Developing capabilities in the seed industry: which direction to follow?

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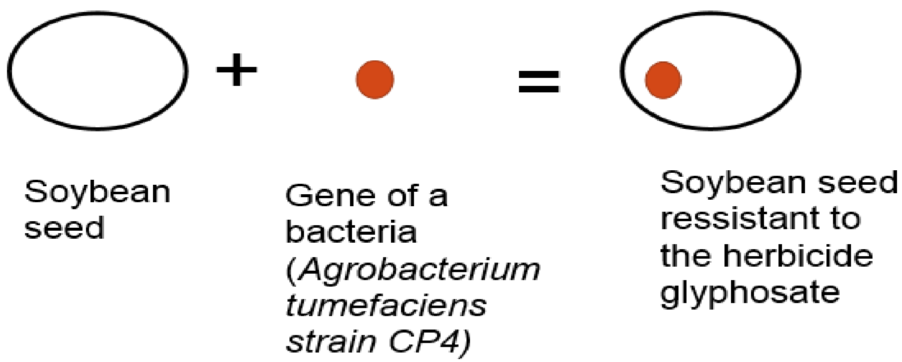
CENIT - Argentina

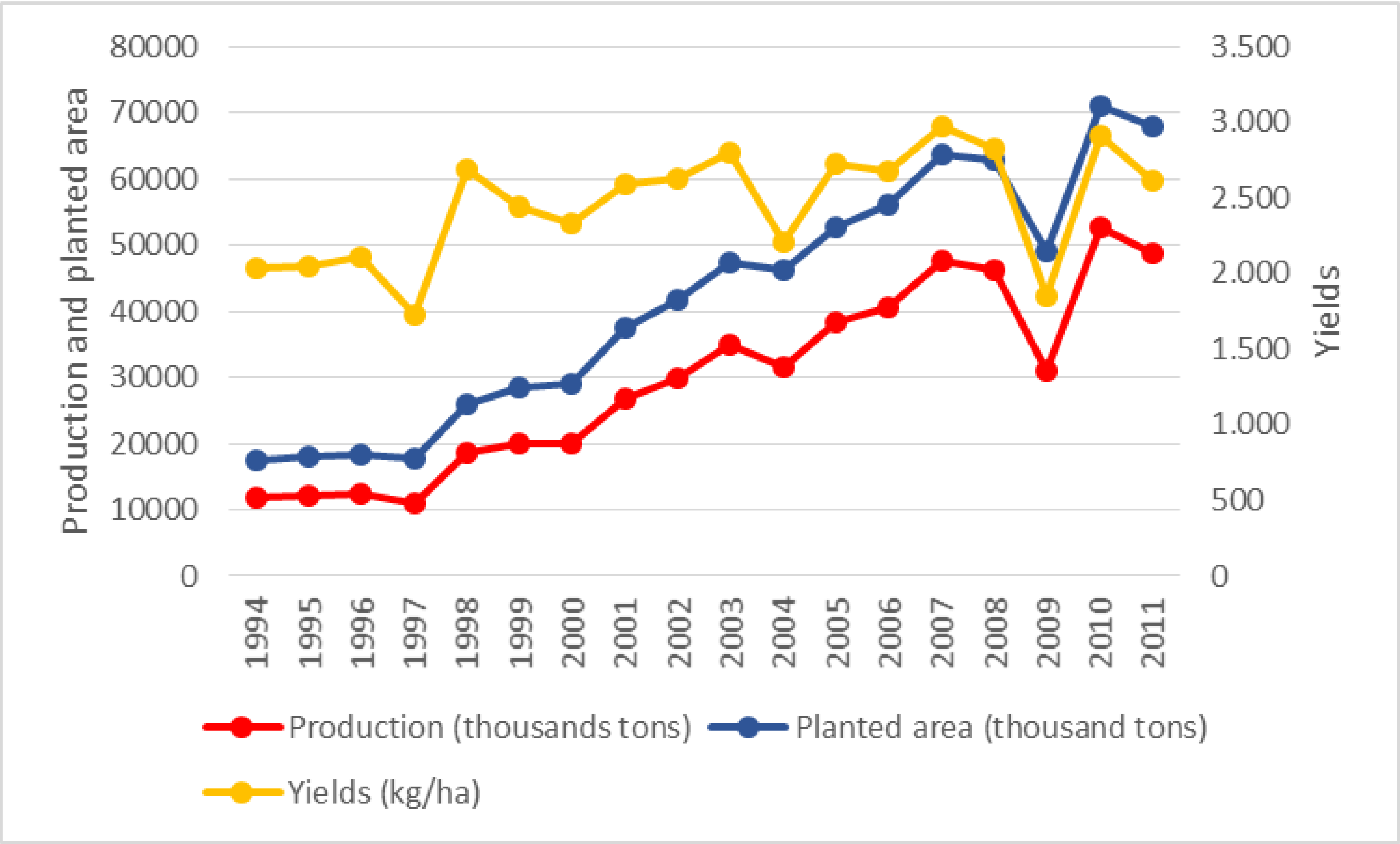
Background

- Argentina is a world leader in agricultural production
- It was one of the first countries that introduced GM seeds (in 1996).
- Today is the third country that produces more GM crops in the world
- In 1996 the **RR soybean** was introduced



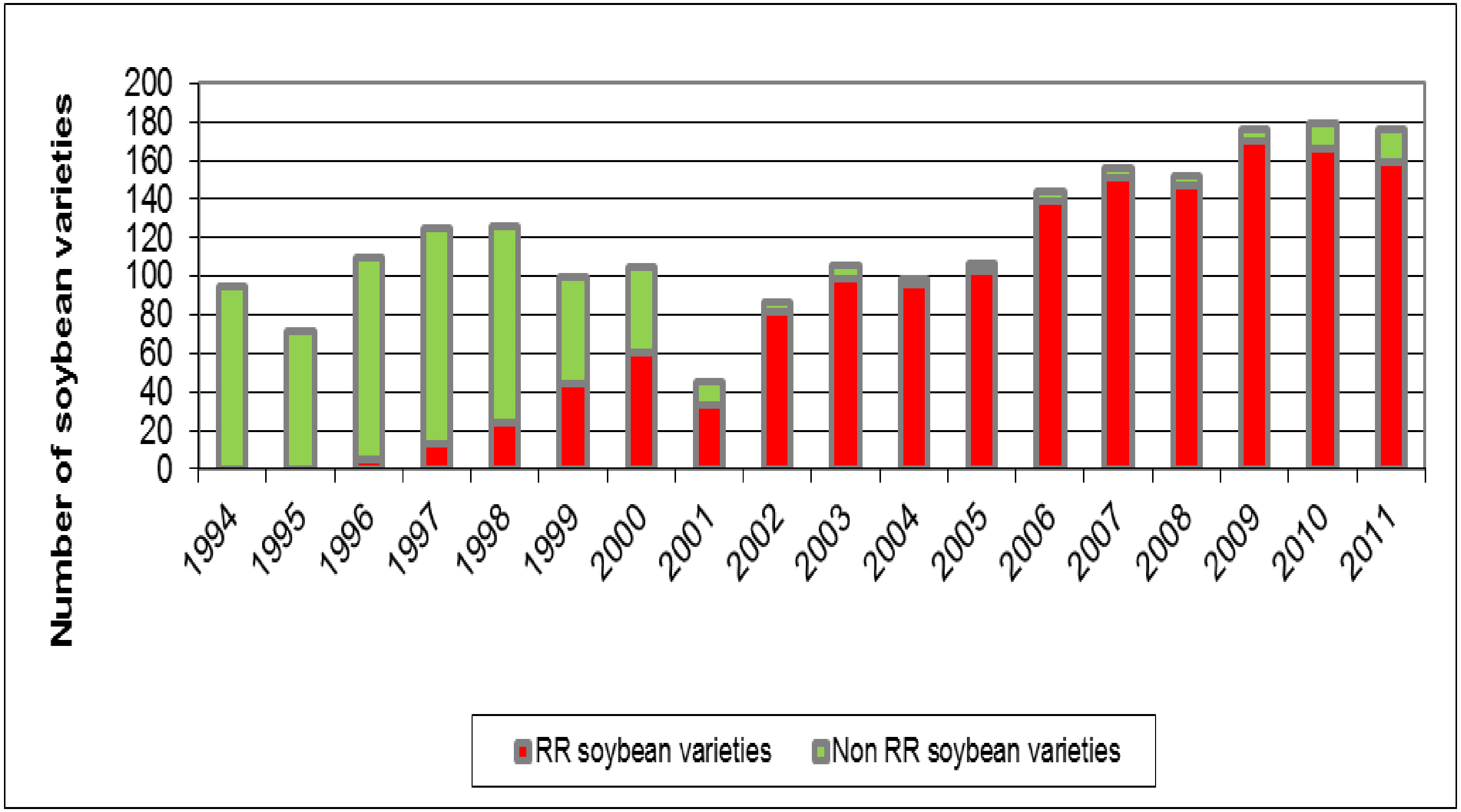
Motivation

Since 1996, production, planted area and yields expanded significantly



Motivation

The Argentinean soybean seed market turned into a <u>transgenic soybean market</u>



One posible interpretation

- Existing analysis of the Argentinean agricultural expansion attribute a prominent role to the diffusion of **GM seeds** (RR trait)
- It is often assumed a **causality** running from “the introduction of GM seeds” to “increases in productivity, land expansion and production”
- This view gives to transgenic technologies a central, driving role by putting the genetic transformation at the centre of innovation process in seeds.

Our analysis: a re-interpretation

We re-examine critically the existing evidence (and interpretations done) of the role of GM seeds in the Argentinean soybean experience.

To do so we:

- Adopt a **multidirectional framework** to understand technological options for seed innovation
- Use more qualitative evidence about seeds innovation in soy seeds in Argentina

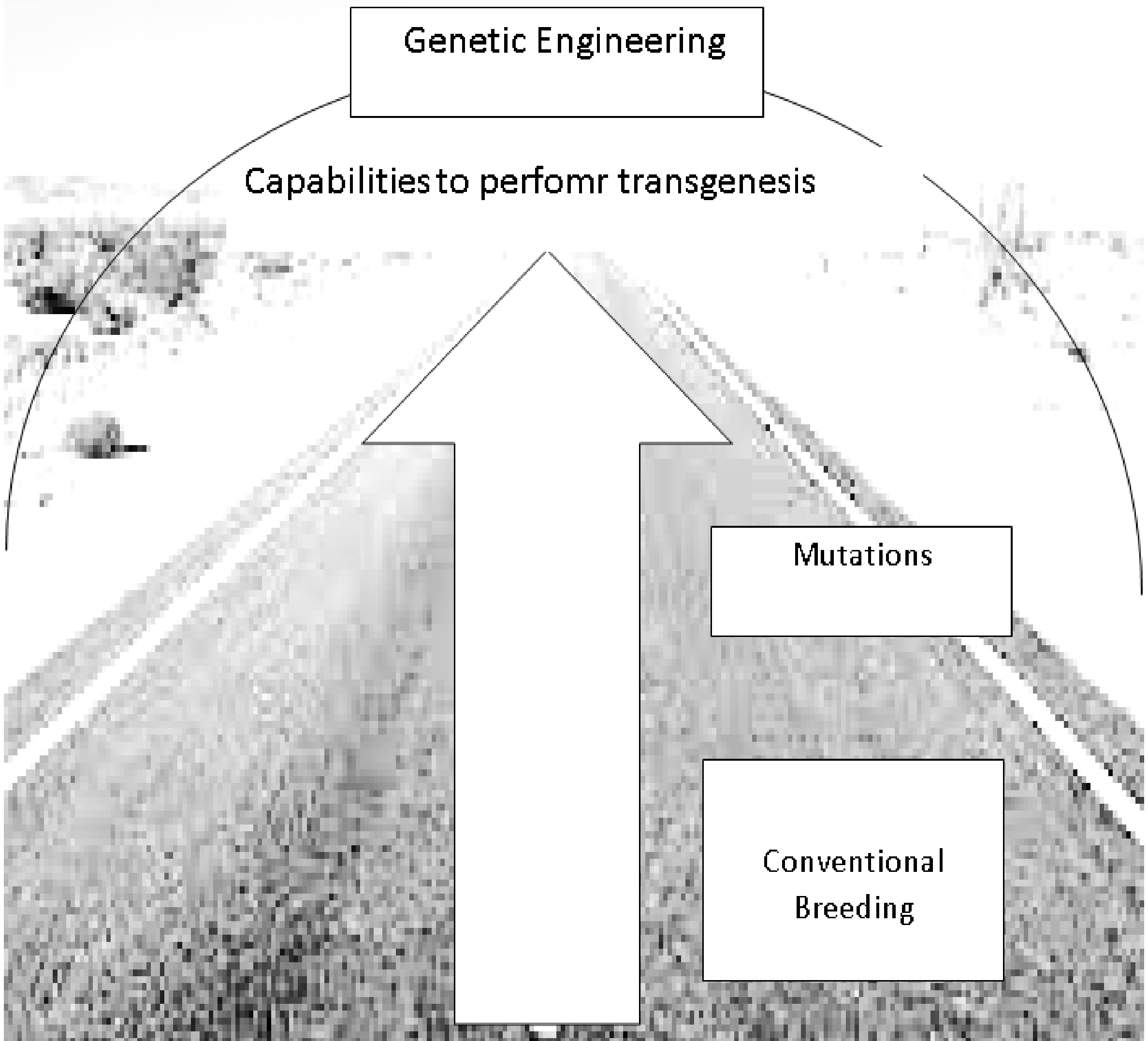
To make things clear..

Seed innovation consists of the identification of desirable plant characteristics and the creation of new plant varieties (or ‘cultivars’) that contain those traits.

Three technologies

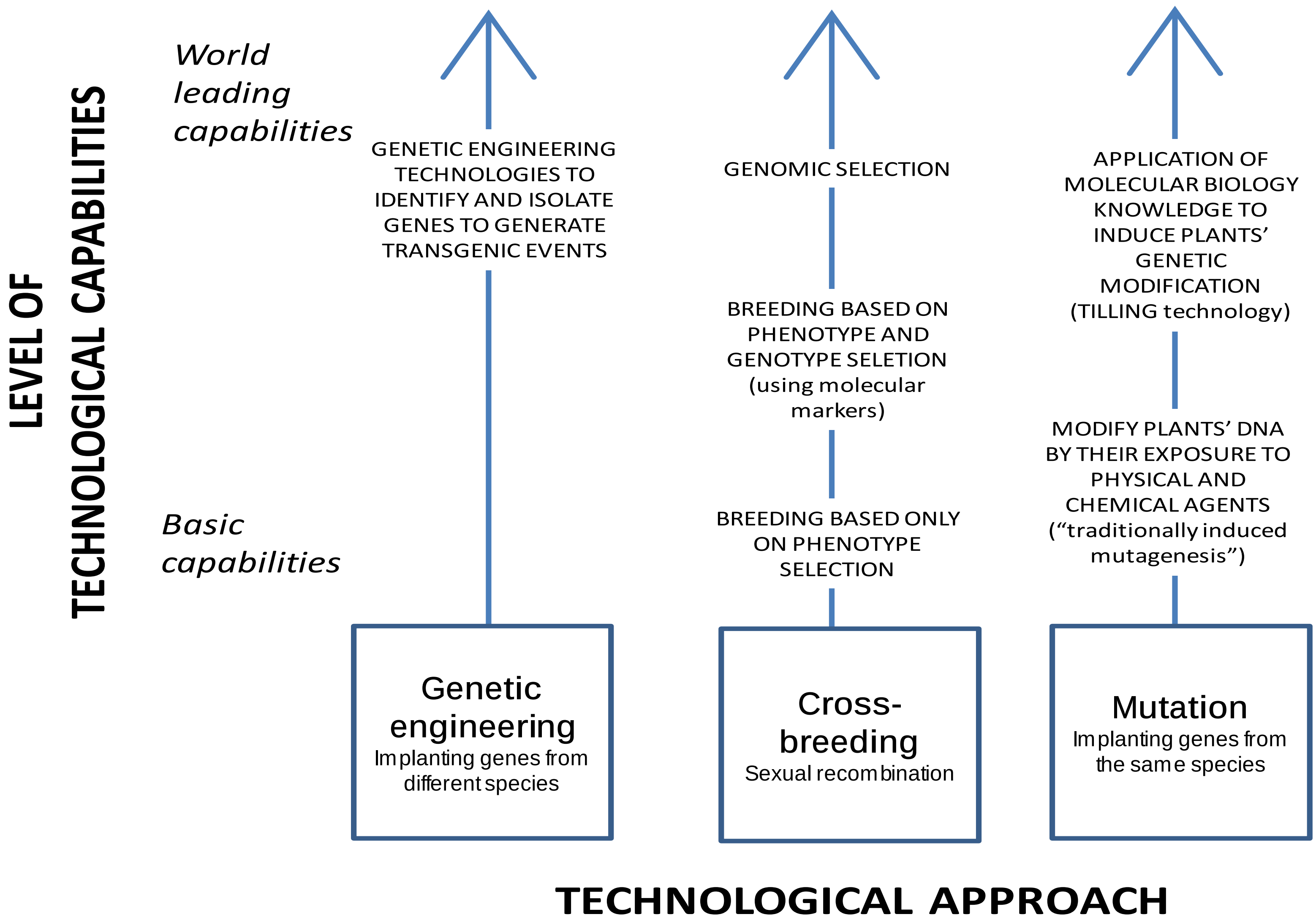
1) Cross-breeding
2) Mutagensis
3) Genetic engineering

Technological options for seed innovation: the unidirectional view



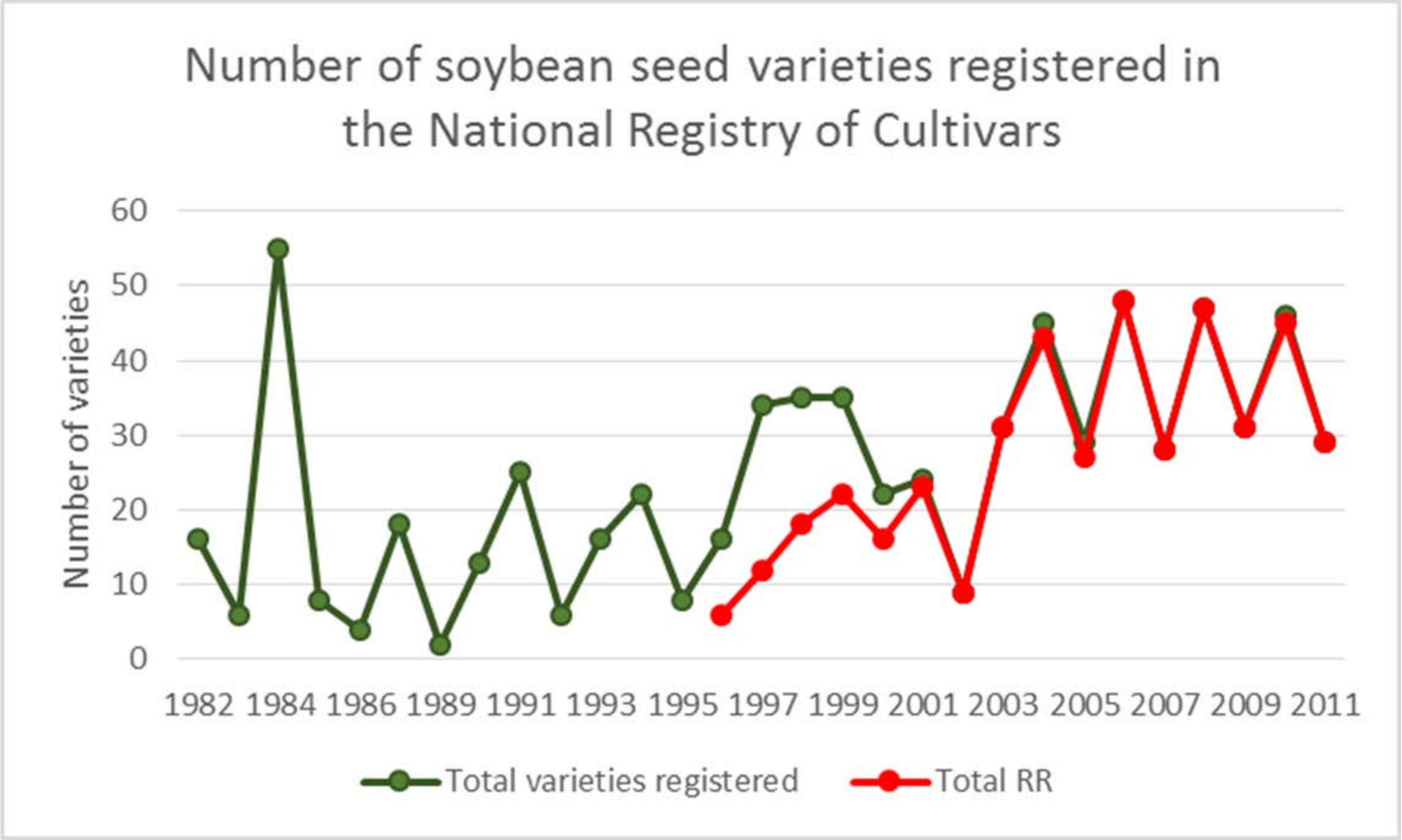
Technological progress as a carrier along an unidirectional fixed path

Technological options for seed innovation: a multidirectional framework



Let´s look at the data again …

The rate of seed innovation expanded significantly
Most soybean IPR registered contain the RR trait (are glyphosate resistant)



Which other characteristics these seeds have?

DIFFICULTY: databases generally identify which seeds are tranasgenic or not, but they do not give more information about these other characteristics apart from the fact that they are distinct.

Qualitative work!!

Innovations

- Disease ressistance

10-15 % of production losses can be attribute to dieseases.

Diaphorte phaseolorum f.sp. Meridionalis

Phytophthora megasperma f.sp. Sojae

Cercospora sojina

Fusarium virguliforme & tucumaniae

Heterodera glycine

Xanthomonas axonopodis

Traits obtained by cross-breeding

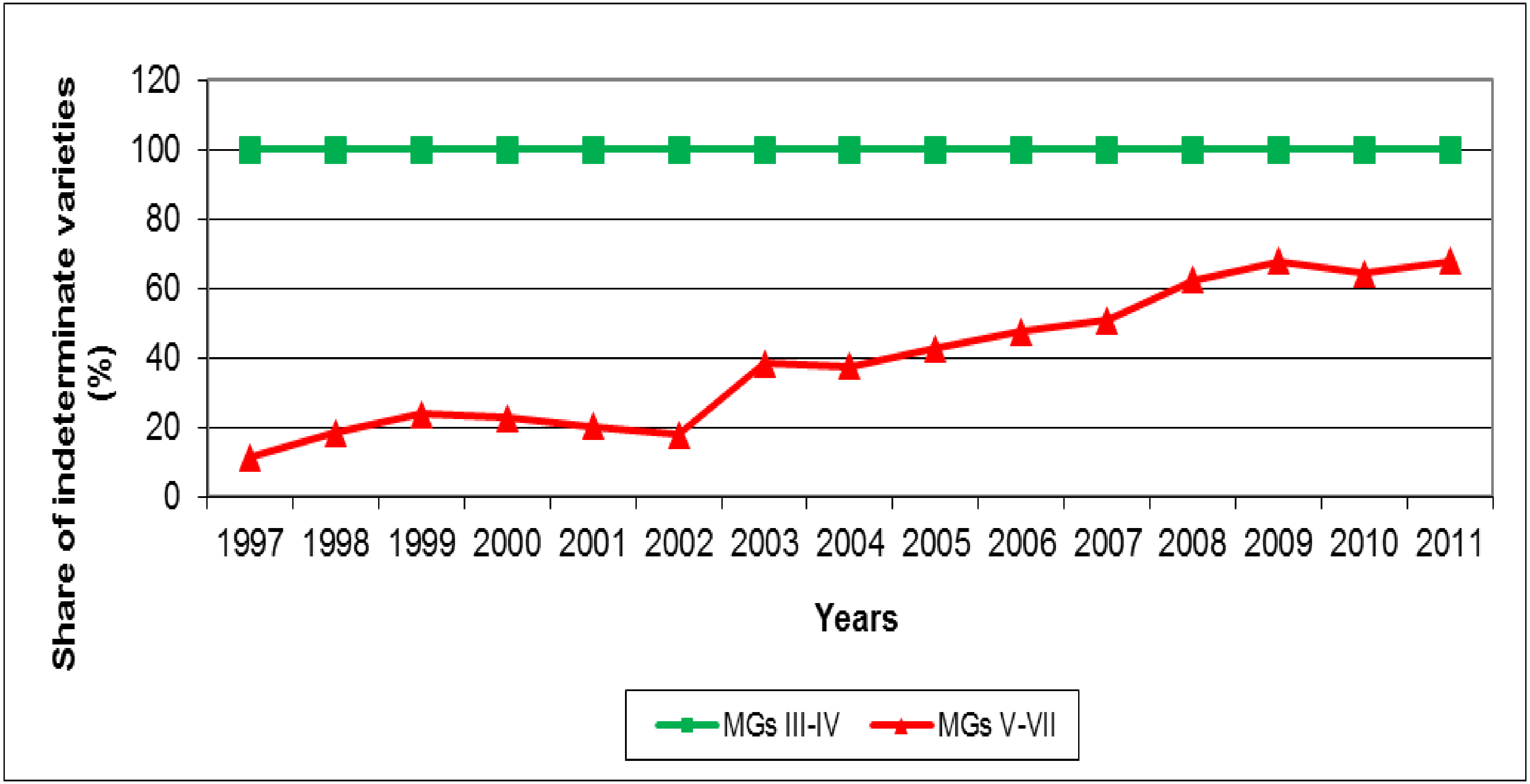
- Changes in growth habits

Cross-breeding

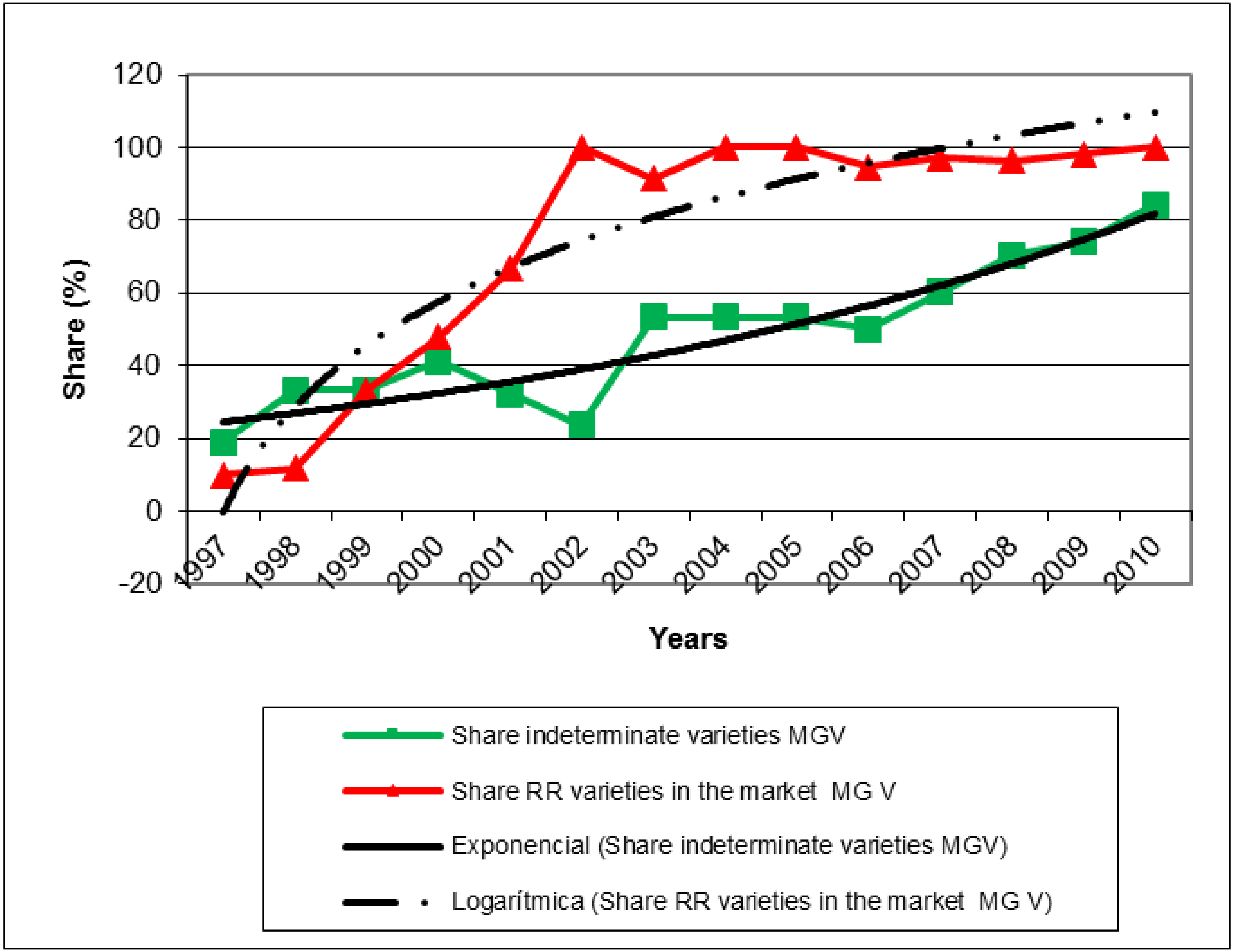
Changing growth habit of soybean varieties

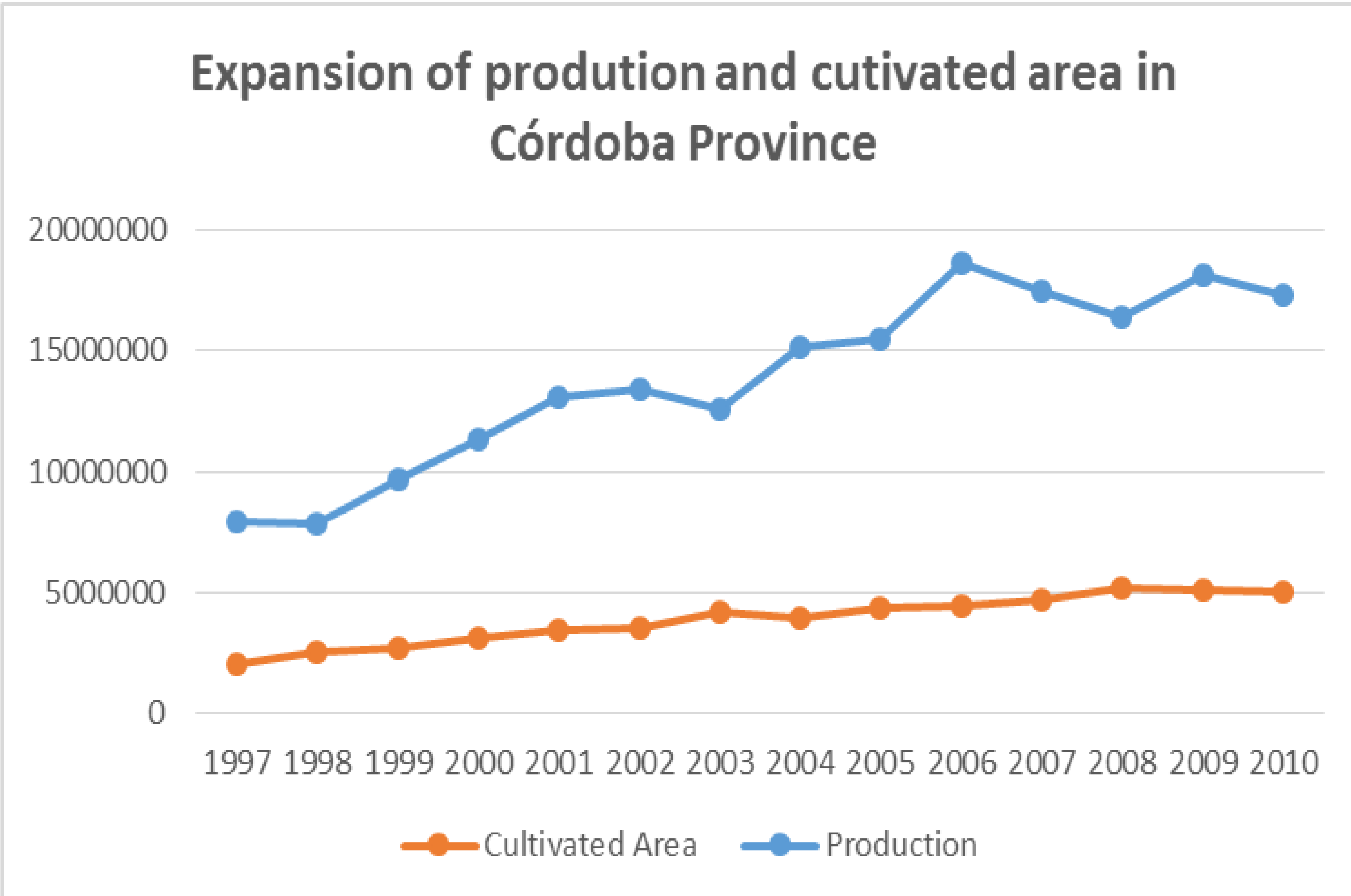
- Soybean plants are <u>determinate</u> or <u>indeterminate</u> varieties.
- Two huge advantages of indeterminate soybean varieties are:
  - They can recuperate after periods of dry weather.
  - They mature early providing time to plant a second crop after soybean is harvested.
- Innovation: to change the growth habit of soybean varieties of MGs V to VII (typically determinate) to inderminate

Share of determinate and indeterminate varieties (1997-2011)



Diffusion of indeterminate and glyphosate resistant soybean varieties in Córdoba province (1997-2010)

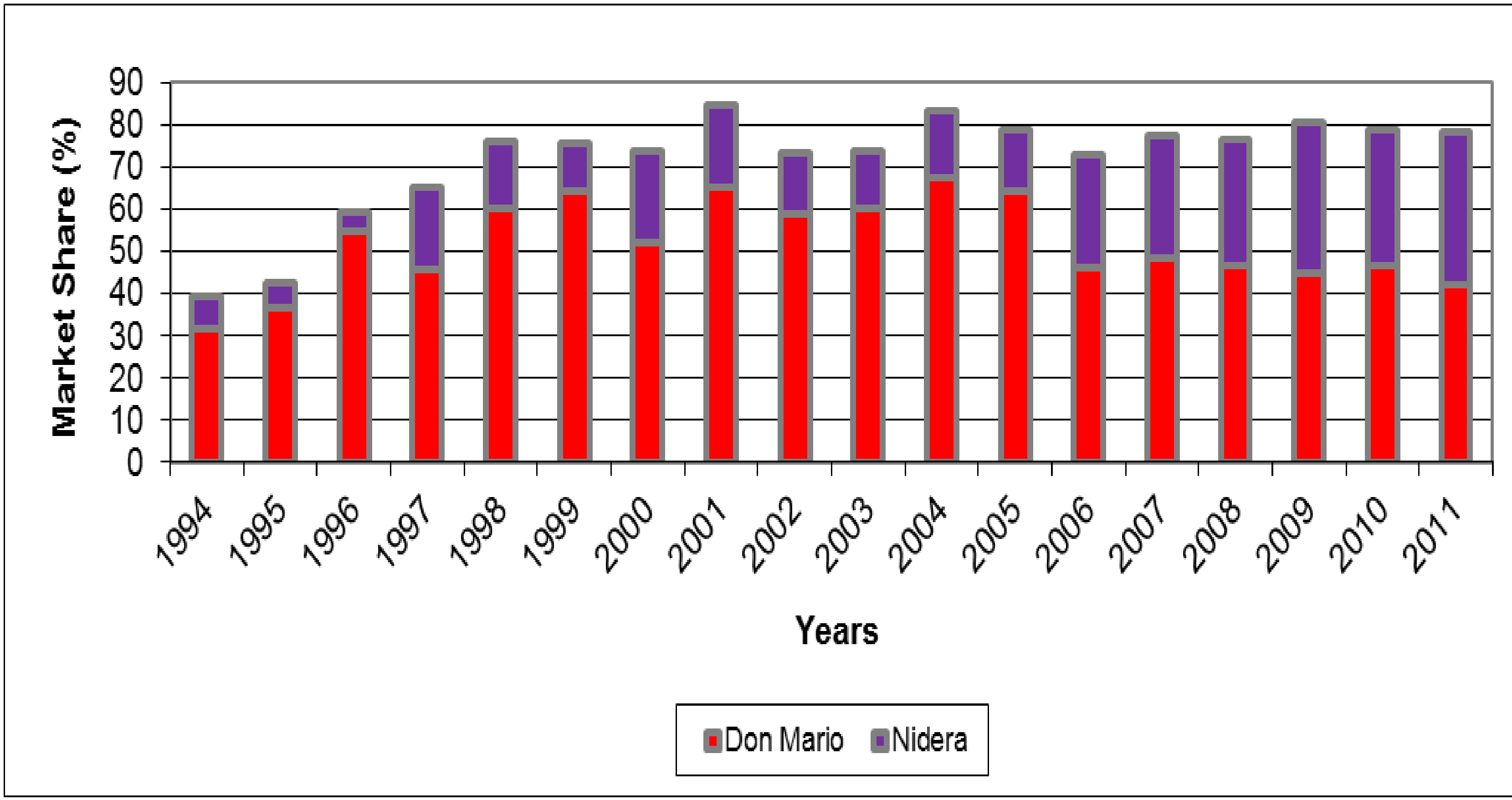



Expansion of prodution and cutivated area in Córdoba Province
20000000
15000000
10000000
5000000
0
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Cultivated Area
Production

Correlations before and after 2002

		Share indeterminate MG VI (ii)	Share RR varieties (GM VI) (iv)
Period 1997-2002			
Contemporaneous	Production	29%	**91%**
	Cultivated Area	20%	**94%**
Lagged 1 period	Production	**46%**	**89%**
	Cultivated Area	**-61%**	**94%**
Period 2002/2010			
Contemporaneous	Production	**46%**	27%
	Cultivated Area	9%	28%
Lagged 1 period	Production	**40%**	28%
	Cultiated. Area	**40%**	28%

Participation of domestic firms in the local soy seed market



Quantify the direct impact of transgenic and non-transgenic innovations on farmers income in the period 1997-2011.

Evidence:

- Soy yields increased by a total of **32%** (an annual average growth rate of 3%)
- The introduction of RR soybeans had **no effect on yields**, but that it has **reduced production costs** (Penna and Lema 2003, Qaim and Traxler 2005)
- The estimate is a reduction in costs of **21 US dollars** per hectare
- Yield increases are explained by:

a) better performing seeds (60%)

b) better performing agronomic practices

(Santos et al 2001, 2004, Schnepf et al 2001, Spetch and Williams 1984).

Table 5: Contribution of seed improvement technological approaches to agricultural performance

Years	Average productivity (tons per hectare) (1)	Gains			Gains explained by germplasm improvements (60 %)		Costs reduction attributed to improvements by RR (dollars per hectare) (7)
		In yields (%) (2)	In tonnes per hectare (3)	In USD per hectare (4)	In yields (5)	In USD per hectare (6)	
1971/72-1974/75	1,46	10	0,130		0,078		
1975/76-1980/81	1,96	34	0,500		0,300		
1981/82-1985/86	2,08	6	0,120		0,072		
1986/87-1990/91	2,05	-1	-0,030		-0,018		
1991/92-1995/96	2,13	4	0,080	19,76	0,048	11,86	
1996/97-2000/01	2,26	6	0,130	27,95	0,078	16,77	20,00
2001/02-2005/06	2,59	15	0,330	79,20	0,198	47,52	
2006/07-2010/11	2,64	2	0,050	21,45	0,030	12,87	
1996/2011		23	0,51	128,60	0,306	77,16	20,00
1981/1996		9	0,17		0,102		
1971/1981		44	0,630		0,378		

Increase in yields

1997 – 2001

- 21 u$s reduction in production costs of transgenic
- 27.95 u$s gain in production due to improvements obtained by non GM approaches

2002 – 2006

- 47.53 u$s gain due to non GM improvements

2007-2011

- 12.87 u$s gain due to non GM improvements

Total GM = 21

Total non GM= 77.16 u$s of all monetary gains

To sum up

The conventional interpretation of the role of GM seeds in agricultural expansion in Argentina has several problems:

- It tends to ignore other contextual factors (i.e. increases in prices)
- Assumes causalities difficult to sustain.

1) assumes that the introduction of the glyphosate-ressistance trait has been the only significant novelty produced through seed innovation over the last two decades
2) It hides (or minimize) the contribution of other technologies to seeds innovation.
3) Attributes to GM benefits that might be derived from other approaches

Our contribution

- Using a multidirectional framework, we examined the possible impacts of the use of different technologies to improve seeds on the soy sector.
- We found that all approaches to seed innovation have resulted in significant innovative outputs. Nevertheless, non-transgenic improvements are more hidden
- We illustrated, by way of an example, how a particular non-transgenic innovation, the introduction of indetermination to soy varieties, is likely to have had significant effects on the performance of soy production
- These findings contrast significantly with widely held views about the central role of seed genetic engineering in transforming the Argentinean soy sector

Implications

One implication of our analysis is that that new evidence needs to be collected to discriminate carefully between the impact of genetic engineering and other seed innovation approaches on agricultural performance.

- Important each technologiey requieres and implies different capabilities, resources, equipment, institutions (IPR), etc.
- because support for one technological approach rather than another is likely to contribute, over time, to lock-in effects, and the crowding out of less well supported (but perhaps potentially better performing) innovation approaches.
- Commitments to a single technological approach may therefore become, at least to some extent, irreversible over time

Thank you!

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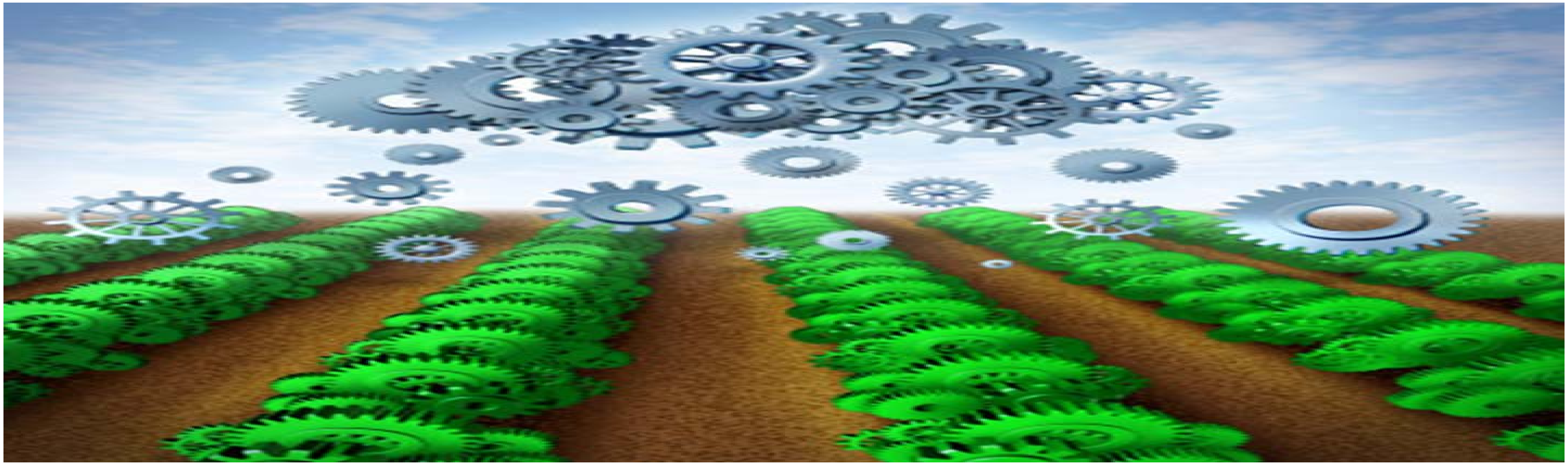
<u>Two reasons</u>:

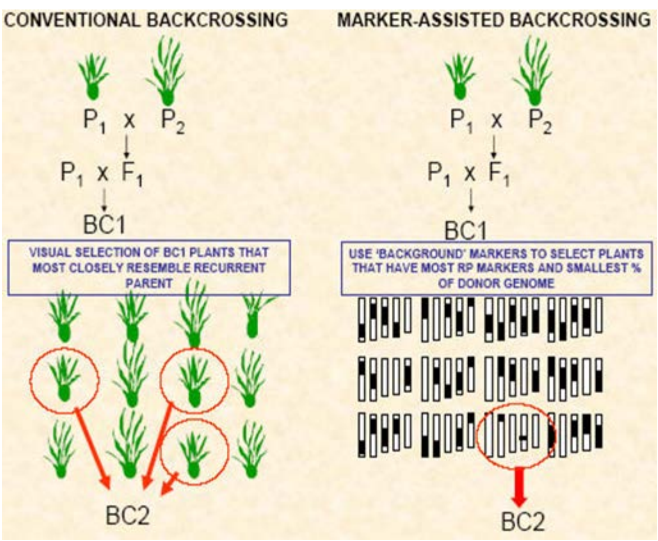


1) Genetic engineering techniques improve the *process* of seed innovation (precision), because it uses advanced scientific knowledge in molecular biology.

2) Genetic engineering can improve the *outcome* of seed innovation because is able to draw on genetic material beyond species boundaries…

Process Improvents?

All technological approaches can use the advances in molecular biology and improve processes (e.g. molecular markers)



Product improvements

A lot of expectatives

Key traits achieved by genetic engineering - for herbicide tolerance, coleopteran pest resistance, *b*-carotene enrichment and delayed ripening - have all been introduced by advanced cross breeding and mutagenesis techniques

Genetic engineering techniques have not yet been able to modify complex ‘quantitative’ traits, such as for yield (that are determined by numerous interacting genes), but such traits can be modified using cross breeding techniques, especially when using advanced genomic knowledge (Fernie et al. 2006).

At then end thus….

- The only evidence of superiority is the body of data, and its interpretations, indicating that genetically engineered crops have already produced very significant benefits for adopters.
- Yet, at least for soy production in Argentina, the ways in which that evidence has been constructed is circular.
  - It assumes the very hierarchical, unidirectional model of innovation - with genetic engineering at 'the' frontier that evidence subsequently appears to justify.

But: Interaction effects

- GM Zero Tillage
- GM dooouble cropping

Data

- The dynamism of soybean seed innovation is based on two types of archival data:
- 1) Registered plant varieties in the National Registry of Property of Varieties(RNPC).
- 2) Plant varieties certified by the National Seed Institute (INASE). The aim of the certifying system is to protect the buyer. We use this dataset so to establish which plant varieties registered under the RNCP have reached the market each year.

- Argentinean IPR system offer asymmetric levels of protection for transgenic seeds and seeds produced using non-transgenic methods.
- Seeds produced using non-transgenic methods are covered by national seed law (aligned with UPOV 1978)
  - This allows the use of protected varieties as an initial source of germplasm for the purpose of creating new varieties, without the need to seek permission or pay royalties.
- Transgenic seeds, are protected by patents on the inserted genetic constructs.
  - Transgenic seeds cannot be used as a basis for further improvement, without a license from their owner.

- The seeds industry INTERESTING: IT faces important unsettling forces.
  - (a) numerous scientific developments in the several knowledge based connected with seeds, such as genomics, which are opening up the potential for new directions of innovation and new ways of solving technical problems;
  - (b) changing and diverse consumer attitudes towards genetic engineered crops; and
  - (c) changing institutions and regulations
- Argentina INTERESTING
  - It is a prominent agricultural producer..
  - It has a one of the biggest seed markets in the world (sixth in the world, after Brazil)

GM and soy expansion in Brazil

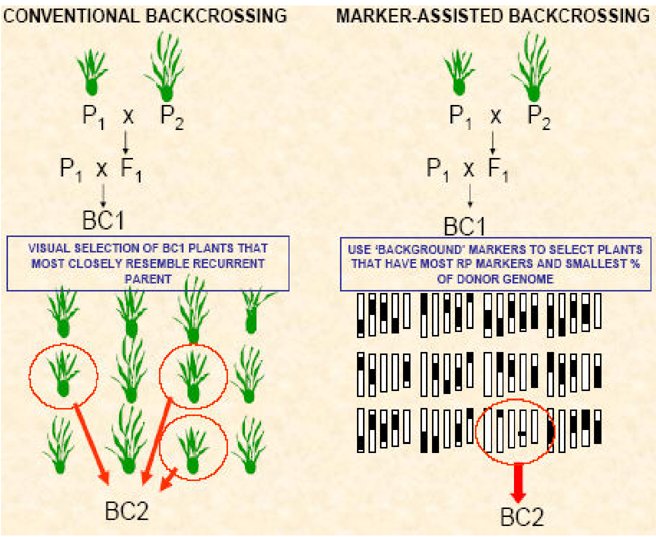
- The slow arrival of gm crops in Brazil allows to explore some issues:
- Until, 2004, Brazil did not approve GM…
- The adoption of gm crops was marginal and confined to Rio Grande
  - Rio Grande became the only state in Brazil where gm soya was the rule rather than the exception by 2004. Because it was an illegal crop, no official statistics of gm crops existed. Estimates ranged from 15% in 1999, to 30% in 2000, to 80% by 2004.

GM and soy expansion in Brazil

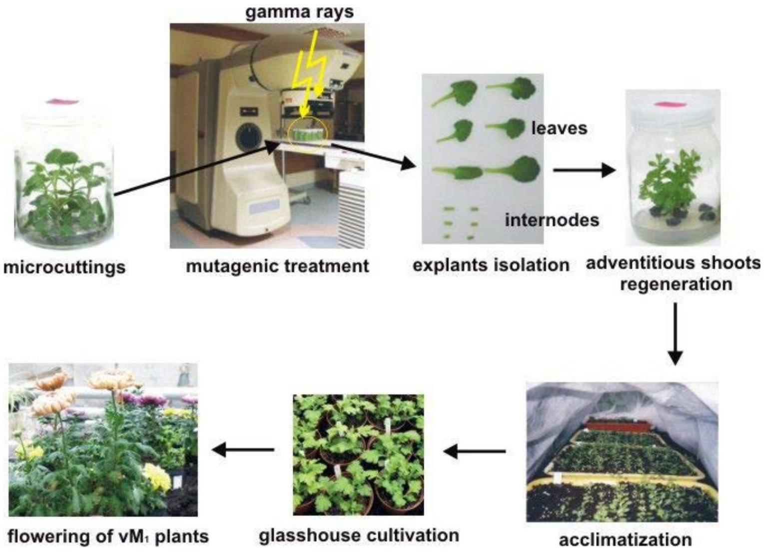
- Other regions without anti-gm policy remained de-facto gm-free and profited from international markets.
  - Soy bean production increased by 160% mainly after 1998, from 23 million tons in 1996 to 51 million tons in 2004. In 1991 it produced 19% of world soya; the USA produced 51%. By 2003 Brazil accounted for 26%, the USA for 34%. Argentina, who adopted gm crops even faster than the USA, doubled its share to 19% of the world production.
- This expansion occurred mainly in the states of Parana and Mato Grosso, accelerating the trend of relocation of soya production within Brazil (Bastiani & Bacha, 2002; Villarim, 2004). It is explained entirely by expansion of traditional non-gm crops for the export market.

Other approaches

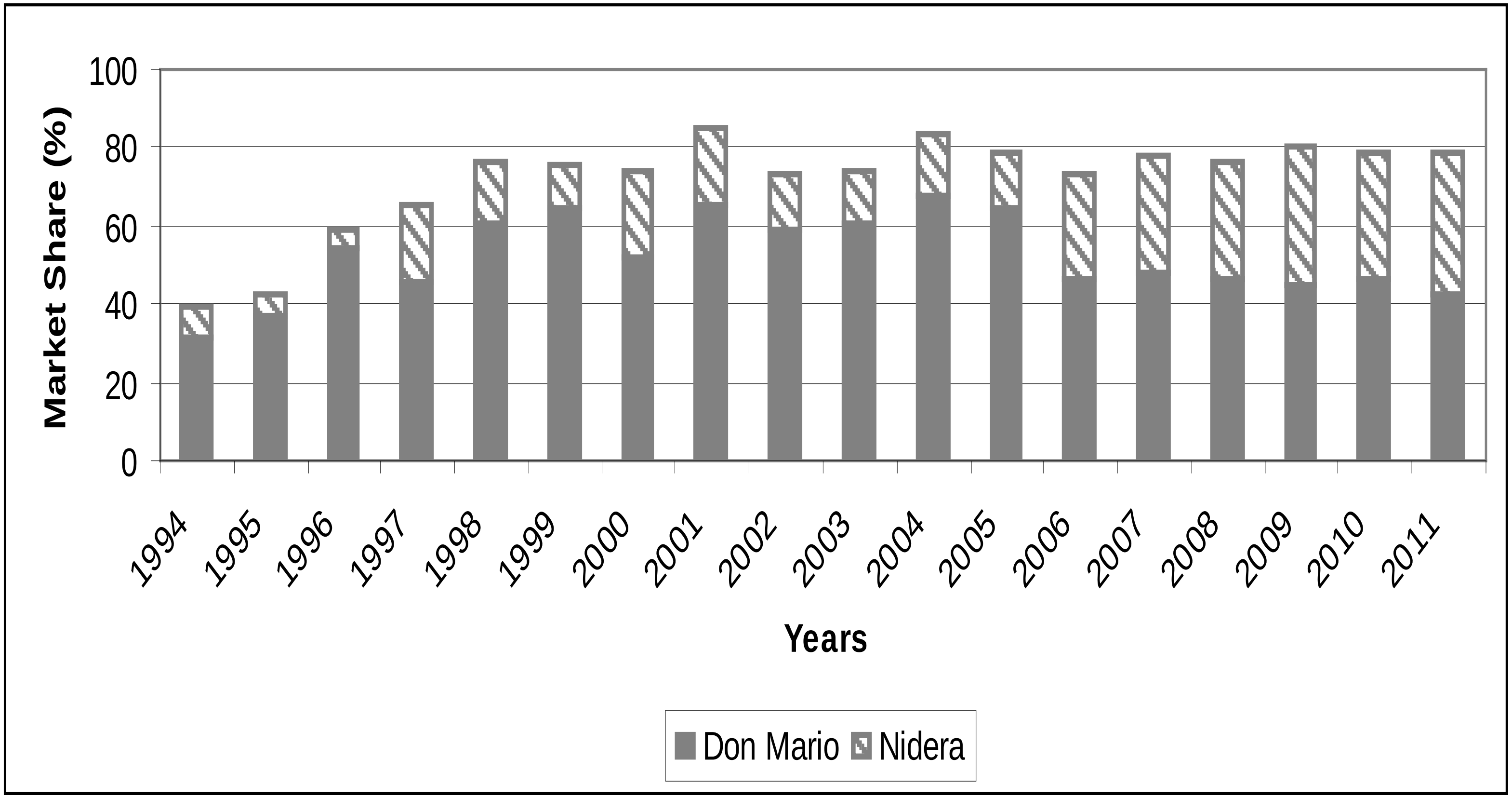
- *Cross breeding*, chooses from available pool of genetic variation, individual plants that contain desirable traits, crosses them, and then selects the progeny for the desired combinations of parental characteristics.



- Mutagenesis: involves artificially increasing natural species variation by exposing an existing plant variety to chemical or physical agents in order to generate random mutants.
  - Some of these will have desirable traits, and these can then be incorporated into conventional cross breeding programmes



Motivation



Two local firms (Don Mario and Nidera) explain capture around 80% of the local soybean seeds market