself giving it a new material form and social content. Finally, the philosophical and political implications of this new approach for biotechnological developments within the field of science and technology studies are discussed in the last section.

Social Relevance of the Production and Use of *Bacillus thuringiensis* for Indian Agriculture

The big majority (70 per cent) among the thousand million inhabitants of India live in the countryside. Approximately 35.6 per cent (390 million) of the population must survive with less than a dollar a day.[5] This research was conducted in Andhra Pradesh (AP) which is India's fifth largest state by population and fourth largest state by area. AP can be broadly divided into three regions, namely Costa (Coastal Andhra), Telanga (west on the Deccan plateau) and Rayalaseema (southeast on the Deccan Plateau).

More specifically, the study was conducted in the Mahaboobnagar district, the largest district in the Telangana Region and the second largest in AP, as well as in the Nalgonda district. The rural population in these districts forms 90 per cent and 87 per cent respectively of the total population. The districts are located in the semiarid region of India with recurring meteorological drought and worsened by overexploitation of meagre groundwater resources.

Many problems affect the life and work of small scale farmers in those areas, like drought, low yields, or pests. Agriculture in the area is rain-fed and the districts are plagued by extreme poverty. The main crops cultivated in the districts are castor, red gram, sorghum and groundnut. Of these crops, Castor[6] is the most important one, occupying 27 per cent of the cultivated area in Mahaboobnagar and 20 per cent in Nalgonda. Furthermore, many insect pests constrain the cultivation of this crop in these dry regions. One of the most important is the Semilooper (*Achea janata*) that causes heavy losses of up to 20 per cent of the total yield.[7]

In fact, pest management is a complicated activity in this context because most commercial products are not affordable by small-scale farmers and moreover these are not trustworthy dealers.[8] In addition, the toxicity of the available chemical pesticides causes health problems to farmers. Farmers are often unable to read the pesticide's instruction labels (either because they cannot read or do not understand the language on the labels) and they don't have the necessary means for protection, like masks. Moreover, the massive use of pesticides has degraded the fertility of the soils and caused problems for non target organisms.[9]

AP is one of the major consumers of agro chemicals in the country.[10] However, there has been a significant decline in pesticide consumption during the past decade. The level of pesticides consumption in the State during 2003-2004 was expected to be around the 3.600 tonnes in contrast to the 13,650 tones used in 1992-93. The officials of the State Agricultural Department attribute this decrease to the adoption of integrated pest management practices and growing awareness among farmers of the risks attached to agro chemicals.[11]

In addition to chemicals[12], many other methodologies are used to manage the castor semilooper. For instance, hand picking and killing of older larvae of semilooper is an effective method practiced by some castor growers. Moreover, some efforts were made to control the pest by releasing parasitoids eggs (*Trichogramma chilonis*, *Telenomus proditor*). However, this practice has not gained popularity among farmers because of the complex set of requirements for an appropriate use.[13] Other biological controls effective against semilooper are the neem seed extracts and many other neem formulations. Finally, the bacterium *Bacilus thuringiensis* has been found effective against semilooper.[14] This article focuses on the development of one biopesticide spray formulated on the basis of Bt, to control the castor semilooper.

The *Bacillus thuringiensis* as a Bio-Pesticide Alternative

Bacillus thuringiensis (Bt) is a soil bacterium. The insect pathogenic activity of Bt is a natural process occurring in the daily organic life of farmers' fields. Bt has toxic effects against certain insects (of Lepidoptera, Coleopteran and Dipteral families). However, Bt is considered to be safe to humans and other mammals.[15] Also, it is highly specific and therefore safe for non targeted insects.[16] Furthermore, Bt could be the beginning of a long series of new and expected safer technologies to augment productivity and to bring about a more sustainable agriculture. Within Bt alone, there are already over 50 genes with known insecticidal properties.[17] It is the only microbe which has been successfully commercially exploited for the management of insect pests. Therefore, Bt products form 95 per cent of the world market of microbial pest control agents.[18] Since the discovery of the mechanisms of its toxicity (in the fifties), Bt based formulas have been used as an effective bio-pesticide in agriculture.[19]

Three main technological trajectories have been followed for the production of Bt based products:

- Recombinant DNA techniques
- Biopesticide Bt-spray (liquid state fermentation)
- Biopesticide Bt-spray (solid state fermentation)

Recently, researchers have transferred certain genes from Bt to some plants, in order to create crops that produce their own insect toxins.[20] However, the development of this technology has provoked a fierce pro-contra debate. In spite of the great expectations of some researchers, the sceptics expect that insects could develop resistance to the massive use of Bt, especially when it is genetically transferred.[21] In addition, a cross-pollination between biotech and non-biotech crops may occur.

Many critics are based on the fact that the life-science corporations (joint business of agro-chemical and biotech companies) heavily control the commercialization of Bt.[22] Fifty-seven percent of all Bt patents have been issued to only eight companies (Monsanto, Novartis, AgrEvo[23] and Mycogen with their own technologies, and DeKalb Genetics Corporation and Pioneer Hi-Bred International through strategic alliances).

In India, some Bt transgenic crops are grown, but because of their high prices, most of the time, resource poor farmers are excluded from their use.[24] For instance, the use of Bt-cotton seeds implies increasing investment in terms of purchasing seeds, fertilisers and pesticides. Farmers frequently need to take loans to be able to afford such costly inputs, but in the case of disappointing harvests or crop failures, these farmers are left with high debts, as the high interest rates are very difficult to repay.[25] Moreover, so far most efforts have been oriented to develop crops of major agrarian and commercial importance, bypassing minor crops like Castor.[26]

In addition to the DNA recombinant trajectory, there are two major methodologies to manufacture the Bt bacteria in a bio-pesticide: solid state fermentation and submerged (liquid state) formulations.[27] Formulation is a crucial link between production and application and dictates the efficiency[28] and economic viability of the final product. Moreover, the maximal production of Bt's toxin[29] can be achieved only by paying careful attention to the interaction between fermentation conditions, media and the Bt isolates involved.[30] Furthermore, the sustainability of the production process is related to:

- cost of raw materials
- strain efficiency
- degree of automation required
- continuous power supply
- required degree of technical skills.[31]

The cost of raw materials is one of the principal expenses involved in overall Bt production. In the conventional (industrial-liquid state) production process, the cost of raw materials varied between 30 and 40 per cent of the total cost depending on the plant production capacity.[32] Therefore, local production of this insecticide in resource poor rural areas should depend on the use of production media made of cheap, locally available resources.

Although the efficiency of the commercial formulations has been proved (for the agrarian contexts with the required economic capacities), the submerged fermentation may not be economically feasible for resource poor rural areas due to the related high costs of technicians and automation (deep-tank fermentor, high speed cooling centrifuge as well as drying facilities e.g. spray dryer.[33]

In India, Bt bio-pesticides have been produced by the liquid state fermentation. The companies involved in this method to manufacture biopesticides were importing the technical materials and producing the Bt in India.[34]

This commercial strategy has not succeeded in developing suitable technologies for small scale agriculture because it requires:

- high capital investment
- high level of automation
- high technical skills
- continuous power supply[35]

That is why solid state fermentation emerges as a feasible methodology for those regions of the world that lack human and economic capacities to reproduce the liquid state fermentation. Advances of the solid state fermentation are:

- low cost of the methodology
- low capital investment
- low level of automation
- low technical skills
- low amount of wastewater.[36]

Solid state fermentation is a critical methodology for the production of efficient locally oriented bio-pesticides in developing countries; nevertheless, little has been published on the subject.[37]

In summarising this, within the narrow context of an industrialising agriculture, no suitable pest-management technique has been developed attuned to the potentialities and constrains of resource poor farmers in the dry agriculture of these regions. This article focuses on the dynamics engaged in by local networks to redesign the production of a Bt biopesticide from a liquid state fermentation to a solid state fermentation for the management of the Castor-Semilooper. This article attempts to gain in understanding the social construction of technology and of the technological construction of society.

Bt-Spray's Redesigning Process

The Reorganization and Mobilization of Natural and Human Resources available within the Locality

In this section we will follow the Bt chain, from the isolation of the bacteria in farmer's fields, to the lab, and from there to the production units and back to the fields where the product is used. Therefore, we witness how the formal and informal knowledge of the local labour forces (from researchers to farmers) jointly reorganise the use of the available natural resources (like Bt strains) to develop appropriate biotechnologies for the local circumstances. Finally, the section addresses the main bottlenecks for those purposes.

The APNLBP network coordinates the Bt biopesticide redesigning experience. Commonly, APNLBP organises its different projects[38] as follows; first, they define the problems that have priority for resource poor farmers and could be addressed through biotechnologies. Second, the programme looks for different social agents with the skills required to develop the biotechnological choice.

Naturally, the Castor-semilooper emerged as one of the major problems for farmers in Mahaboobnagar and Nalgonda. Therefore, researchers, NGO's and farmers met and exchanged their agrarian knowledge about the management of Castor-semilooper. The available pest-management techniques were discussed. Farmers formulated the problems caused by the semilooper and the inappropriateness of, and problems caused by the commercial formulas. During those discussions the search for a cost-effective redesign of Bt-spray was decided.[39]

Moreover, isolation of the local Bt strains was decided upon, rather than the use of commercially available formulas, for two main reasons. First, in India, in order to promote Bt for pest management, the final product requires to be registered by the Central Insecticides Board (CIB). Their guidelines permit only the registration of formulations which employ local isolates. Second, local isolates seem to have a better capacity to withstand the environmental stresses in the field and can persist longer. In order to isolate these local strains, researchers of the Directorate of Oilseeds Research (DOR) and farmers collected samples of soil and dead larvae of Castor-semilooper in farmers' fields.

Afterwards, the local isolates of Bt were analysed by the microbiologist of the DOR in Hyderabad. In India, a molecular analysis is required when a large use of the pest-management product is expected. Moreover, genomic DNA from the samples was analysed (using the Polymerase Chain Reaction with three sets of primers *viz*. ERIC, BOX and REP) to identify which species and subspecies of Bt were present in the isolates and what cry genes were there (cry gene profiling). Furthermore, a total of 120 local isolates where used for further analysis. They were compared with the commercial isolates (Delfin from Margo Biocontrol Pvt. Ltd., Dipel from M/s Cheminova, and Halt form Wockhardt Ltd.) and with five strains purchased from the Ohio State University (USA) to evaluate their efficiency against the semilooper.[40]

After that, several bioassays in the lab were performed, followed by various tests in farmers' fields (in collaboration with farmers). Two local strains were found to be very effective in controlling semilooper under field conditions. DOR-1[41] was chosen for further mass multiplication.

Mobilization of the Local Labour Force

Throughout the field trials, scientists shared their knowledge with farmers. Both groups gained further understanding about the management of the pest by Bt under field conditions. At the moment, farmers are able to decide the best moment to spray. Moreover, in the fields where farmers managed the semilooper with chemical pesticides like quinalphos, four or five sprays of the insecticide had to be applied while the pest could be managed in Bt sprayed fields with only two sprays. This is because the natural enemies like *M. maculipennis*, *Euplectrus maternae*, and several others leading to natural pest suppression of the pest in the later stages survived the Bt-spray.[42] Furthermore, farmers are able to detect if the deceased semilooper larva died because of the Bt spray.[43] As far as they are concerned, scientists recognise the crucial element of involving farmers at all the stages of biotechnology development, allowing them to understand the nuts and bolts of the technology. Also, as some of them declare, to "easily get the acceptance of the technology by farmers and therefore, avoid the possible rejection of the technology in some of its latest stages". However, in this article the collaboration between the different kinds of knowledge is perceived not as a means to get acceptance of the technology but as an end in itself. Therefore, at this stage we are confronted with an issue of a moral nature. Allow me to restructure as a question what was originally a statement of Richard Sclove (1995): "is it a kind of moral right or a matter of justice, that people should be able to influence the basic social circumstances of their lives?" If our answer is affirmative, this view may imply for instance, that farmers should get access to decision making in biotechnology along relatively egalitarian and participatory lines.[44] It is not only morally appropriate but it could also be more efficient. Therefore, because of the rural dispersion of villages, a decentralised system of small scale biotechnology units seems a good option for farmers to exercise local control over and get access to the negotiations around the development of pest management techniques. Consequently, it is possible to gain efficiency, for instance, in the supply of the final product.

The mass production of Bt spores was redesigned by developing an alternative to the conventional liquid state fermentation. This alternative implied the multiplication of Bt by its fermentation in a solid medium in which *local agricultural wastes/by products were used,* such as wheat bran and molasses. Since magnesium, manganese, iron, zinc and calcium ions are present abundantly in wheat bran, the need to supplement these ingredients in the medium has been overcome, reducing (a small share of) the costs. Moreover, it has been decided not to invest in costly fermentors, but to use *plastic basins* in which the multiplication of the Bt-isolates takes place and in which the wheat husks are used as a medium for Bt-multiplication. Multiplication in plastic tubs brings the cost of production further down because of the low costs of plastic tubs as well as their re-usable nature when compared to the use of glassware. The latter is costly as well as easily subjected to fracture.[45] Because the inoculations are carried out separately in different plastic basins, mistakes would only lead to the loss of a small amount of the inoculated medium in some of these plastic basins. In this production process risks are spread out over more units, whilst within the submerged fermentation process a falling out of electricity power may completely destroy the inoculated medium.[46]

In addition to the use of local agricultural wastes and plastic basins a third innovation of the Bt networks is that the inoculated medium within the plastic basins can be kept in a room for around 65 hours and be carried out at the villages level. Aeration is provided every eight hours after the second day in a laminar air-flow cabinet or in a chamber where the desired conditions of a laminar air-flow are simulated. This aeration system also implies that the production can be *decentralized* and carried out in biotech units at the village level. The downstream processing for obtaining the final product is carried out through *centrifugation* in which the medium is filtered with distilled water. The supernatant containing the beta exotoxin is discarded. The pellet containing the spores and crystals of Bt is mixed with the carrier, *shade dried and powdered* with a kitchen coffee mill. The final Bt product *is mixed with water* by the farmers in the fields and *sprayed* on the Castor.

Due to the low skills required for the Bt-spray production and to cover the growing demand of the non toxic and effective product by local farmers, the NGO's (SDDPA and GMM) involved in the project have assumed the responsibility to produce the spray, at an affordable price, in mass multiplication centres in different villages spread over the region. These centres are assisted by scientists of the APNLBP's partner research institutes. The units seem to be able to guaranty the product supply at farm level. Young local biotech technicians are working on these centres; most of them are sons and daughters of local farmers.

To develop biotechnologies in tune with the natural and social environment, the APNLBP tries to mobilise the available resources and therefore the existing biotechnologies. Both the high and low-technologies are separately used in some projects (like vermiculture or recombinant DNA) and mixed in others. For instance, for the redesign of the Bt-spray, the latest genomics techniques (e.g. sequencing of the genome of BT DOR-1) have been assembled with a traditional solid state fermentation. By doing so the programme has won the confidence of farmer communities because of the tangible and quick results provided by the low-tech biotechnologies.[47]

Finally, the large-scale field trials of DOR Bt-1 formulation in Mahaboobnagar and Nalgonda districts have shown that the pest can be managed with two sprays at 15 day intervals. The pest-management's costs have been reduced threefold when compared to the chemical insecticide. The final Bt product *is mixed with water* by the farmers in the fields and *sprayed* on Castor. Around 100-150 l of spray suspension is required per acre for the management of Castor semilooper depending on the stage of the crop. The material cost for production of one kg Bt would be Rs. 32[48] (about 1 Euro).[49]

Bottlenecks for Sustainability

Although the intention of this article is to understand the social and technical changes that occurred during the efforts made by the local Bt networks to develop a new biopesticide appropriate to the local conditions, it is also recognised that redesigning is still an ongoing process in the tryout phase. Therefore, some bottlenecks may that threaten the sustainability of the biopesticide's redesigning process have been identified.

In my view, the collaboration efforts and new partnerships between the pluriform set of actors involved in the redesign process should be a long-term route; first because of the obvious benefits of inclusive dynamics for poverty alleviation. Second, it seems important to make an assessment of the performance of the Bt-spray over a period of time; for instance to avoid the emergence of possible resistances of the Castor-semilooper to the DOR Bt-1. Third, once the Bt production is fully assumed by the local NGOs, some technical problems may appear that will need the support of scientist from the DOR in Hyderabad. Finally, it is important to monitor possible future health problems which are unexpected though at this stage still might emerge from a massive use of bio-pesticide in those two districts.

In order to guaranttee the long-term stability of this decentralised production, collaboration between local producers and scientists is vital. However, this long-term collaboration of the network can be jeopardised by the lack of reflection (and motivation) of the individual human actors belonging to the Bt-spray network. For instance, some scientists do not feel as if they belong to a network beyond their research institute. For them the Bt spray is “one more of their projects” which requires a ‘peculiar’ methodology with more visits to the field than usual. Similarly, most of the NGO staff members working at the multiplication centres seem to develop a routine laboratory labour to earn their wages.[50]

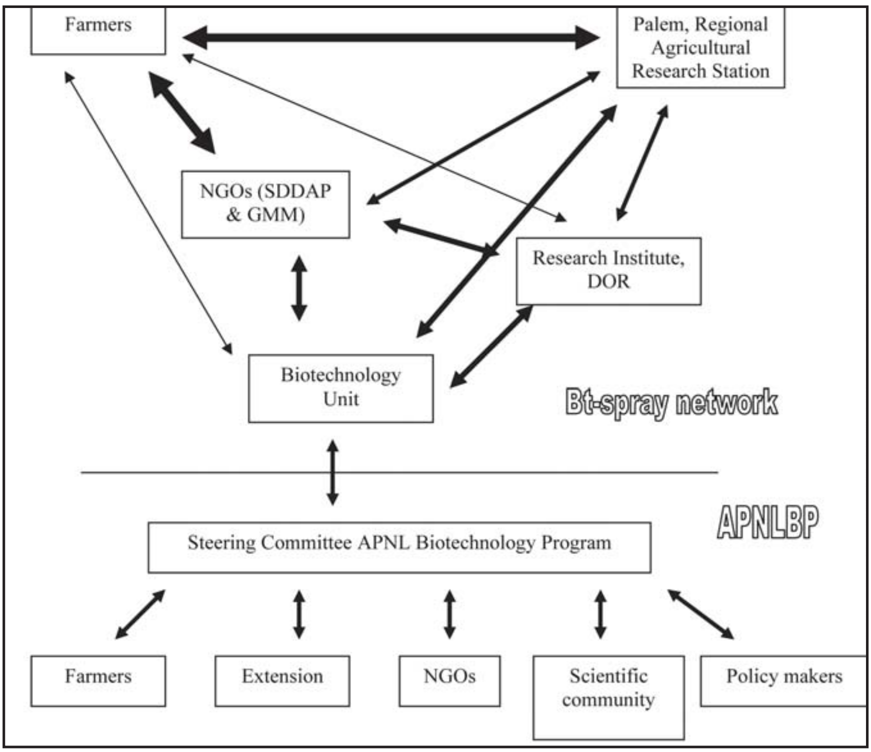
Another bottleneck in relation to the available human resources is the difficulty in finding (young) researchers to occupy positions in the isolated rural areas. Unfortunately, this brain drain, from villages to cities and form India to other countries, is taking place at all levels of Indian society.[51]

In this section we have analysed how by a reorganization and mobilization of the local human and natural available resources, the new Bt bio-pesticide has been redesigned and has emerged as highly effective, non-toxic and affordable for farmers. Furthermore, the redesign process has been possible as a result of the control exercised by the multi-stakeholder network in the process. The next paragraph attempts to understand the politics of that process.

The Self-Management on the Bt-Spray Redesigning Process- A Try Out

To understand the APNLBP programme we should realize that the Dutch Ministry of Foreign Affaires (financial institution of the APNLBP), from the very beginning, decided to delegate the responsibility of the management of the projects to a local steering committee (Fig. 1). The Biotechnology Unit (BTU) is an autonomous body inside the institutional public scientific agrarian research system, and it is led by a multidisciplinary team. The task of this unit is to coordinate and monitor more than 60 projects which are developed in the APNLBP. The decisions of the BTU, based on scientific analysis, are in principle recommendations that have to be validated by the steering committee which has a more holistic view over the regional reality because of the plurality of its members.

One of the interesting features of the APNLBP is that it follows an Interactive Bottom Up (IBU) approach.[52] The aim is to formulate all the projects and programmes on the basis of local needs assessment and priority setting. Consequently, in the first stage of the programme's projects workshops are organised in which farmers, researchers, governmental and non-governmental organizations are involved. This should lead to a decision making about the most appropriate biotechnological path for the local context, to be followed. Moreover, one of the important elements of these workshops is the presence of NGOs. The NGOs involved in the project mobilize the local labour force (farmers or technicians) and integrate and stimulate the use of local resources. In the same way, research institutes involved get experience to work with local resources; like crops and their pests.



Note: The thickness of the arrows indicates the intensity of the relation. The arrowheads indicate the direction of the relation.[53] Acronyms: APNLBP- Andhra Pradesh, Netherlands Biotechnology Programme. DOR - Directorate of Oilseeds Research; SDDAP- Society for Development of Drought Prone Area; and GMM - Grameena Mahila Mandali.

These workshops were also the starting phase of the development of the new Bt product. Therefore, once the problem was identified (Castor-semilooper) and the biotechnological choice defined (Bt-spray), an apparent regular interaction has taken place between the farming community and the scientists while developing the technology. As a result, an opening is created for civil society organizations and farmers to get some control (larger or shorter) over the development process of biotechnology. The engagement of the network on participation dynamics unlocks the opportunity to integrate farmers' knowledge and experience in the development of new biotechnologies. Nevertheless, there are moments during the development of the Bt-spray when the presence of a certain kind of actor is crucial, and where the decision making capacity of other actors is rather small (as it is the case during the characterization process of isolates by molecular biologist).

Moreover, these dynamics open not only the possibility for larger sectors of the population to plan and organize the development of biotechnology, but it also offers some control for farmers and civil society organizations on the deployment strategies. The deployment of the Bt biopesticide takes place in the rural areas. In this way, the *benefits and responsibilities coming out of the Bt redesign process can be regionally redistributed*.

Consequently, micro-enterprises have been created in some villages for the production of the final Bt powder. Those units are run by the local NGOs and technically supported by the research institutes. It is also important to notice that those micro-enterprises are not only producing Bt. In their labs other bio-pesticides (like trichoderma or baculovirus) are also developed. In some cases these labs are integrated in what is called a bio-resource centre, with the facilities to manufacture other kind of bio-pesticides and fertilisers like vermiculture or Neem tree products. Furthermore, the programme has the intention to promote these decentralised bio-resource centres as (economical and organizational) autonomous units.

These bio-resource centres seem to have some potential to become a catalyst for local agrarian development. In these centres the heterogeneous set of social agents (researchers, farmers and NGOs) converges to coordinate the production of the new bio-pesticide. In fact, the bio-resource centres are situated at the village level; this facilitates the access of farmers to information about the product (use, risk or quality) and it offers them a certain control over the units.[54] However, future studies about these experiences will address to what extent the control exercised by the farmers can be defined as significant and how far the new emerging biotech elites, in the social form of NGOs, are more effective to address the problems of resource poor farmers than the research stations (situated at the farm level)until now.

Public and Private Sector Engagement in Local Biotech Programmes in India

This section addresses the local biotechnology redesigning processes viewed against the background of the broad Indian national biotechnology developments. The aim here is to develop a further understanding of the significance of the political reorganization around the production of the Bt-spray.

India has a very strong *public-sector* concerning agrarian science and research infrastructure; however, it seems that this system is organised around a centralised model of technology development and transfer that could jeopardise its usefulness for resource poor farmers. Some important elements of this situation are, for instance, the strong hierarchies and separation between research, extension and farmers. It has been described as a 'hard science' approach which gives less importance to sociological matters, and which tends to perpetuate the hierarchy of science and society and the patterns of control that this implies.[55] However, the work of the described Bt-network here is unthinkable without the structures and persons working in the Indian public sector (see Fig. 1). In fact, two good examples of this public presence in the project are the Biotechnology Unit in Hyderabad, which coordinates the project and the research institute called Directorate of Oilseeds Research (DOR) that has done the molecular analysis and developed the novel Bt multiplication methodology.

Next to the extensive public sector, the *biotech private sector* grows rapidly in the country.[56] Moreover, there are special biotech-plans for the different states which promise fiscal and infrastructure support measures to prospective entrepreneurs. In the concrete case of AP this has lead to creation of the Genomics Valley in Hyderabad (mainly pharmaco-genomics oriented) where private companies have the leading role. These companies are first and foremost focusing on markets to reimburse their expensive investments in R&D. Therefore, they have little incentives to develop products for resource-poor farmers since farmers lack the economic capacities to pay the product's high prices. The high prices are required to recover those investments.[57]

Other scientists who have analyzed the APNLBP network[58] have mentioned the absence of the private sector in the programme. This absence is understandable, in the initial phases of the programme, not only because of the absence of private companies in those rural regions, but also because (as mentioned before) resource poor farmers lack the economic attractiveness which is necessary to become a target group for the private sector. However, some traces of private sector participation do emerge in phases close to concrete moments in the development of some products. For instance, due to the lack of genome sequencing infrastructures in the public research institutes and universities involved in the Bt-spray project, and because the compulsory official registration of the product, the services of some private companies[59] are required to map the genome of the most powerful Bt isolate found against the castor-semilooper.

Going deeper into the Indian landscape; poverty is concentrated in the rural areas that, according to the World Bank,[60] are the home for three quarters of India's poor. This situation is also true for the state of Andhra Pradesh, where due to the bad public sector performance in those rural areas, a breeding ground is created for the growth of radical movements like Maoists guerrillas and the multiplication of NGOs that are filling the space that the government is not able to cover. Moreover, developmental NGOs and intermediary research provide a critical link between farmers and scientists in initiating decentralised participatory plant breeding or other biotechnological developments at "left behind" locations.[61] These *civil society organizations* are essential to open the *room for manoeuvre* for a wider sector of the population in the development of (bio) technologies. This is because of the high degree of collaboration between NGOs and farmers. During the development of the Bt-spray the high level of trust between farmers and the NGOs involved in the project has been decisive; this is because the design phase of the pest-management techniques is a long-term process, and the return from the labour investments is uncertain.

The Politics of the Bt-Spray

We have witnessed the efforts of the Bt-spray networks to manage the political reorganization of the natural and human resources to develop an appropriate pest-management technique in the rural context of

Andhra Pradesh. Herewith, the traditional top-down Indian model of biotechnology developments[62] has been reversed in a way into a kind of bottom up approach where the whole set of actors is, to some extend, involved in the different phases of the Bt-spray's development.[63]

The redesign and reorganization of the production of the Bt-spray takes place within the global context of industrialisation of agriculture. As we have seen before (Section 2), this historical context has not been able to develop suitable pest-management alternatives for resource poor farmers in these regions. Moreover, some philosophers have analysed how the political and politicising elements involved in the development of biotechnologies within this global industrialization process are creating new identities by shaping the social context in which the techniques are implemented.[64]

The industrialization process of agriculture has been possible by the deployment of the next three political characteristics and politicising consequences:

- The *industrial appropriation* of some key farming activities, like crop and pest management by external institutions through the supply of industrial inputs.[65]
- The *scientification* of agricultural research has taken place. Subsequently, it has produced an increasing prescription of farming practices from the scientific domain.[66]
- With the biotechnologization of agriculture a *remote control*[67] (control at a distance) on different farmers activities has emerged.[68]

These three developments are challenged by the strategies of local self-organization in the production of the new Bt-spray. For instance, the *industrial appropriation* of farming activities by external institutions is reversed by the self-organized practices of local networks to create their own pest-management technique; by isolate, select and multiply Bt within the locality.

The *scientification* of agricultural research is challenged by the creation of horizontal structures of multi-stakeholders where the interests and problems of resource poor farmers are included and central to the R&D agenda. In addiction, the scientification is challenged by the relative low technical requirements to produce the Bt spray. Finally, the *remote control* is broken by the dynamics and new partnerships in which scientists, farmers, civil society organizations and villagers communicate with each other and cooperate in the management of the local available resources.

Therefore, the adaptation of the production of the Bt-spray to the local circumstances not only represents the appearance of a new product, but also the emergence of new social relations. These new social relations are breaking through the (already) traditional dependence of farmers on external institutions.

During the redesigning process of the bio-pesticide, the self-organising dynamics engaged by the network has provoked a shift in the power relations that traditionally are structured around the development of biotechnology products. Therefore, new identities have been adopted by the different actors, like social researchers of the BTU who became key actors by linking scientists, NGOs and farmers during negotiations around biotech developments, or scientists that are forced to abandon their ("ivory tower") labs in town to come closer to the potentials and constrains of rural India. Accordingly, the Bt-product has acquired new politicizing dimensions that push the network to reproduce local appropriate developments. This becomes visible by the further local deployment of the technology across the decentralised mass multiplication centres at the village level. In these centres, again new political roles are assumed. This time in the form of NGOs members who become biotech producers.

Concluding, the Bt-spray is political in the sense that its emergence brings about the appearance of new social dynamics that not only creates material goods but also inclusive relationships and ultimately reorganises social life itself.

Placing the Scope of the Social Relations Shifts in Perspective

Before we go further with the final discussion, two bottlenecks concerning the political control exercised by the biotech network can be mentioned.

David Noble (1977), when discussing the centrality of claims for radical changes about to come with technological transformations, has noted that despite the promises of revolutionary changes, the old order reproduces itself, 'a change without change'.[69] Although these words of Noble are quite pessimistic in general and may deny social change or human agency, they are in a certain way true. As far as our case is concerned, the hierarchic Indian social structure goes on in reproducing itself by supporting the old elites, like scientists (some of them don't feel like belonging to the Bt network, but to the one of their urban institutes) or creating new ones, for instance, the empowered NGOs that can create new clientelist relations with farmers' communities by acquiring the control on the Bt production centres.

Another important issue for the sustainability of the Bt network is the financial support of the APNLBP by the Dutch ministry of foreign affairs. Further studies of this biotech network should be done to find out whether this unique economic financial source and dependence may become a bottleneck for the different projects (and therefore, for the Bt-spray).[70] However, by the local reorganization of the production of the bio-pesticide this economic dependence can be overcome because of the autonomy earned by the Bt network in the form of Bt multiplication centres.

Discussion

Is the APNLBP Bt-spray a new pest-management product? If we just look at the final product the answer will be simply no; it is just a bio-pesticide on the basis of Bt which is sprayed in farmers' fields. But if we analyse the new social code attached to the redesigned product we are able to appreciate the qualitative differences that make the new pest management product indeed a suitable alternative for small scale agriculture in Andhra Pradesh. To reach this position, the techniques are designed to facilitate an organization of the Bt production process based on primarily (though not exclusively) locally available resources. The political management on the Bt technology development has been reorganized towards an increased involvement of multi-stakeholders platforms in the design, production and deployment of the new Bt products. Finally, the benefits and responsibilities have been redistributed within the region where the biotechnology development is taking place. Thereforem, new identities have been and are shaped (like NGOs that became producers of biotech products, or social scientists that get involved in the coordination of biotechnology programmes) that are transforming the traditional Indian structures of biotechnology development.

However, some friction still remains between the present Indian landscape concerning biotechnology development and the moral dimensions of the Bt-spray product. For instance, of the problems and limitations can be perceived is that the largest, but culturally and economically marginalized stratum of the society, the resource poor farmers, have to gain access to the discussions around biotechnology (e.g. knowledge asymmetries, NGOs mediation roles, etc.).

Moreover, the objectives of the Bt-spray project are not only the development of a cost-effective pest-management technique but also rural development. Therefore, from a social science perspective, it could be helpful to understand that between technology and society there is a deeply mutual interaction or a co-construction.[71] In fact, technology is one more of the politic arenas in which society is constructed.[72] Consequently, it is necessary to recognise the rights that larger sectors of the population have to gain control on technological developments that are affecting their daily lives; like farmers on the production of (bio) technologies that for good or bad are shaping rural life. It is not only morally appropriated to incorporate farmers in those developments but it could also be more efficient.

Traditionally, an external control on the development of pest-management techniques has been framed within, what some scholars have called the modernization or industrialization process of agriculture. That was assumed to be unilinear and encouraged farmers to become more integrated in markets and dependent on the use of external inputs, technologies and capital.[73] It promoted a more uniform pattern of farming. As such it resulted in a weakening of the linkages between farming and local ecology[74] and was, therefore, devaluating the informal farmers' knowledge.[75] While the tendency was to look at innovation primarily as a process of 'scientific research', scholars now tend to look at it as a process of 'network building',[76] 'alignment', 'social learning' and 'negotiation.'[77] In addition, as Latour has alleged, scientific research is conducted less and less in autonomous institutions of pure research or vast centralized public facilities, and more and more in collaborative networks which cut across the distinctions between the pure and the applied, the public and the private, the academic and the commercial.

Moreover, the unidimensionality of biotechnology developments has been abandoned and replaced by the notion of co-construction of various technical and social arrangements within a concrete reality. Analysis of the redesigning of our bio-pesticide takes place within this dialogue between the material and social elements. Therefore, since it is accepted that a variety of relevant social groups are involved in the social construction of technologies and that the co-construction process between society and technology continues through all phases of an artefact's life, it makes sense to extend in a timeless continuum the set of groups involved in political deliberation about technological choices.[78] Therefore, it becomes desirable to extend the pluriform participation also to the deployment phase, and to the daily use of the technology to asses its performance. This is the way in which the emerging *bioresource-centres* in the rural landscape of AP may play an interesting role by acting as the catalyst for local development through a politically conscious construction and reconstruction of biotechnologies.

In conclusion, by the local management of the available human and natural resources and the subsequent redistribution of the benefits and responsibilities coming out of the development of the Bt-product, the new bio-pesticide has acquired a politic and politicising character that encourage the reproduction of the social structures, roles and identities organised around it to guaranttee the sustainability of the biotechnological rural developmental process. Future studies on the topic will address whether the exposed biotechnological developments engaged by the local agents gain momentum and whether those dynamics indeed work as a catalyst for local development in Mahaboobnagar and Nalgonda.

Endnotes

1 In this paper, biotechnology is understood as "any technological application that uses biological systems, living products or processes for specific purposes". This is the definition given to biotechnology at the 1992 Rio Convention of Biological Diversity. Quoted in: (Adler 2000: 175). Therefore, in this article biotechnology means both fermentation processes and the last applications of genomics.

2 Some of these experiences are organised around the international Tailor Made BioTechnology Network

3 The Dutch Ministry of Foreign Affairs, across its development-cooperation agency (DEGIS), has launched a special programme on biotechnology to improve the quality of life of resource poor farmers in two predominantly dry land districts , Mahaboobnagar and Nalgonda in Andhra Pradesh (which is one of the federal states of India). The Programme is implemented in the name of "The Andhra Pradesh Netherlands Biotechnology Program for Dryland Agriculture" (APNLBP). The APNLBP use a methodology where the biotech projects are based on local needs assessment and priority setting. The network is formed by farmers, NGOs, policy makers and scientists (see figure 1). Very recently, APNLBP has changed its name to Agri Biotech Foundation (ABF). The Dutch Government has provided the necessary financial support, while the local Agricultural University has provided land to build ABF's own campus (June 2, 2007). The mandate of the

Programme has been expanded to other states of India as well as to other developing countries. For more information see: www.abfindia.org (G. Pakki Reddy – ABF's executive director – personal communication August 6, 2007)

4 The use of bio-pesticides is one of the alternatives employed worldwide for pest management. Bio-pesticides make use of naturally occurring pest killers (fungi, bacteria and nematodes). One of the bio-pesticides with larger use is the soil bacteria Bacillus thuringiensis.

5 www.worldbank.org/in

6 Castor is one of the major oilseed crops of India accounting for 76% of the world exports. Within India, Andhra Pradesh is one of the major castor growing states (0.39 million ha.) with an annual production of 0.13 million tonnes (DOR 2003).

7 Gaikwad & Bilapate (1992); DOR (2005).

8 Unlicensed dealers and retailers sell pesticides without being aware of their toxicity. This uncontrolled marketing has escalated pesticide misuse. In addition, from time to time 'ghost companies' come to the villages to sell pest-management products that vary from out of date pesticides, to just water in pesticide package. Furthermore, banned pesticides like DDT and BHC are still being sold on these regions. This could mean that the actual pesticide consumption is higher than the available official figures (Shetty 2004).

9 Vimala Devi & Rao (2005a).

10 Kolanu & Kumar (2007).

11 Reddy (2003).

12 Among those Monocrotophos 0.05%, quilalphos 0.05%, endosulfan 0.07% and acephate 0.075% are reported to be efficient against the semilooper (DOR 2003; 2005). But they are also reported to be highly toxic for human health and other organisms (Shetty 2004).

13 DOR (2005).

14 Vimala Devi, Prasad et al. (1996).

15 Kough (2003).

16 Vimala Devi, Ravinder et al. (2005).

17 Krattiger (1997).

18 Vimala Devi, Ravinder et al. (2005).

19 Kleinman (2005).

20 In 1995 the US Environmental Protection Agency approved the commercial release of the first transgenic crop containing a pesticide in the form of a Bt-potato to control the Colorado potato beetle (Krimsky & Wrubel 1996; Kleinman 2005).

21 Krimsky & Wrubel (1996); Jenkins (1998); Kleinman (2005)

22 Jenkins (1998).

23 AgrEvo and Rhône-Poulenc Agro formed in 2000 Aventis CropScience which in 2002 was bought by Bayer forming Bayer CropScience (info available at www.bayercropscience.com).

24 Qayum & Sakkhari (2005).

25 The most illustrative example is the massive suicide of farmers because of the debts gained by the purchasing of the transgenic cotton seeds provided by Mayco-Monsanto in the Warandal District in Andhra Pradesh (Shiva & Jafri 1998; Stone 2002).

26 APNLBP is also developing a transgenic castor variety to manage the castor-semilooper: Bt-castor. Although the Bt-castor has already been developed in the lab, the bottleneck in this project is the absence of a deployment strategy for the

Bt-crop for the poor regions. Also a question of feasibility remains: where will the Bt-castor seeds be produced? What will be the price of those seeds? How will the Bt-castor deal with the negative image that some farmers and especially local NGOs have regarding transgenics?

27 In India, Bt based pesticides are being marketed by three companies. The total sale in 1999 was about 70 tonness (Dr MC Sharma, pers. Comm.. Director, Biotech International, New Delhi)

28 In this context, efficiency means: longer shelf life, ease of application and enhanced performance of Bt formulations (Brar, Verma et al. 2006)

29 The basic active agent of Bt, called delta endotoxin, is produced in the form of crystalline parasporals inclusions during the sporulation. According to Rowe and Margaritis (1987) and WHO (WHO 1999), nine different toxins have been described in Bt strains. Of those toxins, the delta endotoxin have received much attention in the production of bio-pesticides (El-Bendary 2006)

30 Vimala Devi & Rao (2005b).

31 Vimala Devi & Rao (2005b); El-Bendary (2006).

32 El-Bendary (2006).

33 ibid

34 ibid

35 Vimala Devi & Rao (2005b).

36 Vimala Devi & Rao (2005b); El-Bendary (2006).

37 El-Bendary (2006).

38 Actually, APNLBP is coordinating about 65 different projects.

39 Here we want to put the quality of this knowledge exchange in perspective. For instance, some communication problems were caused because some city-scientists were unfamiliar with the local rural-languages. This forced us to hold some of the meetings in a different language than the language used by local farmers.

40 From these five, two Bt kurstaki strains (4D17 and 4D21) were found effective against the castor semilooper, Achoea janata. These two were used for the study in addition to four local isolates of Bt from the farmers fields.

41 DOR-1 contains the cry genes: cry 1Ab, cry 1Ac, cry 2Ac, cry 2Ab, cry 1.

42 Vimala Devi & Rao (2005b). The cost benefit ratio for DOR Bt-1 treatment (2 sprays) was 3.10 while it was 1.62-1.80 in quinalphos – 5 sprays (Ekalux EC 25) (Vimala Devi & Rao 2005a).

43 They are able to do it by checking the hardness of the dead larva.

44 Nevertheless, we have to recognize the difficulty for farmers and lay persons in general to be able to understand technological discussions. Here, we are confronted for instance with problems such as the local educational systems that are beyond the scope of this article.

45 Vimala Devi & Rao (2005b).

46 ibid

47 There are some researchers that have pointed out that this use of high and low biotechnologies is part of a “short and long term perspective”; the short term perspective focus on low-tech and the long term on high-tech (Clark, Yoganand et al. 2002). Although this is indeed the official intentions of the APNLBP, in my view this network is in practice developing an integral biotechnological approach where all the biotechnological choices are considered in the struggle of poverty alleviation. This point is illustrated by the case analyzed on this article.

48 Vimala Devi & Rao (2005b,113)

49 About 150 grams of Bt powder are used to spray one acre (2.5 acres =1 Hectare).

50 For instance, some of them even don't know how much will be the price of the final product.

51 Ghose & Ghosh (2003).

52 The IBU was named so deliberately to show the contrast with 'the 'top-down model' of external development of biotechnology (Bunders 1990; Broerse & Bunders 2005).

53 This scheme was inspired by (Buijs 2002)

54 The most basic control, one can think of, regards the quality and price. If the product is too expensive and not effective, farmers will simply not buy it.

55 Rajeswari (1999); Clark, Yoganand et al. (2002); Sualiman & Hall (2002).

56 Damodaran (2004).

57 Pingali & Traxler (2002); Broerse & Bunders (2005).

58 Clark, Yoganand et al. (2002).

59 Bioserve (Lead by Bioserve USA) and Bangalore Genei (owned by the Indian chemical corporation "Sarman Group")

60 www.worldbank.org.in (09-05-2006)

61 Humphries, Gallardo et al. (2005).

62 Clark, Yoganand et al. (2002).

63 At this stage we could speak of the subpolitical (Beck 1997) character of the local networks because it mobilises resources and organise politics beyond the representative institutions of the political system of the Indian nation-state.

64 Ruivenkamp (2003a); Kloppenburg (2004)

65 Goodman, Sorj et al. (1987).

66 Ploeg & Frouws (1999).

67 Ruivenkamp (1989; 2003a) has analysed, how through the development of tissue culture or r-DNA techniques, seeds companies are becoming increasingly able to intervene more radically and efficiently in the genetic structure of plants and to determine where, when and how a crop should be sown, (with or without herbicides) harvested and processed. And it is precisely through the supply of these new seeds with specific properties that the companies can 'program the agricultural production from a distance'(ibid.2005a; p. 14)

68 Ruivenkamp (1987; 2005a).

69 (ibid.; p. xxiii)

70 The APNLBP is one of the four country programme supported by the Dutch Ministry of Foreign Affairs. The other three country programmes were in operation in Colombia, Kenya and Zimbabwe. In the last two countries, the economic support has stopped, what has meant the end of the local projects.

71 Misa (2003).

72 Feenberg (1995); Sclove (1995); Feenberg (1999); Ruivenkamp (2005a; 2005b); Bijker (2006).

73 Toledo (1990); Ploeg & Frouws (1999); Ruivenkamp (2005b; 2005a).

74 Renting & Ploeg (2001).

75 Ploeg (1991); Ruivenkamp (2003b).

76 Callon & Law (1986).

77 Leeuwis & Remmers (1999).

78 Bijker (2006).

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