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Impact of Genetically Modified Crops on Productivity: Way Forward for India

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Abstract: There is a tendency in the policy space in India whether to embrace genetically modified crops as a major strategy to improve agricultural productivity. The scientific claims about benefits of GM crops have been challenged by orthodox farming groups, political parties, and strident NGOs. The paper seeks to evaluate the public policy so far and the debate that centres around the issue of genetically modified crops in India and their merit. It argues that the current agricultural public policy has substantially increased the agricultural production in crops like wheat and rice. However, a country like India would need to widen its range of technological foray to more crops. This will, besides ensuring self sufficiency in food production, will bolster India's foot print in agricultural exports and minimize BOT (Balance of Trade) deficits, particularly vis-a-vis countries like China. The hypotheses that increase in area under GM crops will lead to increase in crops yield has been tested through an inter-country examination of area under GM crops and corresponding yields. Linear regression analysis has been undertaken to determine the co-efficient of correlation, line-of-best fit etc, and the hypotheses is proven. Data regarding Bt cotton in India, GM maize in Portugal, and GM soybean in Brazil have been collected and analyzed to determine the correlation. The paper brings out there is a strong correlation between the area under GM crops and the corresponding yield of the crop. The success of Bt cotton, India's cotton export market is examined and a trend of increasing exports is found through time-series data, and the potential criticism of Bt cotton is addressed. The export market for soybean in Brazil is analyzed through time-series data to show the spillover benefits of the increasing yield on exports. The market for GM maize in Portugal is analyzed and summarized. The paper delineates a course of interventions that can provide a boost to GM crops. The government has recently taken a number of policy initiatives to usher in market reforms and increasing private sector intervention, like dismantling APMC, repealing ECA, encouraging contract farming. The paper strongly argues that the govt. must take one more bold step to encourage application of GM crops, beyond Bt Cotton.

Keywords: *Area, Yield, Bt cotton, GM soybean, GM maize*

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I. INTRODUCTION

The success of the agricultural sector is predicated on three determinants - price, productivity, and public policy. The experience of the commercialization of genetically modified crops in countries over the last two decades is a testimony to the success of the gene revolution in increasing agricultural productivity. The idea of inclusive growth and equity under the regime of genetically modified crops is immensely important for small and marginal's farmers in a country like India, where a large section of the population (85%) still practices subsistence agriculture. Biotechnology has impacted the social and economic life of more than 18 million farmers (80% constituting small and marginal farmers) in countries across all continents. Increase in productivity, lower vulnerability to climate change, self-sufficiency, export competitiveness, conserving biodiversity by reducing deforestation, thus contributing to higher incomes, export revenues, food security, and better social outcomes. However, the agricultural reforms introduced by the government have attached no importance in the development of agricultural biotechnology. The determinants of productivity like irrigation, mechanization, GM crops etc. face neglect and thus translates into a low productivity, which decreases the export abilities and competitiveness of the country [1].

The adoption rate of GM crops throughout the world has experienced exponential growth over the last two decades. The growth has catapulted in countries from Latin America, Asia, and Africa who have substantially and consistently increased their area under GM crops over the years of commercialization. The early years of commercialization were dominated by industrial nations who witnessed a steep increase in adoption rates, however, low income and agrarian economies like India, Pakistan, China, etc. have also increased their acreage of these crops (ISAAA) [2].

Although Bt cotton has been able to successfully augment cotton productivity in India, the public debate, controversies, and policymaking fail to benefit from scientific advancements due to unnecessary mass mobilizations, complex legal procedures, and uncertainty in decision-making [3]. Besides, several claims and biased empirical studies undermine the benefits bestowed by these crops in terms of productivity, however, Jagdish Bhagwati, in his book 'In Defense of Globalization', criticized NGOs for rallying around the issue of GM crops without justifiable scientific evidence. Such pressure has hugely shaped the 'precautionary policy 'of the Indian government on GM crops. Arvind Panagariya led Niti Aayog had set GM crops as one of its contingency measures to relieve the agrarian distress in the country, however, there were huge conflicts with RSS, despite scientific backing of the decision.

II. OBJECTIVES OF THE PAPER

The objectives of the paper are as follows:

- To analyze the public debate, policy and regulatory mechanism for genetically modified crops.
- To examine the relationship between GM crops and productivity through econometric analysis in three countries: India (Bt cotton), Brazil (GM soybean) and Portugal (Bt maize) and analyze the impact of these crops.

III. RESEARCH METHODOLOGY

To traverse the research question, data of area under GM crops and yield were collected and compiled from FAOSTAT and ISAAA Briefs [4]. The data was analyzed and plotted using IBM SPSS Statistics software. The transpiration of secondary research came mostly through the research publications and journals related to public debate on GM crops and, government mechanisms. Sources like reports on GM crops, annual report and evaluation reports helped in analyzing socio-economic impact and yield changes. Newspaper articles have been used to delineate the course of debate, extract opinions of

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eminent economists and various agencies. Books like 'In Defence of Globalisation', 'Governing the GM Crop Revolution: Policy Choices for Developing Countries' etc. has been used for the research [5].

IV. PUBLIC DEBATE AND PUBLIC POLICY ON GM CROPS

Public Policy

The course of public policy towards GM crops is a testimony to the apprehension of Indian farmers about the loss of indigenous verities, activists, and NGOs about ineffectiveness and health concerns, rampant illiteracy, and a lack of sound agricultural research infrastructure. The Indian debate on GM crops is the result of a dynamic interaction between legal, environmental, agrarian, political forces, etc. on the subjects of globalization, liberalization, modernization, etc. The experience of GM crops shows the rampant prevalence of governance failure and exacerbation of the seed crisis through the creation of parallel or underground markets that frustrate the objectives of regulations and farmers fall prey to unscrupulous seed companies charging exorbitantly high prices for the biotech seeds.

India's gene revolution was started as the Indian government formulated a New Seed Development policy in 1988, possible through funding of US $150 Million from the World Bank on the pretext of deregulation of the industry and encouraging the penetration of the market dynamics. As a signatory to the Cartagena Protocol on Biosafety Clearing House and other institutions, India is required to assess the issues concerning GM crops through creation of specialized mechanisms and institutions. The GM crops in India are regulated by the Environment Protection Act (1986). Under the framework, RCGM (Review Committee on Genetic Modification) and GEAC (Genetic Engineering Approval Committee) was formed under the supervision, funding, and control of the Ministry of Environment and Forest, and Department of Biotechnology for regulating the industry. They are involved in the approval of the Institutional Bio-safety Committee and were put into place to look into the applications, forward records to NBC (National Bio-safety Committee) for information collection. After the approval, companies can conduct field testing at sites and gather data, analyze results under the monitoring of SBCC (State Bio-safety Coordination Committees) and DLC (District Level Committee). RDAC (Recombinant DNA Advisory Committee) functions as an advisory under this framework.

The gene revolution in India was initiated by the US-based biotechnology firm Monsanto, which sought to express its interest to forge PPPs with indigenous public sector research institutions. The agricultural PPP in Egypt between AGERI, USAID, MSU, and Pioneer-Hi bred has reflected a substantial boost in productivity after the partnership. However, an inherent global skepticism about bio-safety laws, health concerns, stakeholder conflict, and political agendas has stunted that path for GM crops. The anxiety is prevalent in many nations and India is not bereft of it.

In 1998, Vajpayee led BJP government pioneered the penetration of GM crops, approved the commercialization, and released three varieties of Bt-cotton in 2001. This was the foundation of the famous Gujarat model, leading cotton farmers in the path of innovation and prosperity. The government recognized the looming food security and declining productivity growth rates, international pressure from predominantly agrarian economies like China, etc. and led massive public investments in agricultural R&D and offered incentives for private investments in this sector.

Intellectual Property Rights (1998-99) laws concerning GM crops were the core of parliamentary discussion in the 1990s, receiving immense media attention and triggering widespread debate throughout the country. Private companies criticized this Act to be too weak and virtually offered no protection to while NGOs expressed their apprehension of the corporates seizing control of improved farm practices, which have been followed over thousands of years. India is the only country where intellectual property laws have caused problems for the farmers in the effort of offering protection, and do not prevent farmers from saving or selling seeds in various degrees. Without such protections, several seed companies in India prefer the importation n hybrids because they lose their genetic stability when their seeds are replanted, as opposed to open-pollinated varieties. This miscalculated step has forced the farmers to repurchase seeds each year, thus protecting corporate revenues.

The proposed draft Biotech policy is an unprecedented move of the government that attempts to speed the process of approvals for commercial cultivation of GM crops through a systematic dismantling of unjustified regulations and requirements, reducing the constraints of trials and impact assessment on various stakeholders. The regulatory authority for biotechnology supervises genetically modified crops. The institute was first proposed under the Biotechnology Regulatory Authority of India (BRAI) draft bill of the Department of Biotechnology in 2008. This is an autonomous body, created to specifically all issues concerning biotechnology in India, and as a signatory to Cartagena protocol, the setting up of an independent regulatory body reduces the complexities and independence from political agendas and pressure group mobilizations.

In 2006, Andhra Pradesh imposed a ceiling (price control) of Rs.750/- on Bt cotton seed price in Andhra Pradesh to increase its affordability and accessibility to the vast population of small and marginal farmers. Some other states followed the suit, with adoption rates recording an increase of 192% over the previous year. The corresponding increase was 63% in 2007, and 23% in 2008. However, private companies might face lesser incentives to invest in further research and the market disequilibrium could thus reduce the supply. This might create underground markets to cater to the demand of the farmers, who are dissatisfied due to under allocation of resources for the production of the good. Thus, the hampering of profit margin to these companies should be avoided in a situation where there is inadequate successful indigenous research in agriculture.

In 2006, the state government in Andhra Pradesh filed a lawsuit against Monsanto under Monopolies and Restrictive Trade Policies (MRTP) Act, accusing the company of maintaining excessively high-profit margins, where a packet of 450gm sold at Rs.1850 of seeds yielded a royalty of Rs.1250. This was a very high margin for the company in comparison to the price charged in the US and other countries. This highlights the need for market regulators in the seed industry to ensure that these suppliers don’t exploit farmers. This is an urgent issue because the lack of credit is widespread; pushing farmers into the debt trap and poverty cycle, thus an increase in the price of inputs would be very expensive for the economy. This suit was followed by other Indian states like Karnataka, Sikkim, Uttarakhand, Meghalaya, Kerala, etc. in a bid to strengthen their agricultural policies, including prioritization of organic farming. The articulation of alternative state-level policies forced the central government to makes changes in its budget allocation. Inter-state dissimilarities on agricultural policy have translated to uncertainty and non-uniformity in terms of acceptance of the technology. This indicates that the mere existence of a central regulatory body for GM crops fails to involve the states' participation in the adoption of agricultural biotechnology and relies on various other political and economic priorities of the respective governments [6].

In 2016, the pursuit of strengthening the bio-safety regulatory system in India led the Genetic Engineering Appraisal Committee (GEAC) of MOEF&CC to prepare and release a new guideline titled “Guidelines for the Environmental Risk Assessment of Genetically Engineered Plants” 2016 emphasizing the importance of proper assessment of environmental effects. In early 2016, the project has

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also released the manual on the "Monitoring of Confined field trials of Regulated Genetically Engineered (GE) Plants" inorder to improve the capacity of researchers and regulators to conduct field trials of biotech crops in a specified way [7].

Contrarian Views

Activists opposing GM crops like Vandana Shiva etc. have been vocal about the whitefly infestation of bt-cotton, increasing rural indebtedness and other failures but they fail to account for other agricultural inputs brought through subsidies have been hampered to cuts in subsidies and other climatic factors. Sukhal Singh of Punjab agricultural university undermines this argument on the grounds of a lack of consideration of the resistance from Bollworm offered by the varieties. A study conducted by Karl Haro von Mogel, who compiles a database of GMO studies at the website Biofortified found that a substantial number of independent studies also concluded consistent outcomes. Besides, the concerns of health risks have been repeatedly dismissed by scientific research, deeming GM crops to be safe for human consumption. According to Megan L. Norris in the Molecular, Cellular, and Organismal Biology Program at Harvard University, "After more than 20 years of monitoring by countries and researchers around the world, many of the suspicions surrounding the effects of GMOs on organ health, our offspring, and our DNA have been addressed and tested. Though each new product will require careful analysis and assessment of safety, it appears that GMOs as a class are no more likely to be harmful than traditionally bred and grown food sources".

In the 1990s, after facing a setback from the Congress-led government, Monsanto bought 20% stakes in a Maharashtra-based biotech firm, Maharashtra Hybrid Seeds Company or MAHTCO, with the department of biotechnology permitting the commercialization of Bt-cotton. However, these efforts suffered a backlash due to farmer riots and protests in cotton-growing areas like Andhra Pradesh, etc.

In 2009, Bt Brinjal was forwarded for commercial release after field trials, but the apprehension again took over the entire country. Jairam Ramesh conducted a large number of consultations and public hearings with respective stakeholders, and termed the 'public sentiment to be negative', thus calling for a ban on the commercial release. However, the changing attitude towards modernization was still visible, with several academicians like scientists, economists, etc. involved in drafting reports on GM crops. However, citing biased influences in the report, a moratorium was imposed on the commercial release of Bt brinjal. Ironically, Bangladesh's farmers are cultivating Bt Brinjal whose roots can be traced to India and could not be used for ideological opposition. It has been also seen that there is a steep rise in the cases of illegal smuggling of GM seeds from other countries in the presence of unjustified and stringent law enforcement that punishes and fines farmers who illegally produce them [8].

The IPR policies have won populist support due to mass mobilizations by NGOs which are trusted by people more than the government and corporations. These policies can be categorized as 'preventive' and successfully dissuades companies from bringing in new varieties, and have so far brought only hybrid GM varieties to the Indian seed market. Besides, international organizations like Amnesty International, Greenpeace, Centre for Sustainable Development, Deccan Development Society, etc have conducted empirical studies in various regions of the country and undermined the environmental, economic, and social impact of Bt cotton. However, it cannot be forgotten that these NGOs seek media attention and might be able to generate a lot of publicity through taking part in the Indian agricultural debate, one of the most highly politicized areas and benefit from the presence of high illiteracy and low awareness among farmers.

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V. INTER-COUNTRY ECONOMETRIC ANALYSIS

Linear regression is used for determining the relationship between the area under GM crops and corresponding yield in three countries – India (Bt cotton), Brazil (GM soybean), and Portugal (GM maize).

The general formula for the regression model is shown as follows:

$$E(Y/Xi) = \beta 1 + \beta 2Xi$$

Pearson's coefficient or 'R' was calculated to determine the correlation between the variables. It was calculated using the formula:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

India

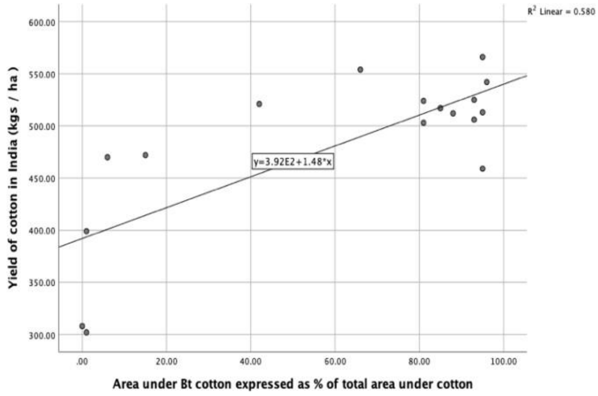
The table shows the area under Bt cotton expressed as % of total area under cotton and the yield of cotton in (kgs/ha) from 2001-2018.

Table 1: Area under Bt Cotton & Yield of Cotton in India (2001-2018)

Year	Area under *Bt* cotton expressed as % of total area under cotton	Yield of cotton in India (kgs / ha)
2001-2002	0	308
2002 - 2003	1	302
2003 - 2004	1	399
2004 - 2005	6	470
2005 – 2006	15	472
2006 - 2007	42	521
2007 – 2008	66	554
2008 - 2009	81	524
2009 - 2010	81	503
2010 – 2011	85	517
2011 - 2012	88	512
2012 - 2013	93	525
2013 – 2014	95	566
2014 - 2015	95	513
2015 - 2016	95	459
2016 - 2017	96	542
2017 - 2018	93	506

Source: Data compiled by author from ISAAA Briefs and Cotton Corporation of India

Figure 2: Linear Regression of Area under Bt Cotton in India



Here, Y is the dependent variable (yield). β1 and β2 are the unknown values but fixed parameters representing the Y- coefficient and slope respectively. Xi represents the independent variable or the area under Bt cotton as a percentage of total area under cotton.

The simple linear regression was calculated to predict yield of cotton in hg/ha based on area under Bt cotton in India. A significant regression equation was found ($F(1,15) = 20.179$, $p < 0.000b$), with an R^2 of 0.580. The yield of cotton is equal to 392.055 + 1.479 kg/ha when area under Bt cotton is measured as a percentage of total area under cotton. This leads to the conclusion that average yield increased by 1.479 kg/ha for each increase in percentage of area under Bt cotton. The equation of the line of the best fit is:

$$Y = 392.055 + 1.479Xi$$

The line of best fit in the scatterplot suggests a positive correlation between the two variables with an upward sloping curve. Here, $\bar{x}$ represents the mean of area under bt cotton as % of total area under cotton and $\bar{y}$ represents the mean of yield of cotton. The R value or Pearson's coefficient of +0.762, greater than the value 0.7 show a very strong positive correlation between β1 and β2.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.762[a]	.580	.552	51.68439

a. Predictors: (Constant), Area under Bt cotton expressed as % of total area under cotton

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ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	55345.802	1	55345.802	20.719	.000[b]
	Residual	40069.139	15	2671.276		
	Total	95414.941	16			

a. Dependent Variable: Yield of cotton in India (kgs / ha)

b. Predictors: (Constant), Area under Bt cotton expressed as % of total area under cotton

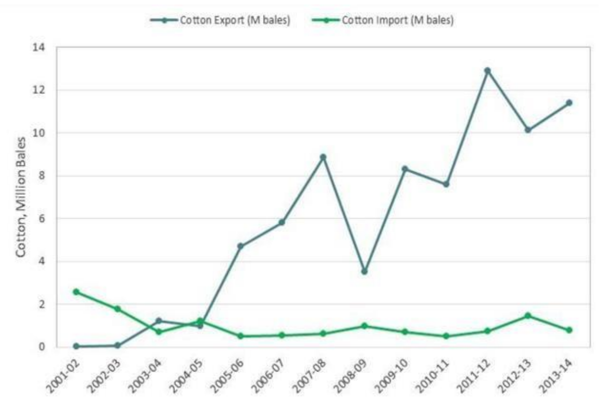
Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	392.055	23.390		16.762	.000
	Area under Bt cotton expressed as % of total area under cotton	1.479	.325	.762	4.552	.000

a. Dependent Variable: Yield of cotton in India (kgs / ha)

It can be seen that cotton production has experienced an exponential boom, skyrocketing India to the largest cotton producer in the world. The graph shows a massive and steep increase in the cotton exports of India. The increase in exports with a constant level of import of cotton stresses on the improvement of export competitiveness in the international market, facilitating a higher import demand from other countries. India has catapulted to the position of the largest cotton exporting country with cotton export ranging between 8 to 12 million bales over last few years (ISAAA).

Figure 2: The Cotton Export and Imports of India (2001-2014)



Source: Cotton Advisory Board, 2014, Analysed by ISAAA, 2014

Brazil

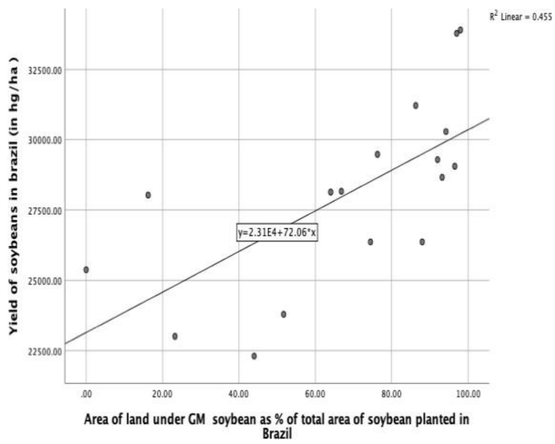
The table shows the area under GM soybean expressed as % of total area of soybean planted and the yield of soybeans in (hg/ha) from 2002-2018.

Table 2: Area of Land under GM Soybean and Yield of Soybeans in Brazil (2002-2018)

Year	Area of land under GM soybean as % of total area of soybean planted in Brazil	Yield of soybeans in brazil (in hg/ha)
2002	00.00	25379
2003	16.20	28027
2004	23.21	23005
2005	44.00	22303
2006	51.70	23796
2007	64.00	28133
2008	66.83	28162
2009	74.48	26365
2010	76.3	29475
2011	86.3	31214
2012	88	26366
2013	92	29285
2014	93.2	28659
2015	94.2	30286
2016	96.5	29049
2017	97	33785
2018	98	33903

Source: Compiled from ISAAA briefs and FAOSTAT

Figure 3: Linear Regression of Area under GM Soybean in Brazil



Here, Y is the dependent variable (yield). β1 and β2 are the unknown values but fixed parameters representing the Y- coefficient and slope respectively. Xi represents the independent variable or the area under GM soybeans as a percentage of total area of soybean planted in Brazil.

The simple linear regression was calculated to predict yield of soybean in hgs/ha based on area under GM soybean in Brazil. A moderately high regression equation was found (F (1,14) = 12.744, p <0.003b), with an R^2 of 0.477. The yield of soybean is equal to 21883.592 + 87.506 hg/ha when area

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under GM corn is measured as a percentage of total area of harvest. This leads to the conclusion that average yield increased by 87.506 hg/ha for each increase in percentage of area under GM corn.

The equation of the line of the best fit is:

$$Y = 21883.592 + 87.506X_i$$

The line of best fit in the scatterplot suggests a positive correlation between the two variables with an upward sloping. Here, $\bar{x}$ represents the mean of area under GM soybeans as a percentage of total area of soybean planted in Brazil. The R value or Pearson's coefficient of + 0.690, marginally and negligibly less than the value of 0.7 suggests a moderately high relationship between β1 and β2.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.690[a]	.477	.439	2512.23499

a. Predictors: (Constant), Area of land under GM soybean as % of total area of soybean planted in Brazil

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	80428820.3	1	80428820.3	12.744	.003[b]
	Residual	88358545.2	14	6311324.65		
	Total	168787365	15			

a. Dependent Variable: Yield of soybeans in brazil (in hg/ha)

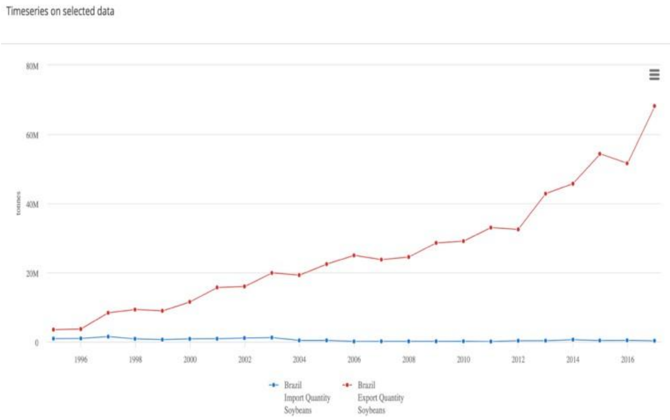
b. Predictors: (Constant), Area of land under GM soybean as % of total area of soybean planted in Brazil

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21883.592	1887.673		11.593	.000
	Area of land under GM soybean as % of total area of soybean planted in Brazil	87.506	24.513	.690	3.570	.003

a. Dependent Variable: Yield of soybeans in brazil (in hg/ha)

Figure 4: Export and Import of Soybean in Brazil (1996-2016)



Source: FAOSTAT

In 2003, Brazil granted the permission for commercialization of GM soybean and accelerated its planting. The time series data on the import and export quantity of soybean shows that the imports have remained fairly stagnant at less than 1 million tonns (with the import equaling to 0.25 million tonnes in 2017) and the exports have increased exponentially over the last two decades, increasing from 3.5.million tonnes in 1995 to 68 million tonnes in 2017. This shows that as the area under GM soybean increased, the exports of Brazil multiplied and thus helping the country is maintaining its current account balance and earning export revenues. This corresponds to a higher export competitiveness and greater farm incomes. In addition to the export demand from China, the huge domestic demand for GM soybean created by biodiesel producers, soybean meal used for livestock has helped in the prosperity of the producers. Favorable climatic conditions, coupled with adequate investments on technology and favorable economic conditions have helped the producers to maintain their high profit margins and maintain the growth rates of productivity, and increase acreage of the crop.

Portugal

The table shows the area under Bt maize expressed as % of total area of maize harvested and the yield of maize in (hg/ha) from 2007-2018.

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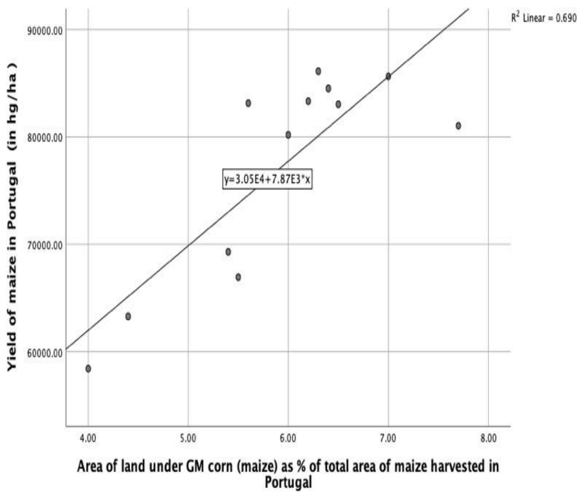
Table 3: Area of Land under GM Corn (Maize) and Yield in Portugal (2007-2018)

Year	Area of land under GM corn (maize) as % of total area of maize harvested in Portugal	Yield of maize in Portugal (in hg/ha)
2007	4.00	58412
2008	4.4	63278
2009	5.5	66936
2010	5.4	69295
2011	7.7	81040
2012	6.5	83042
2013	5.6	83149
2014	6.2	83331
2015	6.4	84520
2016	6.0	80194
2017	6.3	86121
2018	7.0	85640

Source : Data compiled by author from FAOSTAT 2020 , Ministerio de Agricultural y Pesca Alimentacion, Dados Nacionais Republica Portuguesa, EuropaBio and DGAV

Figure 5: Linear Regression of Area of Land under GM Corn (Maize) in Portugal



Here, Y is the dependent variable (yield). β1 and β2 are the unknown values but fixed parameters representing the Y- coefficient and slope respectively. Xi represents the independent variable or the area under GM corn (maize) as a percentage of total area of maize harvested in Portugal.

The simple linear regression was calculated to predict yield of cotton in kgs/ha based on area under GM corn in Portugal. A significant regression equation was found (F(1,10) = 22.231, p <0.001b), with an R^2 of 0.690. The yield of maize is equal to 30490.044 + 7874.331 hg/ha when area under GM corn is measured as a percentage of total area of harvest. This leads to the conclusion that average yield increased by 7874.331 hg/ha for each increase in percentage of area under GM corn.

The equation of the line of the best fit is:

$$Y = 30490.044 + 7874.331\,Xi$$

The line of best fit in the scatter plot suggests a positive correlation between the two variables with an upward sloping curve. Here, $\overline{x}$ represents the mean of area under GM corn (maize) as a percentage of total area of maize harvested in Portugal. The R value or Pearson's coefficient of + 0.831, greater than the value 0.7 shows a very strong and significant positive correlation between β1 and β2.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.831[a]	.690	.659	5706.85901

a. Predictors: (Constant), Area of land under GM corn (maize) as % of total area of maize harvested in Portugal

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	724012674	1	724012674	22.231	.001[b]
	Residual	325682398	10	32568239.8		
	Total	1.050E+9	11			

a. Dependent Variable: Yield of maize in Portugal (in hg/ha)

b. Predictors: (Constant), Area of land under GM corn (maize) as % of total area of maize harvested in Portugal

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	30490.044	10017.706		3.044	.012
	Area of land under GM corn (maize) as % of total area of maize harvested in Portugal	7874.331	1670.082	.831	4.715	.001

a. Dependent Variable: Yield of maize in Portugal (in hg/ha)

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GM crops have been subject to a vast multitude of responses in the EU. Portugal started planting GM maize from 2005, as a part of the European Union, under the leadership of Spain. Although there have been huge leaps in productivity, the area under GM maize has remained highly volatile, experiencing consistent fluctuation. This can be attributed to prevalence of droughts and adverse natural phenomena, as well as changing tastes and preference, identified by an increase in demand of bio-tech free maize by agro-based industries.

VI. WAY FORWARD

The pandemic has very adversely affected the manufacturing and service sector activity of the country. Amidst this recessionary trend experienced by the economy, the Indian agrarian sector remains unaffected and is a silver lining during these adverse economic conditions. India is sitting on a massive reserve of food grains, with a record-high production of 295 million tons in 2019-20, and a prediction of a favourable monsoon this year. The initiative of the finance minister for major structural reforms in agricultural marketing, contract farming and amending EMA are definite steps to bring agricultural sector into the entire panoply of economic liberalisation. However, the issue of price, productivity and vulnerability of small and marginal farmers and agricultural workers remain largely unaddressed. The subject of 'GM crops' remains largely out of focus, with a prevalent ignorance on the importance of yield and agricultural exports. The foregoing article has clearly established that adopting GM crops on a wider scale could bolster India's Productivity in crops like maize, soya bin and millets significantly and help India to become a major agriculture exporter. The slow pace of initiatives in this domain has cost the nation huge yields, which could be used for maintaining current account deficits through exports. As stated by eminent agricultural economist Ashok Gulati, India does not have the luxury to sit on the issue of GM crops, and hence must ensure appropriate policy and market-based initiatives to invest in irrigation, mechanization, GM crops etc. in a bid to achieve higher productivity levels. A large scale production through diversification into other GM crops, other than cotton, will be a major force multiplier to improve agricultural productivity in India. As the eminent economist JM Keynes had observed: The difficulty does not lie in adapting new ideas but in replacing old ideas'. Abdicating old ideas and eschewing irrational fear is the need of the hour in India's policy space for GM crops.

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