Potential and constraints of employing agricultural biotechnology as a development tool: GMO cultivation and small-holder farmers in Dharmapuri District, India

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1. INTRODUCTION

Agricultural biotechnologies (1) have increasingly been regarded by developing countries' policymakers as a significant tool for developing their rural areas and eventually benefit resource-poor farmers. Yet, it has become apparent that for these benefits to be realised, a range of technical obstacles need to be overcome, as well as institutional and socio-economic contexts to be taken into account, even when the technology is technically feasible.

In the case of India, in light of the central role Indian governmental agencies attribute to biotechnology to burst rural development, this paper will examine the actual determinants of access to this technology, as well as the consequential variety in timing of adoption and benefit distribution between different categories of farmers. These factors determine how/if

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(1) Biotechnology is a very broad term. In this paper, it will be used exclusively referring to the application of genetic engineering in agricultural biotechnology.

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biotechnology can be used as a rural development tool in each specific location and should therefore be carefully considered at the time of formulating a biotechnology project/policy.

A number of important determinants of the benefits of biotechnology adoption by small-holders relate to the *suitability of the technology* for the needs of the farmers, as well as to issues of *access to complementary resources* (for example land rights, access to credit and input/output markets) needed for adoption. In the context of India, suitability of transgenic varieties for small-holder agriculture could be questioned, firstly, in terms of the appropriateness of the technology to small-holders' agronomic constraints. Thus, the proposed solutions should aim towards assuring biotechnology is shaped to tackle their priorities: mainly low-input use, robustness and capacity to resist abiotic stresses (FAO, 2004; Lipton, 2007). Secondly, concerns can be directed to the possible negative impact the traits embodied in these varieties (mainly referring to pest and herbicide-resistant varieties) can produce on the labour market (De Janvry and Sadoulet, 2002).

Impacts are direct and indirect; while farmers are impacted through changes in productivity and price, farm-workers are impacted through changes in wage-rate and employment. In developing countries where land is mostly unequally distributed and farmers tend to be mostly labourers, biotechnology can be designed to benefit both landless workers and land-owner farmers who supplement their incomes by working as labourers on larger farms (De Janvry and Sadoulet, 2000). This can be achieved by focusing research on the expansion of crop production on previously unusable lands or on crop production in seasons when it was previously not possible. However, for this to happen, research needs to target yield increasing traits in labour intensive and un-mechanised crops. These characteristics should be specifically targeted in research, since much of the biotechnology devices used in developing countries were initially developed to suit rich country conditions and constraints – primarily the high labour cost.

Thus far, the *problem* has been conceived as the suitability of the technology to tackle poor farmers' constraints and the *solution* to assure technology is developed to meet their needs. However, this is only part of the picture. As access to complementary resources affects adoption (Feder *et al.*, 1985), understanding the constrictions farmers face in accessing those resources is crucial in determining adoption and benefit derived from the technology. When *access to input markets* is constrained by inefficient infrastructures and marketing system, seeds cannot get to the farmers in marginal and remote areas (Acharya, 2006). Moreover, when transgenic seeds are costly, *lack of credit* may disallow farmers from adopting this technology innovation (Qaim and de Janvry, 2003; Ameden *et al.*, 2005; Giné and Klonner, 2006). In addition, there may be comprehension and learning constraints to deal with the new system (Stone, 2007), as the *quality and source of information* is proved to be a critical factor in influencing farmers' adoption and benefit from this technology (Tripp and Pal, 2000; Marra *et al.*, 2001; Tripp, 2001; Stone, 2011). Eventually, on *access to input and output markets,* depends whether or not farmers will be able to access the new technology and benefit from increases in production (Shilpi and Umali-Deininger, 2008).

Moreover, the different *timing of adoption* can also impact on the distribution of the benefits of this technology (Burton *et al.*, 1999). If adoption of the improved varieties depends on particular resources and if large holders/better off farmers tend to have better access to these inputs than small-holders (because of their wealth or social-cultural reasons), then in that context, the technology will produce different timing of adoption, which, in turn will impact on the distribution of the benefits of the technology (2) (Giné and Klonner, 2006; Severn-Walsh, 2006). As described in Lipton (2007) relative to the increased production derived from *Bt* cotton, the risk is that once local production rises (due to richer farmers being early-adopters), prices and income may result depressed. Thus the late-comers would lose from price falls when others adopted *Bt* varieties, but would also benefit less when they eventually adopt *Bt* seeds (Lipton, 2007). This process produces consequences over local inequalities. Evidence is provided by Morse *et al.* (2007) who show that adopting *Bt* cotton reduced inequality among growers but increased inequality for non-adopters (Morse *et al.*, 2007).

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(2) In this regard, wealth is proved to overcome supply constraints and give enhanced access to the new technology. Giné and Klonner (2006) identify determinants of the timing of technology adoption as well as resulting income and inequality dynamics during this process. Moreover, Severn-Walsh (2006) analyzes the factors affecting the adoption of transgenic Bt cotton by smallholder farmers in Tamil Nadu. The author finds farmers with larger farms and greater overall wealth to be more likely to adopt, and benefit, from Bt cotton relative to farmers with smaller farms or less wealth.

Therefore, if differences in adoption depend on unequal access to complementary inputs, then this finding has important policy implications and indicates that assuring a more equitable adoption of biotechnologies may not exclusively depend upon a shift in the research approach, but also on the establishment of measures that ensure better access for the small-holders to these complementary inputs. Using field survey data from *Bt* cotton farmers in Tamil Nadu, we attempt to identify what are the constraints that farmers face in accessing this technology and reaping benefits from it. These answers will spread light on the chances and the constraints for agricultural biotechnology to serve the purpose of agricultural and rural development.

The paper has four sections. Section I presents the case of India, one of the first among the developing countries to identify biotechnology as a major tool for the development of its rural areas. Firstly, the institutional framework set by India's central state is considered. Secondly, the analysis narrows its focus on the biotechnology policies defined at the State level – taking the case of Tamil Nadu into consideration. Section II presents the empirical setting of the paper, wherein a brief note on the study area as well as the sampling design is presented. Section III proposes a categorisation of the socio-economic constraints encountered by farmers in accessing and benefiting from biotechnology. These considerations allow drawing some conclusions regarding the impact of biotechnology applications on the rural structure and specifically on the smallholders.

From this categorization it will be concluded that to be used as development tools, biotechnology projects and policies need to be integrated with socio-economic considerations. However, this task could prove to be not only time-consuming and resource-expensive, but indeed a difficult and complex challenge. The concluding section (Section IV) will tackle this question and eventually propose a number of pointers for policy.

2. BIOTECHNOLOGY AS A DEVELOPMENT TOOL

2.1. Institutional framework at the national level: the case of India

As an active contributor to an international dispute over the potentialities and the risks of agricultural biotechnology, India adds its own specific issues to this debate. Concerns over the efficacy of the technology, the control of agriculture by multinational companies, farmers' rights, as well as the role of the state and public research, explain the endurance and fervour of the controversy (for a more detailed discussion see Bharathan, 2000; Gupta and Chandak, 2005 and Scoones, 2003). Ahead of this debate, stands high political support. The recent biotechnology policies of the Indian government demonstrate the eagerness with which politicians and prominent members of the elite scientific establishment are exploring the potential for transgenic technology to bring economic growth and meet food security needs.

India has been one of the first among the developing countries to have attributed a major role to biotechnology as a tool for the advancement of the agricultural sector as early as the 1980s (Chaturvedi, 2005). This recognition, sided by a significant increase in government spending to promote this sector, was formalized by the establishment of a fully-fledged government department, the Department of Biotechnology.

The objective of the department is stated as: "attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – especially for the welfare of the poor" (DBT, 2001). In the discourse of the national government, with regards to the National Biotechnology Development Strategy, the attainment of "new heights" in biotechnology research is explicitly related to agricultural development, with a specific focus on the poor (DBT, 2007).

Moreover, with biotechnology being seen as a key "new economy" industry following India's information technology (IT) success, the promotion of biotechnology in policy making is increasingly being regarded as a key aspect for future economic growth. This is true not only at the level of the central government but also at state level.

As the states of Andhra Pradesh, Karnataka, Maharashtra, Gujarat, Kerala and Tamil Nadu draw up their own sub-national biotechnology policies, the "enthusiasm with which Chief Ministers and state policy-makers have latched onto the "IT to BT" hype" (Seshia and Scoones, 2003) has become evident. In order to attract the biotechnology industry to their respective states, they promised fiscal and infrastructural support measures similar to the ones already available to the IT sector, such as tax concessions, capital subsidies, the creation of industrial infrastructure, special economic zones, technology incubators, and so on (Chaturvedi, 2005; Konde, 2008).

The next section highlights this process through the case of Tamil Nadu; the state's specific policies on biotechnology regulation and promotion are analyzed. This analysis serves to characterize the institutional framework of our case study of Dharmapuri District.

2.2. Institutional framework at the state level: Tamil Nadu

"Tamil Nadu has emerged as a front ranking State in attracting investments. The growth in knowledge-based industries in the State in recent years has been phenomenal. In order to consolidate these gains and carry the State forward in the path of economic development, the Government of Tamil Nadu has decided to focus on another knowledge-based industry, i.e., Biotechnology" TN Government, Biotechnology Policy 2000-01.

Tamil Nadu was the first Indian state to develop its own biotechnology policy, doing so under the guidance of M.S. Swaminathan. The influence of Swaminathan, whose efforts in biotechnology are explicitly related to poverty-uplifting strategies, is clearly visible throughout government policy.

The institutional approach of Tamil Nadu is analyzed by Scoones (2006) as "part of a familiar policy discourse in which state governments, in partnership with the centre and (somewhat more vaguely) the private sector, committed themselves to a public enterprise aimed at the broad developmental goals of tackling poverty and encouraging economic uplift" (Scoones, 2006: 209). According to this framework, the government focused on two main strategies in order to exploit the potential of biotechnology for the benefit of the farmers and the agricultural sector as a whole: strengthening the coverage of extension services and their competence in new technologies and encouraging a public-private partnership in spreading biotechnology through the promotion of contract/corporate farming (TNAD, 2007-08). Both these propositions are part of a bigger strategy initiated nationwide in India.

On one side, a nationwide reform of public extension aimed at transforming this service into a demand-driven, broad-based and holistic system (Birner and Anderson, 2007). (3) In line with this reform, Tamil Nadu proposed the replacement of the "top-down approach" with the "bottom-up approach" at village level; specifically promoting the "group approach" to replace the traditional "training and visit approach" (TNAD, 2007-2008: 25). Moreover, in setting its policy to reform extension services, the Government called for the need of specific attention to provide women farmers with appropriate technology, training, and information.

On the other side, the government's policy aimed at encouraging public-private partnership in promoting biotechnology uptake in the rural areas through contract/corporate farming arrangements. As expressed in the Policy Note "to link farmers with the assured marketing and to protect the interest of both the farmer and the industry, contract farming is promoted by the State Government through Department of Agriculture" (TNAD, 2007-2008: 15). Although among the public institutional sphere this arrangement appeared to be a priority for rural development, its merits and demerits are still subject to strong disagreement (see Erappa, 2006).

This institutional framework helps characterizing the area being studied in this research article: the Dharmapuri District in the state of Tamil Nadu.

3. EMPIRICAL SETTING

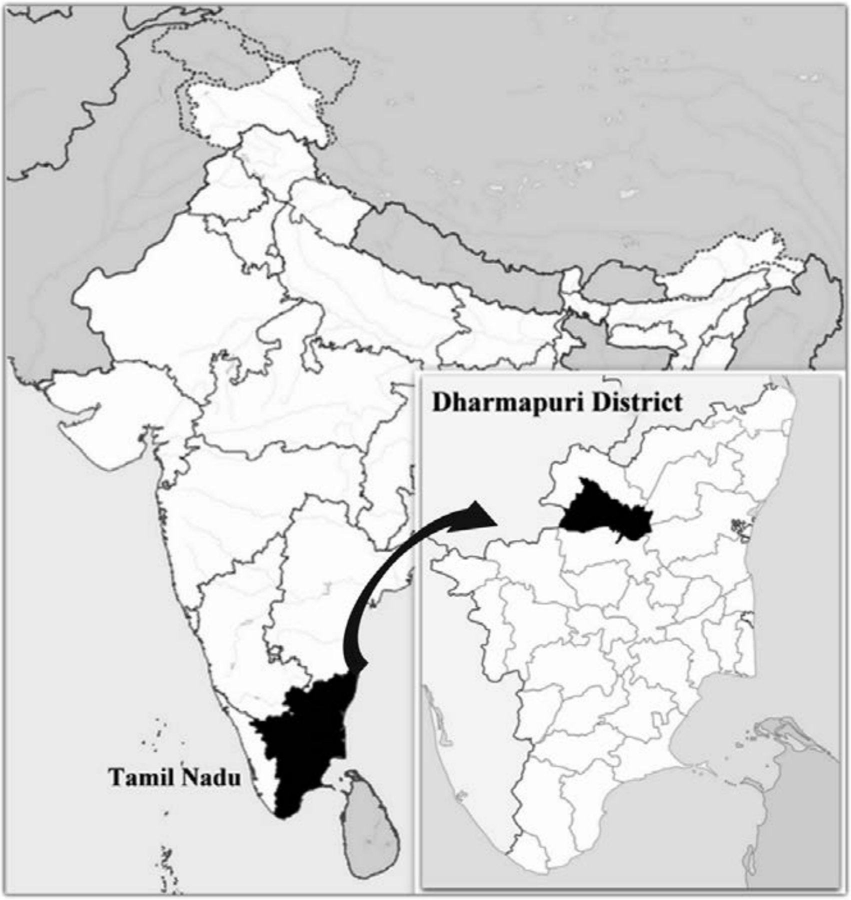
Dharmapuri District is located in the North Western part of Tamil Nadu. It is the second most populated district of the State, as well as one of the poorest and least ranked in terms of the Human Development Index (Government of TN, 2003). The economy of Dharmapuri is mainly agrarian in nature. Almost seventy percent of the workforce is dependent on agriculture and allied activities. In the arid and semi-arid harsh environmental conditions of the District (the region receives only 400 to 500 millimetres of rainfall annually and less than 10 percent of farmland is

(3) For more details on the strategies adopted nationwide to strengthen agricultural extension systems see Sulaiman (2003) on the implemented innovations; Sulaiman and Hall (2002) on the challenges encountered during the reform and Raabe (2008) for a review of what eventually worked where and why.

irrigated) crops like paddy, millets, pulses and cotton account for the major area under cultivation (CARDS, 2008; Smale et al., 2009).

Figure 1

MAP OF INDIA AND DHARMAPURI DISTRICT, TAMIL NADU



As in the rest of the state, in Dharmapuri the uptake of genetically engineered crops has been very rapid. Traditionally belonging to the cotton belt, the release and promotion of genetically modified (GM) cotton has produced a visible change on the district's agricultural production and distribution structure, as well as on the labour market.

Our exploratory study of Dharmapuri District aims at analysing these changes in the life of the cotton small-holder farmers. For this purpose, five cotton-growing villages were randomly selected (Mukkanur, Kuppur, Settikarai, Adagappadi and Bolanahalli) to conduct a survey. Information was collected from a sample of 100 farm managers (out of which 24 percent were women) who had cultivated *Bt* cotton crop during kharif season 2007. 41 % of our sample farms owned less than 5 acres of land and 59 % owned 5 to 10 acres, reflecting the District's landholding distribution. Given the difficulties of obtaining an official census of cotton farmers in each village, the purposive sampling method was applied to select *Bt* cotton farmers. Official farmer records were available only for *Bt* cotton farmers under contract, whose particular characteristics (generally more educated and equipped with irrigation facilities) did not represent the actual situation of the farmers in this area.

Data were gathered on farmers' socio-economic characteristics, input-output quantities and management practices; moreover information on farmers' access to extension information and institutional support was gathered. The following Table 1 summarises the results of the main qualitative socio-economic data collected.

Table 1

DEFINITION AND SUMMARY STATISTICS OF QUALITATIVE SOCIO-ECONOMIC DATA

Variable	Description	Percentage
GENDER	1. Male 2. Female	76% 24%
EDUCATION	1. Illiterate 2. Functionally literate 3. Primary schooling 4. Middle schooling 5. Secondary schooling 6. Above secondary schooling	12% 28% 38% 16% 6% 0%
YEARS OF BT COTTON CULTIVATION	1. First Year 2. Second Year 3. Third Year 4. More than three years	10% 18% 56% 16%
SOURCES OF INCOME	1. Only agricultural 2. Other sources	86% 14%
MEMBERSHIP OF FARMING ORGANIZATIONS	1. No memberships 2. Yes of Self-Help-Group 3. Yes of Farmers 'club 4. Yes of Cooperative	85% 12% 3% 0%

Quantitative survey results can be summarised as follows: sample farms cultivate, on average, 6.6 acres of land (usually owned by farms) that yield 7,8 quintals of cotton per acre. The large majority of plots are rain-fed, whereas the main form of irrigation is through bore-dug wells. The average income obtained per quintal is slightly below 3,500 rupees. Among production costs, hired labor is the most relevant, followed by fertilizer, pesticides and seeds. The low cost of seeds is due to government intervention, which in 2006 set maximum retail prices for *Bt* seeds at Rs 750 per packet, which was less than half the price previously charged by seed companies. The average per quintal net income is around 1,250 rupees. Farm income represents almost 86% of the income obtained by sample households. Sample farms rarely own farm machinery, being the tenure of a bullock more common (around 44% of sample farms). Around 92% of sample farms sell their produce to the State's Co-operative Spinning Mills Federation, being the rest sold to private agents.

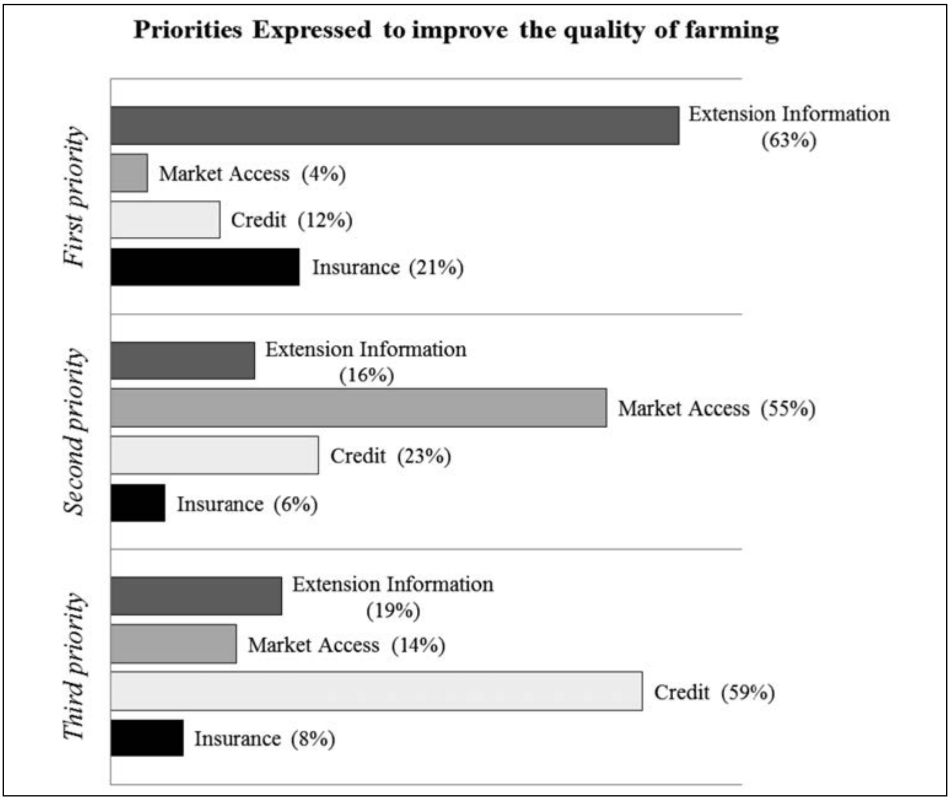
4. RESULTS AND DISCUSSION

Extensive reviews of technology adoption studies in developing countries can be find in the academic literature (starting from the reference works of Feder et al., 1985 and Feder and Umali, 1993). There are number of factors that have been found to influence the extent of adoption of technology such as its characteristics or attributes; the profile of the adopter, the change agent (extension worker, or the retail companies promoting the technology, etc.); and the socio-economic and physical environment in which the technology is introduced. The socio-cultural traits of the farmers are also important. His/her age, education, income, family size, tenure status, credit access, social status and beliefs also influence adoption. The personal characteristics of extension workers (or the seed company/seed shop/fellow farmers etc. which are sponsoring the technology) such as trustworthiness, good relationship with farmers, ability to communicate with farmers and previous experience, are important at the time of technology acceptance. The biophysical environment also plays a role. The conditions of the farm, which include its location, availability of resources and other facilities such as roads, markets, transportation, irrigation facilities, soil type, and electricity matter as well. Least, but not last, the price of the outcome product is taken into account by farmers at the time of adopting.

In our study of Dharmapuri District, we attempt to identify the actual complementary inputs which affect the capacity of small-holder farmers to adopt and benefit from adoption of *Bt* cotton. For this purpose, sample farmers were enquired on the three main factors considered as priorities for improving their quality of farming and farm management. Farmers were asked to rank priorities out of four factors/options given to them based on preliminary qualitative interviews: "Insurance against crop failure", "Credit provision", "Input/Output market access" and "Extension/Technical information". The results revealed *three* high *priorities,* as shown in Figure 2, identified as "*Credit*" "*Extension information*" and "*Market Access*". A more in-depth analysis of these three factors is presented below.

Figure 2

PRIORITIES EXPRESSED BY SAMPLE FARMERS TO IMPROVE THEIR QUALITY OF FARMING



Access to credit

For biotechnology to spread over rural areas, smallholder cotton growers need to acquire the necessary production inputs. In many instances, credit is the major constraint. The type of credit available often plays a large role in determining what inputs are available to farmers, and indirectly, it affects the risk behaviour of the famers, thereby affecting technology choice and adoption (Ameden et al., 1995; Qaim and de Janvry, 2003; Giné and Klonner, 2006 and Komicha and Öhlmer, 2006).

In the case of India, most rural families have inadequate savings to finance farming activities which, coupled with the seasonality of agricultural income, makes credit availability a fundamental precondition for the adoption of biotechnology. The case of *Bt* cotton adds new facets to this situation. With the emergence of *Bt* cotton, local input markets became highly integrated with the seed, pesticide as well as fertiliser companies. As a result, farmers have been mostly compelled to buy the seed, insecticides and fertilisers from the same shop (Viswanathan and Lalitha, 2009). Though sales of seeds are not on credit, sales of insecticides and fertilisers can be on credit. Buying inputs on credit would be helpful if small-holders could rely on a sound system of formal agricultural credit. However, the Indian agricultural credit sector has not yet been able to respond to the existing high demand for agricultural loans (4); restriction that has pushed certain categories of farmers to depend on seed shops and moneylenders for their credit needs.

The difficulties to access formal sources of credit are even higher when farmers own low quality and rain-fed lands. These farmers find themselves excluded from accessing loans, firstly because land is usually retained as collateral and credit institutions consider the actual size of landholding and the quality of land as an important indicator of the creditworthiness of the borrower. Secondly, apart from land, other valuable assets– particularly agricultural machineries and equipment – and the proportion of

(4) Explanations for the inner causes of this malfunction are many as described in Harris (1980), Basu (1997) and reviewed recently by Giné and Klonner (2006).

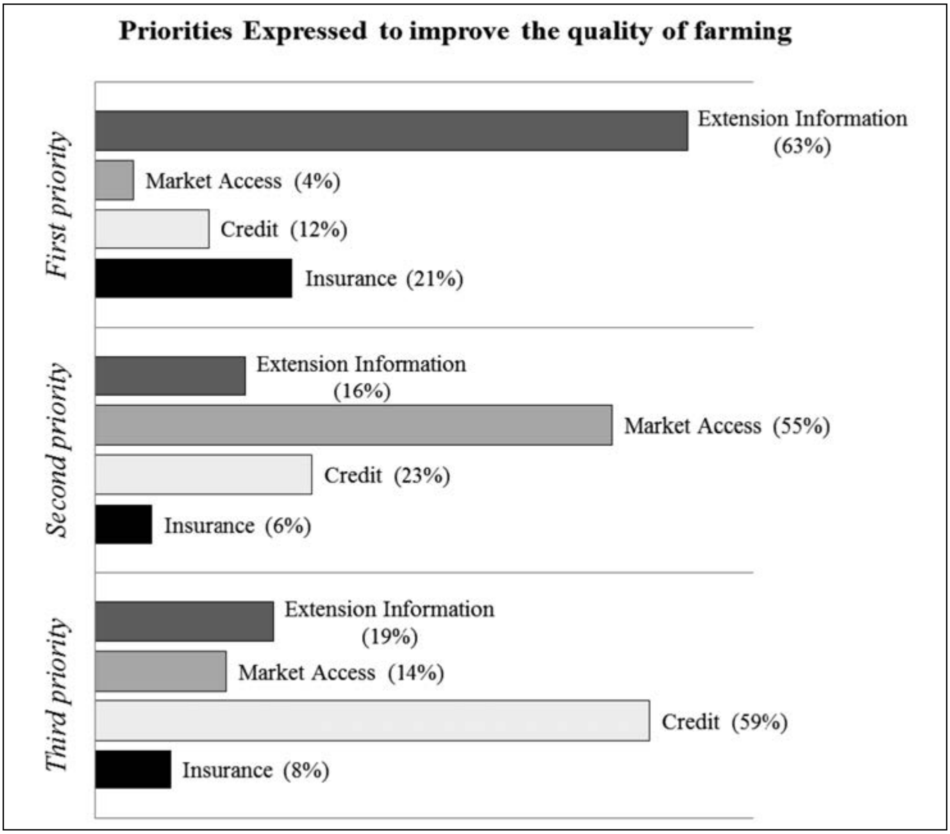
(5) A further issue is that of social discrimination. Credit-disbursing officials may discriminate against lower caste and tribal farmers: first, because this stratum of the society retains less political leverage; and second, because of the predominance of higher caste decision-makers in credit institutions (Sahu et al., 2004; Kalpana, 2008).

non-farm income are also used as creditworthiness indicators. Thirdly, an assured source of irrigation and crop insurance are perceived by banks as adding to the reliability of crop production and therefore to the creditworthiness of the farmer (5) (as detailed in Sahu et al., 2004). Given the large proportion of farmers lacking these requirements, it is not surprising that at present there is considerable unmet demand for rural credit (Acharya, 2006; Golait, 2007; Sidhu et al., 2008; Chaudhuri and Cherical, 2012), which mainly affects marginal and low-income farmers.

This situation is reflected in the results of our study of Dharmapuri, as detailed in Figure 3, which summarises the responses of sample farmers on access to agricultural credit and its sources.

Figure 3

SAMPLE FARMERS' ACCESS TO AGRICULTURAL CREDIT AND ITS DIFFERENT SOURCES



Access to credit not only affects the inputs available to cotton farmers, but also the income they can get out of *Bt* technology. Depending on their credit access and its terms, farmers are able to afford different timing of sales to the open market, which in turns affects the price obtained for the produce. Since small farmers need cash more urgently, they are forced to sell their produce immediately after the harvest, when prices are generally low. On the contrary, wealth and/or access to capital enable large farmers to withhold their produce and sell when prices rise, during periods of scarcity (Sahu et al., 2004).

Nevertheless, if small-holders were affiliated to a strong producer association, they may gain better access to various sources of credit and thus to the expensive inputs related to *Bt* technology. However, to run such organizations and assure their long-term sustainability is not an easy task, as appeared in our exploratory study of Dharmapuri. There, cases of small-holder farmers participating in any kind of producer associations were very rare. None of the *Bt* cotton farmers interviewed was part of a cooperative and a small percentage of them were part of a farmers' club or self-help group, with no more than ten members.

All over India, however, many different new options to promote farmer organizations have been conceived and new institutional channels for credit are being undertaken: financial self-help organisations, landless credit and savings groups as well as partnership of these new institutions with formal financial ones such as the SHG-Bank Linkage (Basu, 1997; Acharya, 2006; Golait, 2007). The challenge is now to determine which agency could be best suited for the provision of credit to farmers to adopt and benefit from biotechnology applications; and how the complementary measures could best be integrated with the provision of such credit.

Access to information and extension services

Although for centuries farmers' observation and experimentation have been responsible for the diffusion of many new varieties, in the case of biotechnology it has become much harder for farmers to distinguish among options, particularly if they embody cryptic qualities. It is the case for varieties which have been nutritionally enhanced or made resistant to particular diseases but that without adequate information are hard to distinguish from conventional ones. This is also the case of *Bt* cotton.

Since its introduction to the Indian market, this technology has been characterized by a wave of contradictory advertising, campaigning, and lobbying aimed at farmers, with misleading information being spread by its supporters and opponents alike (see Stone, 2011 and Glover, 2010 for an in-depth analysis). This load of misleading information has been sided by the proliferation of many new *Bt* cotton varieties introduced in the market every year. This process has generated a complex scenario for farmers to experience with *Bt* cotton either through environmental or social learning, eventually slowing down the build-up of their own knowledge based on direct experience.

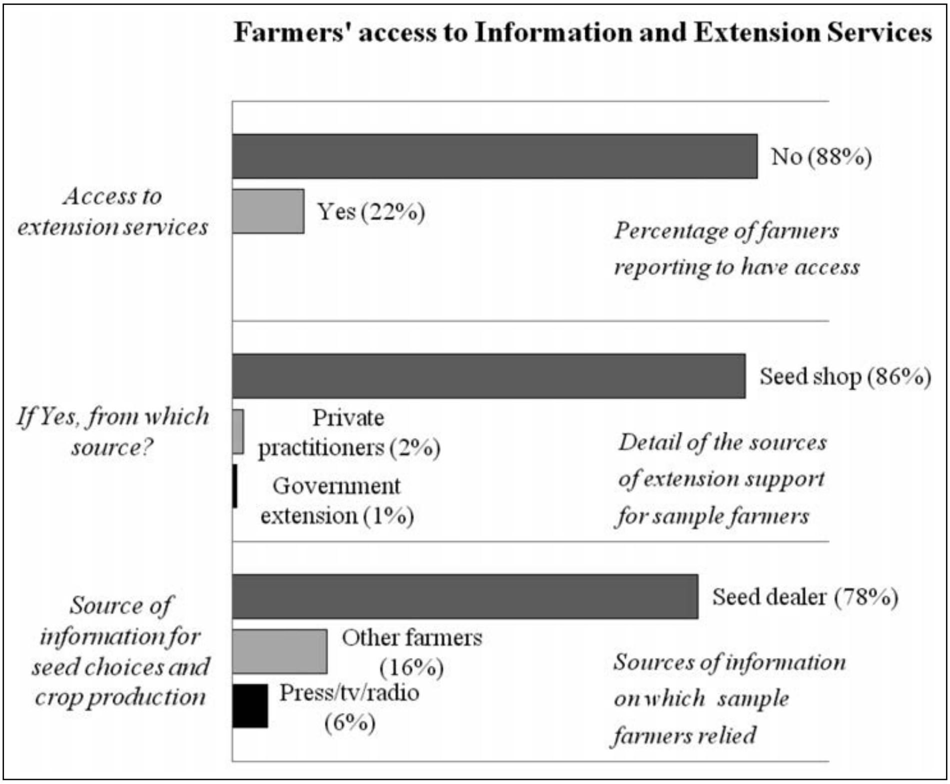
Problems of miss-information on new agricultural technologies are widespread all over India (Birner and Anderson, 2007). Our exploratory study identifies the sources of information available to cotton farmers in Dharmapuri District and acknowledges the potential repercussions of a lack of adequate information provision on *Bt* cotton farmers. After enquiring about their access to extension services and its sources, farmers were asked to select the category of information provider on which they would rely first when seeking technical information on seeds and crop production. Farmers could choose between "seed dealers", "private crop consultants", "government extension officials", "other farmers", "scientists", "farmers' associations" "press/tv/radio" and "other." The responses indicated "seed dealers" as the first choice for the large majority of farmers, followed by "other farmers" and "press/tv/radio". Details of the responses are reported in Figure 4.

Given this general lack of public extension support (6), based on preliminary qualitative interviews, sample farmers were asked to explain the characteristics they attributed to *Bt* cotton seeds prior to planting, given the information received. A number of features were in some cases wrongly at-

(6) Governmental extension services were criticised by the farmers interviewed on various grounds: insufficient coverage, technical weakness and gender biases. However, behind this malfunctioning there are causes which are beyond the control of extension workers. It is the case of outdated pre-service education, inadequate in-service training, low salaries and status, and the need to cover a large number of farmers without having a sufficient operational budget and transportation facilities (Glendenning et al., 2010).

Figure 4

SAMPLE FARMERS' ACCESS TO EXTENSION SERVICES AND TECHNICAL INFORMATION



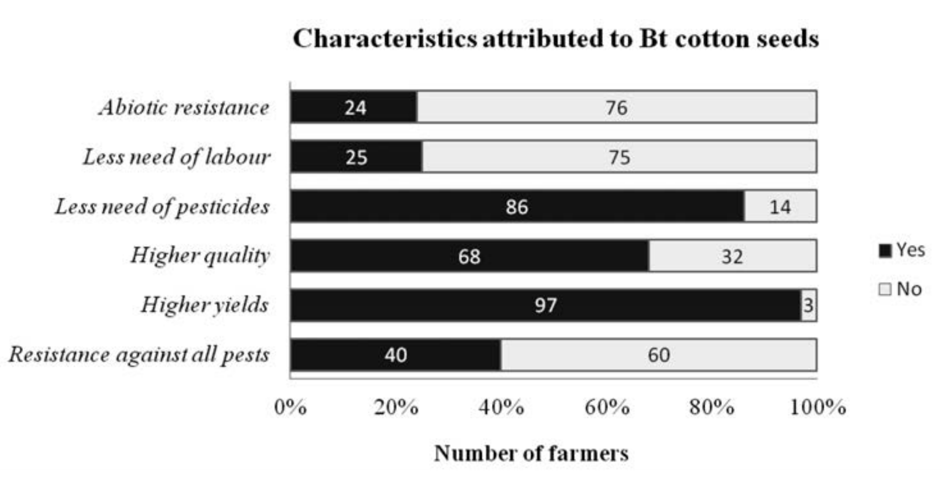
tributed to and, thus, expected from *Bt* seeds (for example resistance to abiotic stresses and yield increase) which showed misconceptions about the actual purpose of this technology. Figure 5 summarises farmers' responses.

The implications of this miss-information were evident in the case of compliance with specific farming management practices related to *Bt* cultivation, namely *refugia*. None of the farmers interviewed planted *refugia* and none of them was aware of its purpose.

The flood of misleading information produced along the spread of this new technology, coupled with the existence of a largely unregulated seed market, calls for the need of providing farmers with specific information support (Tripp, 2001). If this information is lacking, the effectiveness of the technology could be undermined and the technology be indeed harm-

Figure 5

CHARACTERISTICS ATTRIBUTED BY SAMPLE FARMERS TO BT COTTON SEEDS PRIOR TO PLANTING



ful to farmers. For instance, as for the case of pest controlling varieties, if farmers are unaware of the actual properties of *Bt* cotton, one can hardly expect that they will reduce their level of pesticide use. This was confirmed by a survey of *Bt* cotton farmers in Gujarat and Maharashtra conducted by Shetty (2004) who found that farmers followed an unnecessary high spraying schedule, which led to the development of resistance in the bollworm, hence the increase of pest infestation, lowering the yield of *Bt* cotton in the region (7). It follows that absence of extension support and a lack of farmers' knowledge can considerably limit the potential economic, environmental and health benefits of biotechnology application (Glover, 2010).

Availability of market information is another essential aspect of information for farmers to benefit from biotechnology. Market information allows the process of price discovery and transmission of price signals, thereby allowing farmers to acquire the benefits of increased production.

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(7) Similar results are presented in Viswanathan and Lalitha (2009). In other significant studies on farmers' misinformation and over-use of pesticides against Bt cotton pests, market and institutional failure are found to be the main causes (Yang et al., 2005; Pemsl and Waibel, 2005).

Nonetheless, this is a widely lamented issue all over India, where there is no adequate agency to disseminate information relating to markets such as prices, demand, government policies, and so forth (Choubey *et al.,* 2005; Glendenning *et al.,* 2012). Stone (2011) provides a fruitful discussion of the new ways proposed by the Indian government to supply market information to cotton farmers, although the problem is still far from being resolved.

In the light of these constraints, the challenge is to understand what kind of information would allow farmers to take advantage of such technology and how to deliver it best. This implies examining farmers' own information management capacity as individuals as well as farmer organisation; pondering on the options of providing information through public and/or private extension and under what circumstances; and examining the performance of the seed industry in providing inputs and information to the resource-poor farmers (Glenndening et al., 2012).

Access to input and output markets

The Indian agricultural marketing system suffers from a number of structural weaknesses related to the large inadequacy of transportation facilities, the non–availability of market information, and the high market volatility (Acharya, 2006). This situation is mirrored in Tamil Nadu, where agricultural markets, generally small in size and heavily congested, offer only few facilities and limited infrastructure (Shilpi and Umali-Deininger, 2008).

A project aiming at improving the livelihood of small farmers through biotechnology should take these deficiencies into account. And it should for a number of reasons. Firstly, farmers' need to buy fresh seeds for every new crop season calls for the strengthening of physical seed market infrastructure. Without adequate input markets, biotech varieties that would benefit certain particular areas, either because of social or environmental characteristics, are unlikely to reach farmers. Equally, the absence of adequate output market functioning may offset the benefit provided by increased production (Qaim, 1999 and Smith, 2007). A significant increase in production could lead to flooded local markets and reduced local prices. This means the benefit capture of biotechnology-driven increase in production depends on access to markets.

It is thus important to consider how different capacities to access input and output markets impact on different categories of farmers and what the distributional implications of this process are. A number of studies have shown how wealth confers benefits in accessing market facilities. Shilpi and Umali-Deininger (2008) observe that wealthy farmers in Tamil Nadu are able to capture a disproportionate share of the benefits from the facilities available at congested markets. This is consistent with the benefit conferred by wealth to the early adopters as discussed in Serra *et al.* (2008). As Acharya (2004) noted in the context of Indian markets, this may happen either because wealthy farmers are able to afford better transportation facilities or because their wider social network ensures lesser waiting time in accessing facilities at the market place.

Therefore, on one hand, there is a dire need of additional investments in market facilities to benefit poorer farmers. On the other, if small-holders were affiliated to a strong association, advantages would be felt also at the time of selling their produce. In the case of Dharmapuri, all of the farmers interviewed lamented the high volatility of cotton prices and that no farmers' association would support them at the market place. Given the imperfection of the cotton marketing system which often forces farmers to sell their cotton as ungraded, being member of a producer organization would substantially improve their bargaining power vis-a-vis companies and market functionaries (Choubey *et al.*, 2005). These organisations could in fact arrange to collect products from small farms, manage the grading, storing and transportation either to private companies or at the open market (Choubey *et al.* 2005). These are important challenges which have great implications for the viability of *Bt* technology and sustainability of the *Bt* production system.

5. CONCLUSIONS

A sustainable future for Indian agriculture with the presence of GM technology in general and *Bt* technology in particular, would essentially call for many reforms, development strategies and institutional and policy interventions embracing a wide spectrum of activities such as the restructuring of both input and output markets. Ahead of this, realising how the desired changes we expect from the introduction of biotechnology applications are intertwined with the socio-cultural and economic dimension, calls for a reflection of how the interaction between these factors should be taken into account and what are the advantages and disadvantages of so doing.

Taking into account the socio-economic dimension of biotechnology not only demands for a complex set of technical considerations in determining the impact of every new trait introduced, but also for an evaluation of every crop in its own social and economic context (Stone, 2007). Hence, integrating these perspectives into crop biotechnology research and creating policies that can correspond to the new realities associated with this technology are crucial challenges the agricultural policy makers in the developing world are facing. The main challenge is that every variety which is introduced and promoted, although with a pro-poor purpose, will produce both winners and losers in the rural society. Moreover, the developmental impact of technically successful varieties can be heavily limited by non-technical issues (such as difficulties in marketing the increased production). Thus, it appears how necessary are both farmers' participation and long-term interaction with the scientific establishment; firstly at the moment of designing the technology and then progressively in fine-tuning the technology to suit farmers' needs as the socio-economic environment changes.

However, to date, very few participatory exercises with resource poor farmers have led to the implementation of biotechnology research projects (FAO, 2004). This is because involving farmers is not easy, as they tend to lose interest if results take a long time, which is often the case in research. Moreover, participatory research in biotechnology faces the limitations that are common to the programmes using a participatory bottom-up approach: the time lag between project identification, the development of the technology and its availability to farmers. These are the disadvantages that create reluctance in actually including socio-economic considerations when designing biotechnology projects. In fact, when the method applied for formulating projects' activities becomes more time-consuming, more complex and resource-expensive, donors and implementing organisations may wonder whether such process is necessary. In other words, the advantage of conducting costly socio-economic studies involving farmers should be considered (8). Nevertheless, a number of biotechnology projects structured with an interactive participatory process have proved how participation can be valuable in this case (Van de Fliert and Braun, 2002; Laxmi *et al.,* 2007). Whether the approach to biotechnology transfer be participatory, partnership-based or science led (Hall *et al.*, 2001), the matter of whether or not to take into account social elements becomes not only a question of making the implementation of the project more time-consuming or resource intensive; it becomes furthermore a question of choosing until what point specific groups' current social and economic characteristics should impact on the upholding project. This is a question which is faced at every step of the process from technology design to its delivery to the field. It could be taken as an example the delivery of biotechnology-related information to the rural areas.

This task presupposes a prior choice of "how to train" and "who to train": whether to train a number of trainers or to train farmers directly could be the first question. If the second option is chosen, it could be questioned whether training should be targeted directly towards the resource-poor farmers or, alternatively, towards the better-off ones and then expect technology to spread to other layers of the farming community. Furthermore, a choice would be needed regarding training women and/or men farmers and on which subjects respectively.

These questions are still open but shed light on how biotechnology research could be directed to address particular needs and societal aims without regarding socio-economic frames as something rigid and everlasting. Otherwise one would be missing out how the social and economic environment is continuously changing and how it adapts to new conditions. However, such balance is not easy to achieve, and also it is complex to work out the dilemma of how to bring a change without provoking an alteration of the system. This is why farmer's participation becomes so important in this process.

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(8) Broerse and Bunders, (2000) and Thro and Spillane (2000) suggest several reasons as to why participatory research related to biotechnology is needed and which are its drawbacks.

Integrating these perspectives into crop biotechnology research is a challenge that developing countries' agricultural policy makers need to confront. While it is clear that the private sector will pursue its own interest in developing specific aims in research and commercialisation of biotechnological traits, public research has the potential and duty to tackle the question. Developing countries with strong research capacity in biotechnology can (re)design this technology according to their specific socio-economic aims. Here, one may understand that as any other technology, biotechnology also has a social dimension besides technical dimensions. Likewise, biotechnology can hold specific socio-economic aims. As it has been previously shown, certain biotechnological developments within a specific socio-economic context will benefit certain categories of farmers while there will be other categories which will be negatively affected. At this point, the challenge facing the agricultural policy makers in the developing world is to settle a social negotiating process involving farmers and the public scientific establishment in order to discuss further developments of this technology. This way, the technological change introduced by biotechnology can be directed to respond to clear societal targets and aims.

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ABSTRACT

Potential and constraints of employing agricultural biotechnology as a development tool: GMO cultivation and small-holder farmers in Dharmapuri District, India

Drawing on the case of Dharmapuri District, South India, the article aims to investigate the potential and the constraints by which agricultural biotechnologies can be employed to serve the purpose of agricultural and rural development. The analysis follows two main routes: on one side it evaluates the suitability of biotechnology (specifically Bt cotton) to the needs of farmers, while, on the other, it examines access to resources (technical information, access to credit and input/output markets) necessary for the adoption of this technology. Using field survey data from Bt cotton farmers in Dharmapuri District, Tamil Nadu, the paper attempts to identify what are the constraints that small-holder farmers face in accessing this technology and reaping benefits from it. From this analysis it will be concluded that to be used as development tool, biotechnology need to be integrated with socio-economic considerations. Considering the many challenges involved, the paper will propose a number of pointers for policymakers to (re)design biotechnology projects and policies to respond to clear societal targets and aims.

KEYWORDS: Agricultural biotechnology, India, small-holder farmers, socio-economic constraints.

JEL CODES: O2 Q1 O13.

RESUMEN

Potencial y condicionantes para implementar la biotecnología agrícola como instrumento de desarrollo: cultivo de OGM y pequeños agricultores en el Distrito de Dharmapuri, India

El principal objetivo de este estudio ha sido investigar el potencial y los condicionantes para utilizar la biotecnología agrícola como herramienta de desarrollo rural en el contexto del Distrito de Dharmapuri, en el Sur de la India. El análisis ha tenido dos rutas: por un lado se ha evaluado la idoneidad de la biotecnología (especificadamente el algodón bt) para las necesidades de los agricultores; y por el otro, se ha examinado el acceso a los recursos complementarios (acceso a la información técnica, acceso al crédito y a los mercados de inputs y outputs) necesarios para la adopción de esta tecnología por parte de los agricultores. Utilizando los datos de una encuesta de campo a agricultores de algodón Bt en el Distrito de Dharmapuri, Tamil Nadu, el artículo trata de identificar cuáles son las limitaciones con que los pequeños agricultores se enfrentan en el acceso a esta tecnología y en obtener beneficios de ella. De este análisis se concluye que, para ser utilizada como herramienta de desarrollo, la biotecnología debe integrarse con las consideraciones socio-económicas. Teniendo en cuenta todos los desafíos que esto implica, el artículo traza una serie de proposiciones para las autoridades y organismos de desarrollo, para (re)diseñar políticas y proyectos biotecnológicos de desarrollo rural, respondiendo a metas y objetivos sociales claros.

PALABRAS CLAVE: Biotecnología agrícola, India, pequeños agricultores, limitaciones socio-económicas.

CLASIFICACIÓN JEL: O2 Q1 O13.