DISCUSSION

GMCs, whose genetic constitution is altered by inserting one or more genes from other organisms, are considered as the most successful application of genetic engineering. But it still remains as one of the most ticklish issue our country faces today. Even after a decade of its commercial use in the country as Bt Cotton, high uncertainty governs its efficacy and usefulness. Various direct and indirect potential impacts of these crops on human health, ecology and environment as whole have not been scientifically scrutinized and misrepresented by the interested groups. Both the contesting sides i.e. the proponents and conservationists, have convincing arguments to support their respective stands. Therefore, approval and/or disapproval of any of these, needs to be done with logic and work.

A multidisciplinary research module based on both qualitative and quantitative methods analysed the ecological, social and legal repercussions of GMCs. Several hypotheses on ecological, social and legal aspects were drawn to study these repercussions as outlined in chapter-1. These are re-outlined here.

i) Ecological hypotheses
   a) Vicinity of Bt fields as compared to non-Bt will harbor greater vegetational diversity and density.
   b) There is increased incidence and diversity of insects in Bt cotton fields as compared to non-Bt cotton fields due to reduced pesticide sprays.
   c) Morphological characters also change in Bt cotton on account of its genetic modification, to make it resistant to pink bollworms.
   d) The genetically modified seeds of cotton are more vigorous than the conventional and traditional varieties.
   e) Bt Cotton is claimed to produce toxins which lead to death of bollworm. In other words bollworm that feeds on Bt cotton dies while not on non-Bt cotton.
f) Bt Cotton has been reported to release chemicals in soil leading to expected change in microbial flora and fauna. Thus, it is hypothesized that Bt cotton plants affect the soil physio-chemical characteristics.

g) Field performance of Bt-cotton has been highly varied and debatable across the country. However, Bt cotton gives a better yield than conventional/non-Bt cotton.

h) Since the dispersal of Bt cotton pollen can lead to genetic pollution, it is expected that its pollen is distinguishable from conventional and therefore helps in detecting genetic pollution.

i) Since, genetic manipulation is focused on saving cotton lint from bollworm infestation, it is expected that there should not be any change in lint quality.

ii) Social Hypotheses

j) Scientific community in particular and society, in general, are remarkably divided on their opinions on the issue. There are strong opponents and equally strong proponents of the technology with personalized views on the issue.

k) Indian stakeholders are not knowledgeable enough to decide on the acceptance or use of GM Food. The decision on GM food and products should not surmise on the opinion of layman.

iii) Legal Hypotheses

l) The Legislative/Regulatory framework of India is not crystal clear in dealing with the controversy of GMCs due to lack of adequate scientific base.

m) GMC regulation is highly varied and unharmonious globally. The Precautionary Principle as adopted by E.U. and Substantial Equivalence as a driving force for America doesn't seem to fit Indian conditions in isolation.

n) There are a few binding international legislations on GMCs. All the major GMC producing countries have not ratified to such legislations, leading to un-harmonious GMC regulation globally.

The aforesaid questions raised demand logical answers based on data analysis and research. The results drawn under each hypothesis were analysed using statistical tools and qualitative interpretations. In most of the cases the results were in assertion with the hypothesized statements while it failed in a few cases. Each of this is discussed in the following sections.
**Ecological component**

Out of $1.22 \times 10^7$ ha of land under cotton plantations in India, $0.95 \times 10^7$ ha is under Bt-Cotton (CICR, 2012). It was the only GMC available for ecological analysis and experimentation. Three sets of experimental study on Bt and conventional cotton plants was drawn to estimate the scientific validity of the only commercially grown GMC in the country. The ecological study was outlined as following:

- Field Surveys involving vegetation analysis, study of insect diversity, plant morphology, soil analysis
- Experiments conducted in Lab, Glass house and open field.
- Scanning Electron Microscopic analysis of cotton plant pollen and cotton fibre

**Set 1 Field Survey**

First level of the study aimed at gaining grass-root level data on cotton plantations in the north western belt of the country by extensive comparative field surveys of Bt and conventional cotton fields of Punjab and Rajasthan. The field survey was conducted at three sites in each of the three different villages.

- Site A- Village Rupana, District Mukatsar, Punjab
- Site B- Village Muradwala, District Abohar, Punjab
- Site C- Village Fatuhi, District Ganaganagar, Rajasthan

At each site comparative analysis of the Bt and non-Bt cotton fields was conducted. It included vegetation analysis, insect diversity study, plant morphology and soil analysis.

**Vegetation Analysis**

Vegetational analysis of weeds growing in vicinity of the fields was variable in relative density for various species at all the three sites. At site A (Rupana) *Eleusine indica* was the densest species in both Bt and non-Bt cotton fields with relative density of 31% and 27% respectively. Similarly at site C (Fatuhi) E. indica recorded highest relative density of all the species with 22% higher relative density in non-Bt cotton fields. At site B (Muradwala) *Euphorbia microphylla* was the densest species in Bt cotton fields and *Digeria muricata* of non-Bt cotton fields. Relative frequency of all weeds at the three sites was recorded nearly same for both Bt and non-Bt cotton fields with exception of *Dactyloctenium aegyptium*.
which recorded four times higher frequency in the non-Bt cotton fields of site A (Rupana). It was also the most dominant species of site A at non-Bt fields while *Physalis minima* was the most dominant species of Bt cotton fields of the same site.

The total number of individuals of all the species noted during quadrat based vegetation analysis was nearly double in the non-Bt fields as compared to Bt cotton grown fields. But no statistically significant difference could be drawn for the vegetation analysis between Bt and non-Bt cotton grown fields for any of the three sites. Bt cotton genetically modified for insect resistance reduces the pesticide requirement in the field with no impact on herbicide sprays or weed population in its vicinity. The comparative analysis of Bt and non-Bt cotton grown fields for three survey sites highlighted that the change in vegetation diversity was not governed by Bt or non-Bt characteristic but due to changing agro-climatic conditions of three survey sites. These results were in assertion with earlier studies as reported by Raju (2010).

**Insect Diversity**

Study of flying insect diversity using net sweep method generated raw data. The data when analyzed on Shannon Index, measured low insect diversity in the Bt – cotton fields as compared to non-Bt cotton grown fields at all three survey sites. High values of divergence were observed for Bt cotton filed which entailed to low biodiversity. Highest Divergence was recorded for Bt cotton fields of Sit B (Muradwala) at 0.29 followed by Bt cotton fields of Site C and Site A with 0.19 and 0.11 D-values respectively.

Ironically, the insect diversity was hypothesized to be more in Bt cotton fields due to lesser pesticide sprays. Thus, the efficacy of systemic transgenic toxin produced in Bt cotton plants could be doubted for its specificity. Further, the use of broad spectrum insecticides as observed during field survey in the Bt cotton fields negatively effects insect diversity. Therefore the hypothesis failed. The results so obtained are supported by Chinese research study carried out over four academic institutions. It included laboratory experimentation and field research (Xue, 2002). The study reported the stability of insect community in Bt cotton fields was much lesser than in conventional cotton fields, increasing the possibility of outbreaks of secondary pests in Bt cotton.
Plant Morphology
Comparison of plant morphological characteristics of Bt and non-Bt cotton plants depicted improved morphological features of Bt over conventional plants as these GM seeds are developed by inserting the transgene in best of the conventional variants available (Barwale et al., 2004). Bt cotton transgene releases a toxin in the plant which harms the insect only, where as expectedly the success of this genetic manipulation would be if the plant characteristics do not change. As claimed by the scientists Bt transgene only affects the insect with no phenotypic expression. The quality and quantity of the cotton is indirectly affected due to non-interference of the insect pest. Thus there should be no change in the morphology in terms of height, foliage, foliar surface area, root volume, stem surface area and surface topography. However the results showed that there was a significant increase of 40-70 cm in the height for Bt cotton plants at all the three sites.

The number of leaves was on an average double in the Bt cotton plants than the non-Bt cotton plants. The surface area of leaf was significantly higher for Bt cotton plants while the stem surface area showed no significant difference between the two cotton varieties studied. Root volume was recorded similar for both Bt and non-Bt cotton plants at all three sites. The close examination of the morphological features recorded improved features for Bt cotton plants over non-Bt cotton plants. This result could be deduced as favourable outcome as it will be helpful in easy identification of Bt Cotton plants from non-Bt Cotton plants. But, it could not be ascertained scientifically if the improved morphological features were due to the transgene introduced into the plant. Thus, the hypothesis was proved partially correct demanding more experiments to achieve clarity.

Soil Analysis
Soil samples were collected from every field at three depths and analysed for physio-chemical characteristics, macro and micro nutrients. Soil analysis of all the fields surveyed depicted normalcy in most of the macro and micro nutrients. Soil samples of all the six fields at three survey sites measured alkaline in pH. The electrical conductivity of soil samples from all the Bt cotton fields was higher than the respective non-Bt fields. Higher electrical conductivity of the soil samples of Bt-cotton fields hinted towards the possible presence of more chemicals in ionic form. Higher electrical conductivity affects the integrity of the cell membrane in the rhizosphere aiding the process further. Earlier research studies have determined the release of toxins from Bt-corn, yet there is no available evidence for the Bt-cotton plants (Saxena et al., 1999; Saxena and Stotzky, 2003).
Low organic content of Bt cotton soil samples inferred into lower nitrogen concentration. It hinted towards possible impact of Bt-toxin on the soil micro-biota responsible for maintaining the organic content of soil. These results were in contrast to the findings of Wang et al., (2008) who reported adsorption of the Cry1Ab protein on soils to be positively related to the soil organic matter content. Micro nutrients analysis depicted no anomaly except the non-Bt cotton field of site A (Rupana) which was deficient in Zn, Fe and Mn (Lindsay and Norvell, 1978). This result could not be inferred for any significant comparison with Bt cotton field. Thus, hypothesized impact of Bt toxin on the soil physical and chemical parameters could not be determined as clarity in results could not be achieved. Thus a null hypothesis was drawn.

The open fields of both varieties were indistinguishable visibly. Bt –cotton was mostly grown on large landholdings over two acres, by affluent farmers due to its high input costs. But a marginal increase in the yield of cotton was noted for Bt fields as compared to that of non-Bt cotton fields which diminished with subsequent plantations. The yield of Bt cotton and non-Bt cotton fields as recorded during survey was 8 quintals/acre for the former and 5 quintals /acre for the latter. Interaction with the relevant farmers and traders revealed the fact that the quality of the Bt-cotton was similar to that of conventional cotton and was sold at same price in the market even after higher input costs. The cost of cotton varied from Rs. 45-50/kg and changes with season demand and supply. Ironically the traders in the market are unaware of the source the cotton. Therefore it is only the quantity which is expected to be higher for Bt cotton fields than non-Bt cotton grown fields. These economic implications are further discussed in the section of economic considerations.

Set 2 Experiments
In this set of the research study, comparative data on seed germination, seedling characteristics like radical, plumule, root hair, moisture content and chlorophyll content, plant growth, worm infestation were drawn through scientific methods and statistically analysed. Soil analysis for bulk and rhizosphere samples was also performed. The experimentation was carried out in three phases,

- Phase-I Laboratory experiments
- Phase-II Glass house study
- Phase-III open field trial
Phase-I Laboratory experiments

Laboratory experimentation was done on three varieties of cotton seed namely Bt cotton, non-Bt/Conventional cotton and traditional cotton (Desi kapas). All the seeds were tested for seed viability and then proceeded with experimentation. It involved the analysis of the seed germination and speed of seed germination called as seed vigour. The seedling characteristics were compared for all the three varieties under experimentation. Seed germination study indicated higher seed vigour and seed germination of Bt-cotton (BGII) seeds than the conventional and traditional (Desi kapas) variants. The Bt cotton seeds recorded 90% seed germination within four days of experiment. While, seed germinability of traditional (Desi kapas) seeds was erratic as reflected by extremely large deviation in various seedling characteristics studied. While a comparative analysis of seedling characteristics showed marginal variation for all the three varieties with radical length as the only significant characteristic in decreasing order from Bt cotton (8.3cm) < traditional cotton (5.3cm) < conventional cotton (2.2cm).

There was marginal difference seen in the plumule length, root hair, moisture content and chlorophyll content among the three types of seedlings which was found to be statistically insignificant. Total chlorophyll content was recorded in ratio of 1:2:1 for traditional, conventional and Bt-cotton and was meagerly significant on ANOVA analysis.

Increased seed vigour and seed germination of Bt cotton seeds highlighted the competitive advantage of these plants over the others. Thus genetic modification has affected the seed viability and overall seed germination and or speed of seed germination. In assertion to above results, these GM seeds are developed by introducing transgenes in high seed vigour variants as claimed by biotech companies. Barwale et al., (2004) also studied and reported better seed vigour of various GM seeds as compared to non-GM seeds. Although the hypothesis was proven correct, yet it necessitated the need to conduct planting trials for all the three varieties to examine if the competitive advantage of the Bt cotton seed vigour ameliorates into better vegetative and reproductive potential of the plant.
Phase-II Glass dome/house experiments

The three varieties analysed for seed germination were grown in a glass dome to draw comparative account of plant growth and worm infestation. The plant growth characters like height, leaf surface area, stem surface and number leaves per plant were observed for the three cotton varieties grown. Morphological characteristics like height, number of leaves, stem surface area and leaf surface area were observed to be higher in the Bt cotton plants than other two varieties of cotton plants. Both height and number of leaves of the plant was nearly double for Bt plants than the non Bt plants. These characteristics were found to be statistically significant in comparison. This competitive advantage of the Bt cotton plants have been reported in earlier studies as well (Barwale et al., 2004; Karihaloo and Kumar, 2009). Thus, hypothesis was proven partially correct requiring further experimentation to scientifically validate the results. On comparing the plant growth data as measured in the dome conditions with the field survey conditions it was found that it was statistically more significant at the dome conditions. This could be attributed to the controlled conditions during the dome experiments.

The infestation study of the three varieties of cotton plants was analysed on un-augmented soil without any pesticide sprays. Traditional and conventional varieties were heavily infested as compared to Bt cotton. Degree of infestation was measured on the basis of number of leaves infested, number of worms per plant, number of worms per leaf and infested surface area of leaf. On an average around 27 leaves per plant were infested in traditional cotton and 23 leaves per plant in conventional cotton. Around 2-3 worms were found on every leaf in case of traditional and conventional plants and 33 worms per plant. Leaves of Bt cotton, transgenically modified to resist pink bollworm were observed with minimal infestation. All the characters were reported to be highly significant and proved the hypothesis correct. These findings were in sync with earlier reported studies (Betz et al., 2000; Roh et al., 2007) which highlight the advantage of Bt cotton plants resistance to worm infestation.

Incidentally, even the Bt cotton plants were not observed to be 100% resistant to pest attack as minimal degree of bollworm infestation was recorded on Bt plants. To assess the efficacy of the Bt cotton plant to insect resistance, forced infestation studies were also done. The survival rate of bollworms forced to feed on Bt cotton leaves was noted around 40%. This depicted the actual efficiency of Bt plants and the possible fast and strong evolution of bollworms to the Bt-toxin.
Thus proving that pest resistance in Bt plants was not permanent and the possibility of development of resistance by the pest on subsequent plantations. Other research studies also support this result (Pray et al., 2002; Tabashnik et al., 2008, Tabashnik et al., 2013). Thus, the hypothesis failed as the present advantage of Bt-cotton over worm infestation was a short term gain as the pest soon develops resistance.

Moreover, during glass house studies the ball formation occurred in case of Bt plants as other two varieties were heavily infested. But these balls failed to open till late winters and experiment was eventually aborted. The observation suggests that Bt cotton crop is not 100% pest free and free of pesticide use. It does require pesticide sprays for better yield. The pesticide sprayed may not be against bollworms but other insects.

Detailed analysis of bulk and rhizosphere samples was done for all the three varieties. Bulk and rhizosphere soil analysis samples were taken at the end of the experiment. Limitation of taking the same control for bulk and rhizosphere soil samples form an un-cultivated land devoid of any vegetation was acknowledged. It was to be ascertained if it acted as a good control or not. All the bulk and rhizosphere soil samples had close to neutral pH and fell in normal category requiring no treatment and suitable for all crops (Bates, 1954). The EC was also found to be normal in bulk samples except the Bt cotton bulk sample which was 0.11 seimens/cm (Jackson, 1967). The EC of all rhizosphere samples fell in higher category and was abnormally high for Bt cotton.

The results so obtained followed similar trend as reported in the field survey analysis. Low organic content and high electrical conductivity of Bt samples as compared to other samples supported the earlier results as in section 1.1.4. These findings were relatable to the research studies of Saxena et al., (1999). Saxena and Stotzky (2003) determined the release of toxins in soil from the Bt corn plants. But there is still no evidence on release of such chemicals from Bt cotton plants. Macro and micro nutrients analysed were found within the normal range, where Phosphorus acted as a limiting factor at low concentration and governed uptake of other nutrients in the soil due to co-transportation (Schachtman et al., 1998). None of the soil samples were found to be deficient in any of the micro nutrients (Lindsay and Norvell, 1978). Thus, null hypothesis was drawn from the above data and more experiments need to be done to achieve clarity in results.
Phase-lll Open field trial

Third phase of the study, involved an open field trial. A one kanal (500 square yards) plot was taken in village Tasauli in district Mohali for this purpose. The field trial posed a limitation as seeds of Desi kapas a traditional cotton variety were not available. It is no more grown by farmers in Punjab. Thus, only Bt and conventional cotton was grown on two equal halves of one kanal field maintained by a farmer practicing routine farming methods except controlled pesticide spray.

Comparative study of the morphological features to assess their ecological significance was performed. Comparative study of plant morphology showed statistically significant results. 40% increase in height, number of leaves per plant and stem surface area was noted for Bt plants as compared to non-Bt cotton plants. This difference in morphological features among Bt and non-Bt cotton plants was observed to be lesser during the open field trial than the glass house studies. The Bt-cotton plants had better morphological features as well as double the number of cotton balls than the conventional non-Bt cotton plants. Therefore, the total biomass of Bt cotton plants was 50% higher than the non Bt cotton plants. Thus, the basis of the open field trial was justified as it simulated close to field conditions and gave relating results.

These characteristics when inferred on ecological basis showed increased water demand of Bt cotton plants than conventional because of more transpiration pull due to its higher leaf surface area, number of leaves and height (Noble, 1991). The higher biomass of the Bt-plants was directly relatable to double the number of cotton balls on it. Total cotton yield recorded form the two portions of the field was found to be marginally higher for Bt-cotton by 10 kg than conventional cotton. The significantly better plant characteristics including increased number of cotton balls did not correspond to equal increase in yield. These results were in complete contrast to claims of highly increased yields as depicted in many research studies (Qaim and Zilberman, 2003). While other earlier studies support the current findings and report the increased yield of Bt plants as a short term gain (Pray et al., 2002). Thus, it proved the hypothesis partially correct and largely failed.

Morphological studies were done over cotton plants at three stages of experimentation: field survey, glass dome level and open field trials. Although in the field survey clear cut variation in morphological characteristics was significant in most of the features it was not repeated during the dome level experiments under simulated conditions. At dome level study only height and number of leaves
were the only two significantly characteristics higher for Bt than non-Bt cotton plants. The third phase of experimentation at open field trial was in sync with the field survey results where most of the morphological features were found to be significant.

After aborting the experiment, soil analysis was performed for both portions of the field for bulk and rhizosphere samples. pH of both samples was alkaline for bulk and rhizosphere samples. The presence of increased electrolytes in Bt -soils was clear from the high EC values for all Bt samples which nearly double to that of non Bt-cotton soil samples due to release of chemicals in ionic form. But this could not be inferred for the presence of Bt toxins. The current findings hint but do not confirm the presence of Bt toxins in soil due to short term nature of experiment done over single planting season. Although the presence of these toxins as root exudates has been determined earlier (Saxena and Stotzky, 2003) but the process of leaching of root exudates and their adsorption is not fully understood. Further identification of the ions in the soil was beyond the scope of the study.

Repetitive of the results found at the glass house level, the decreased organic content of Bt-cotton soil samples hints towards its inhibiting role in the formation and accumulation of organic matter in soil. But the process of adsorption of soil organic matter remains doubtful; no clear cut evidence could be deduced necessitating further detailed experimentation. Macro nutrients like Phosphorus and Potassium fell under low category for bulk and rhizosphere samples (Olsen et al., 1954; Merwin and Peech, 1950). P is an essential and often limiting nutrient for plant growth but many aspects of P uptake and transport in plants are not thoroughly understood. The uptake of P poses a problem for plants, since the concentration of this mineral in the soil solution is low but plant requirements are high. The form of P most readily accessed by plants is Pi, the concentration of which rarely exceeds 10 μm in soil solutions (Biesleski, 1973). Further it also leads to co-transport of Pi with a cation involving a stoichiometry of more than 1 C+/H₂PO₄⁻ or more than 2 C+/HPO₄²⁻ governing uptake of other minerals like K and Ca (Schachtman et al., 1998). For such reasons low P concentration in soil affects the uptake of K by the plants.

Micro nutrient analysis depicted no anomaly as they fell within normal category (Lindsay and Norvell, 1978). The results so drawn were indicative of impact of Bt-toxins on the soil physio-chemical properties but not validated scientifically because of the short term nature of the experiment. Thus, a null hypothesis was drawn.
Set 3 Scanning Electron Microscopy

Third level of the experimental analysis, studied the detailed surface topography of cotton pollens and cotton fibre of Bt and conventional cotton employing Scanning Electron Microscopy. The SEM results presented secondary images of pollen exine and lint fibrils of both the varieties at different magnifications. The SEM images of pollen exine of Bt and conventional cotton were indistinguishable but the size of the Bt pollen appeared bigger than conventional. Although the size of the pollen was recorded marginally bigger for Bt pollen with an average number of spines 1.25 in 1×1cm² grid of the graph paper. Numbers of spines were 20% higher for Bt than conventional pollen. The results so drawn were in contrast to widely acknowledged studies reporting the pollens to be indistinguishable (Llewellyn et al., 1992). Hypothesis was proved partially correct. The higher biomass of the Bt pollen could be inferred as an obstacle to easy dispersal and can give impetus to further co-existence studies on Bt-cotton plants.

SEM image of fibre depicted conventional fibre to be more coiled than that of Bt-cotton. Fibre length recorded for both Bt and conventional cotton was meagerly different by only 2mm. The fibre length of both cotton varieties fell in the superior medium category as given by Central Institute of Cotton Research (CICR, 2010). Fibre width analysed from the images at magnification of 1500X10μm was only marginally different for the both varieties and stands insignificant because of high magnification. These findings are supported by earlier reported studies by Paterson et al., (2012) and Jenkins (1992). Thus, the hypothesis was proven partially correct.

Sociological analysis

Success of any technology depends on its acceptance by the society. This societal perception over the issue of GMCs was drawn by personal interviews and stakeholder surveys.

Interview Analysis

Personalized interviews and stakeholder surveys made an important component of the research design to assess the societal impact of this technology. It included interaction with people who have played influential role in decision making on the issue of GMCs e categorized as follows:
• Government recognized scientists who act or have acted as Government functionaries, including Prof. M.S. Swaminathan, Dr. P.M. Bhargava
• Expert Scientists including Prof. Ashok Dhawan, Prof. M.S. Kang and Prof. J.S. Singh
• NGO activists/experts including Kavitha Kuruganti and Dr. Amar Singh Azad

Personal interaction with them reasserted the well evident divide of the society as proponents and opponents of the technology. The government functionaries had a positive approach to the issue but followed an escapist route to many crucial issues tagged with GMCs. Scientific community also had a divided opinion on it with direct bearing on the area of their expertise. NGOs who shun this technology blatantly were not very confident of their claims. They avoid an open forum discussion on the same.

Instead none of the experts interviewed projected a fair, well informed and an open minded approach to the issue. For such reasons, the ongoing debate on GMCs in the country lacks scientific backing and logic. It is biased and dwell on the fallacious and dubious claims made by the proponents and opponents alike. The exercise proved the hypothesis correct and increased scope of deliberation. Similar findings were reported by Bagla and Stone (2013).

Stakeholder Survey
Such undefined and vague controversies have negative impact on the society and propound their lack of faith in the system. A panoptic view of the societal perception was drawn by questionnaire survey of various stakeholders. Common man surveyed in two segments as highly educated and less educated had low awareness levels. Outlook of the common man had no relation with the awareness levels. But outlook of common man varied with income. The increased income entailed to better education, more informed citizens and increased negative outlook. In general, public had a dubious perception of this technology, after the widely publicized Bt Brinjal controversy (Jayaraman, 2010). Second category of stakeholder, Retailers gave feeble responses and fell in low awareness and outlook levels, in an effort to avoid any possible harm to their businesses.

In complete contrast, farmers gave proficient responses to the survey questions as it was directly linked to their vocation. Results showed that farming
community was mostly concerned with the economic benefit and profitability of any new technology and was little concerned about its ecological consequences. Although their awareness on subject specific queries was low yet their cognitive understanding of the concept was high. Majority of the farmers surveyed fell in low to moderate awareness levels while 11.8% had a positive outlook. There was no significant interaction found between outlook and demographic features while awareness levels increased with increasing income group, education and landholding.

The representatives of common man in the government, MLAs when approached with questionnaires were clueless of the technology. Yet, they depicted a positive outlook supporting the government's stand on the introduction of GMCs. MLAs projected the most positive outlook of all the stakeholders, while they had low awareness and avoided many questions. It depicted their diplomatic approach to the issue. Broader scientific community when surveyed recorded highest awareness levels. For obvious reasons they were more aware of the science behind the technology and based their opinion on scientific proof. Comparative analysis of awareness and outlook of various stakeholders showed the scientists as the most aware while common man and retailers as least aware. Scientists and experts were the most favoured group by all the stakeholders for any decision making.

The exercise brought forth the lack of science communication and information in the country as reported by Anand et al., (2007). The Indian populace was largely unaware of the issue and lack basic understanding which leads to the birth of the unwarranted fear in their minds. These findings egress due to their lack of awareness and weak understanding of science behind the technology which has been earlier reported by Krishna and Qaim (2008). Therefore, they are not the right group to base the policy decisions necessitating equal participation of various stakeholders. The elaborate exercise proved the hypothesis correct.

The existing social misconception and confusion was further accentuated by the Report of six premier science academies on safety of Bt Brinjal in particular and a rigorous scientific opinion on GMCs in general. The report completely relied on the data provided by Monsanto a biotech MNC and did not conduct any experimentation on its own. This report was reviewed by many independent scientists world over and brought forth many lacunae. The current assessment of
Bt Brinjal according to the report was not conducted in accordance with published standards and did not accurately summarized results. Major health problems among test animals were ignored in these experiments. The single test dose used for biosafety testing was lower than recommended by the Indian protocols (Gallagher, 2010). Post this episode, amount of discontent and doubt in minds of public has reached to limits from where winning the trust will now be even more difficult.

Policy framework

Emergence of GMCs on global platform has challenged the existing agriculture and food regulation. Thus finding space in current regulatory framework to consider the full range of issues tagged with GMCs is a herculean task. GMC policy research was exercised at three levels

- Study of Indian policy
- Comparative global overview
- International legislation

Study of Indian policy

Synthesis drawn for strengths and weakness of the various laws and rules over GMCs in India depicted divergent policy framework to manage and control introduction of GMCs in the country as reported by Ramanna (2006). The present policy failed on various issues like labeling and traceability, biosafety evaluation mechanism over which there are no clear laws. Multi-ministerial and multi-department control of these regulations makes their implementation difficult.

Various rules under EPA 1986, regulating GMCs can be easily altered and bypassed by regulators and interested parties. The proposed BRAI bill, amended Patent Act and newly implemented Traditional Knowledge Act, fail to a comprehensive in their approach. These further dilute the existing biotechnology regulation in the country. None of the so far enacted laws and statues had any provision on social and inter-generational equity and impact of this technology also pointed out by Gupta and Chandak (2005). Many of these legislative orders suffer from poor implementation at national as well as state level. There is an urgent need to generate skilled human resource and infrastructure to implement.
existing policies and amend these regularly with changing understanding and application of science in assertion of the hypothesized statement.

**Comparative Global Overview**

Global analysis of GMC regulation highlighted highly varied and distinctive approach of countries entailing to their economic, political and social conditions. The world today projects a strong inter and intra continental divide on the issue as was determined during the course of research and reaffirming research findings of Davison (2010). As per these findings three basic principles underlying GMO regulation around the globe were found to be as:

- **Precautionary principle**- It embodied the idea that legislators err on the side of caution until foolproof scientific evidence of 100% biosafety is depicted.
- **Step by step principle**- It based the laws on the premise that genetic modification should be allowed to proceed provided there will be no adverse effects on health and environment.
- **Substantial equivalence principle**- It derived the compatibility of existing legislation on conventional products to be applied on their GM counterparts considering both equivalent.

EU regulation over GMC as adopted by its various member states followed a stringent policy in complete contrast to USA which was open to GM products requiring no new regulation. On the other hand, developing countries of the third world were slowly realizing the benefits of the technology and adopting it with great caution as also reported by Gruere and Sengupta (2009). These countries lack sound scientific R&D and evaluation mechanism. The African continent was primitive in its approach to GMC. Except South Africa no other African nation had a comprehensive regulatory mechanism in place. Many countries like Nigeria and Ghana had formulated laws on GMOs but did not have regulatory agency to implement these.

The oceanic nations of New Zealand and Australia have well defined and contrasting legislations on GMOs. If Australia had an open science based policy on GMOs, New Zealand had a stringent regulations considering the impact of GMOs on environment, health, economy, social and cultural aspects of the community. As hypothesized there existed an unharmonious GMO regulation globally, making its trade an arduous task.
**International legislation**

Present international legislations on GMOs studied were few and weak. Cartagena Protocol on Biosafety to Convention on Biodiversity, 2000 was the most important of these legislations studied. It regulated the trade of GMOs between countries but ironically major GMC producing countries like USA, Argentina, Brazil and Australia have not ratified to it, demeaning its existence.

Another GMC producing country, Mexico had ratified to the protocol but grows genetically modified at center of its origin in complete contrast to provisions of the protocol. WTO and its trade related agreements have become major facilitators of GMC trade globally. The provisions of this agreement are not restrictive in nature, in complete contrast to the biosafety protocol. Most of countries depend and follow the Codex Alimentarius standards on biosafety of GMOs as reported by Haslberger (2003). Thus the international legislative framework further disunites nations instead of harmonizing their GMO regulation.

**Economic Considerations**

Economic benefit has been the main driving force behind the development as well as adoption of GMCs. The actual value of these crops is measured in terms of money spent and earned, which is a tangible factor. Many intangible factors like biodiversity loss, soil degradation, long term ecological impacts and health impacts are never taken into consideration. These GMCs do bring economic benefits but such benefits do not extend to all segments of the society (Gupta and Chandak, 2005). Especially in country like India where majority of the farmers have small to marginal land holdings, monoculture based GMCs increase the stress on the agricultural system with increased input costs. Thus an analysis of economic factors for both the Bt-cotton and conventional cotton plantations was drawn on the basis of field surveys and interactive sessions with the farmers growing cotton.

Table 5.1 Comparative analysis of input costs for Bt and non-Bt cotton plantations

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Input cost</th>
<th>Bt-Cotton (Rs per acre)</th>
<th>Conventional Cotton (Rs per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Seeds</td>
<td>2100</td>
<td>250</td>
</tr>
<tr>
<td>2.</td>
<td>Pesticides</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>3.</td>
<td>Fertilizers</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8100</td>
<td>6750</td>
</tr>
</tbody>
</table>
The input costs per acre were calculated for the Bt and non-Bt cotton fields over one season. Most expensive input cost was incurred on the Bt-seed which was 8 times costlier than conventional seed. Some of the farmers added that in case of non-Bt cotton, there was no expenditure incurred on seeds as these were saved from the earlier crops. The market price of Bt cotton seeds is Rs. 1250 for 450gms while conventional seed is available at less than Rs. 350 for 1000gms. Major fertilizers used were DAP, Urea and Potash at rate of Rs. 1200/50kg, Rs. 270/50kg and Rs. 500/50kg respectively. During a single growing season 100kg DAP, 50 kg Urea and 25 kg Potash was added to the soil at an approximate expenditure of Rs. 3000 for both Bt and non-Bt cotton fields.

Irrigation was mostly dependent on the canals with rare use of tube-wells. Only expenditure on irrigation was recorded during the use of generators to run tube-wells which was recorded same for both varieties. In case of Bt-cotton a major benefit is claimed to be the reduced pesticide sprays. The three major categories of pesticides sprayed on cotton were Fipronil, Imidacloprid and Thiamethoxam at different concentrations. These pesticides under different Indian brand names cost nearly the same and are frequently sprayed over cotton fields. On an average conventional cotton field required total 15 pesticide sprays throughout the growing season. Although the number of sprays was noted to be 1/3 rd in the Bt cotton fields but the spraying cost showed little difference. This was due to the use of expensive broad spectrum pesticides in Bt cotton fields like Polo of Syngenta or Corozin of Dupont limited which are at double the cost of the local pesticides. The Biotech seed companies guide farmers to use these expensive pesticides instead of local made for better efficacy and efficiency. Thus the cost of spraying pesticides accounts to be marginally higher for conventional cotton fields than Bt cotton fields even after reduced number of sprays.

A recent interaction with farmers highlighted the fact that the pesticide sprays have increased in Bt cotton fields in last six years of its plantation in Punjab with little benefit in yield. In terms of cost benefit ratio the input cost of Bt and non-Bt cotton grown fields show difference of around Rs. 1450 per acre. This difference in input cost is majorly due to the seed cost as was also reported by farmers. Otherwise the amount of chemical inputs in the Bt and non-Bt cotton fields show little difference. Does this increased input cost materialize into better yield or not? The current data from the cotton fields of Punjab shows that Bt cotton
has yield of 8 Quintals per acre which is equivalent to the conventional cotton yield in the year 1993-94. In the current scenario the yield of non-Bt cotton field is recorded around 5 quintals per acre on an average with higher chemical inputs but a lower input cost on an average. Whereas, cost of cotton in market is same for both types, irrespective of the fact if it is genetically modified or not and varies between Rs. 45-50/kg.

Thus, this analysis of economic factors involved in Bt-cotton and conventional cotton plantation brought forth a clear picture. It makes us dwell on the fact that if the higher input cost of Bt cotton is translated into real economic benefit and at what cost benefit ratio. Moreover these crops are profitable only to large landholders who can practice monoculture. Where as it is a complete misfit for small/marginal landholders who follow multiple cropping on small piece of land. It requires new working methods, increased demand of skilled labor, expensive inputs which convert into additional cost for them. Till date most of the GMCs developed, have been profitable predominantly to its private sector developer and large landholders further concentrating the economic power. Consequently, it widens the gap between rich and poor, leading to stratification and polarization of the society.

The recent Agriculture Ministry Internal Advisory Report 2011 ascribed Bt Cotton for current agricultural crisis and farmer suicides in the country. A closer look at the data showed that the real gain in cotton yield was seen in the country when Bt-Cotton was meager 5.6% of total cotton plantation (CICR, 2010).

Table 5.2 CICR India Cotton Yield Statistics

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Time period</th>
<th>Cotton Yield gain</th>
<th>Bt Cotton area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2001-02 to 2005-06</td>
<td>278 kg/ha to 470 kg/ha</td>
<td>5.6%</td>
</tr>
<tr>
<td>2</td>
<td>2005-06 to 2011-12</td>
<td>470 kg/ha to 481 kg/ha</td>
<td>90%</td>
</tr>
</tbody>
</table>

Source: CICR, 2010

In such a scenario, right of the public to choose is imperative. A choice means additional cost to the developer who will further place it on public by increasing the prices of the products. It also requires the government to formulate extensive regulatory framework so that benefits from such technology extend to all whilst conserving biological and cultural diversity.
The present research module, based on eco-scientific, social and legal study elicits the sustainability of GMC production and use in the country. Summary of the hypotheses has been drawn as under.

Only, two of the hypothesized statements b and e were proved unsuccessful.

- Increased incidence and diversity of insects in Bt cotton fields as compared to non-Bt cotton fields
- Bollworm that feeds on Bt cotton dies while not on non-Bt cotton.

While for the following hypotheses (a and f) no relation could be determined among the variables being compared between Bt and non-Bt cotton field drawing a null hypothesis.

- It is hypothesized that vicinity of Bt fields as compared to non-Bt will harbor greater vegetation diversity and density.
- Bt Cotton has been reported that Bt toxins leach to soil leading to toxicity and expected change in microbial flora and fauna. Thus, it is hypothesized that Bt cotton plants affect the soil physio-chemical characteristics.

Most of the hypotheses were proven correct, in assertion with the possible impacts of GMCs on ecology, policy development and society as a whole. These were hypotheses marked as c, d, i, j, k, l, m, and n based on ecological, social and legal aspects. A few hypotheses necessitated further experimentation as clarity could not be achieved. These were hypothesized statements g and h, where hypothesis was proven partially correct but largely failed.

The ecological studies on Bt-cotton from open fields to controlled laboratory experiments reaffirmed its insect resistance advantage over conventional varieties with marginal benefit in yield. Most importantly, these benefits are short lived with evolution of secondary pests as was reported from Bt –cotton fields of India and China (Wang et al., 2008; Lu et al., 2010). A recent news report highlighted the break out of secondary pests like white fly in the Bt cotton fields of Punjab. Such secondary pests were reported to be affecting the crop yield (Kulkarni, 2013). Although the number of insecticide sprays is reduced but it is not 100% chemical free crop as was found out during glass house studies where the cotton balls on Bt cotton plants failed to open as it was grown on un-augmented soil with zero chemical input. Cotton quality and fibre length was similar for conventional and Bt
cotton plants depicting no impact on its quality. The soil analysis done at every level also hinted towards a possible impact of Bt toxin on soil physiology.

This technology is not an isolated scientific technique instead it is deeply embedded in the society. Thus, its success depends on its acceptance by the society. Especially in a country like India where agriculture accounts for 15.7% of GDP and employs 55% of workforce any such technological shift is going to have far reaching effect on different segments of the society (MoA, 2010). Study of interactions with experts and analysis of stakeholder survey depicted dubious and least aware perception among the public. There is perhaps lack of basic understanding of science behind GMC use and production as the ongoing controversies further increase doubt in people’s mind. Even the well informed and technically skilled experts are not open about their views due to the fear of intriguing conflict of interest. Lack of education and information had further marred the possibility of any healthy and conclusive debate on the issue. People are either not informed or misinformed as the gap between science and society widens. Concerns regarding GMCs are not addressed properly and people who have the power to influence decision making process follow an escapist route.

For such reasons, the GMC policy in India is not found to be effective at grass-root level. The policy decisions do not dwell over basic ecological parameters in the current agricultural setting. Bureaucratic and political interferences further hamper the implementation of policy as multi-departmental control leads to clash of interests. Globally, lack of legally binding international legislations and inharmonious national policies has affected the trade, production and research and development of GMCs as well as conventional crops due to fear of pollution of non-GM products with GM material. The discordant policy at national and global level augments perplexity. The growing networks and contesting frames makes the formation of a harmonious global policy framework an arduous task.

Under current scenario, large asymmetrical database has been generated over the potential impacts of GMCs. Variegated global opinion on its safety, profitability and possible impacts has been formed with no long term ecological studies. Further the enhanced inputs required for these crops (with or without ensuring ecological and biosafety concerns) cater to the economic interests of the few MNCs only.
In our country commercial cultivation of Bt cotton was on trial basis only. But
till date no crystal clear benefits have been recorded from it even after a decade of
its commercial release. In case of food crops a much stringent approach is
required. Why should our country adopt these crops in a hurry when there is no
long term scientifically validated proof of their safety available? Recently,
Supreme Court of India recommended an indefinite moratorium on field trials of
GMCs till the government fixes regulatory and safety aspects and a ban on
introduction of GM varieties in regions of their origin. This ban on the field trials of
any GMC was well thought of and much required (Chauhan, 2013). Urgent need
is to divert time, money, and R&D towards minimizing these losses to achieve
food security i.e. sufficient nutritious food for healthy active life of all.

Consequently, GMCs do not appear to be providing the solution we are
looking for. Therefore, it necessitates the need for thorough scientific analysis and
logical scrutiny before adopting them and formulating a policy for posterity. In the
event otherwise, we are fraught with altering evolution process and biodiversity
pool.