Underpinning Dimensions of Genetic Engineering in Agriculture

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Agricultural sustainability is dependent on soil sustainability. Conventional agriculture ines' the soil faster than it is formed. Genetic engineering in agriculture is essentially an extension of conventional agriculture where the emphasis is primarily on production. Developments in alternative agriculture endeavour to retain soil sustainability, and are more productive when all externalities are taken into account. Genetic engineering in agriculture is being driven technologically, commercially and politically, whereas the resolution of the issues must be social and ontological. The complex ramifications of genetic engineering necessitate a wide and deep public discourse, that explores the risks and benefits, the ethics, our compassion, and meaning in life.

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Introduction

GMFs (genetically modified foods) and GMOs (organisms) in agriculture are promoted as a solution to world hunger. The claims however are not supported with evidence. The introduction and development of GMFs and GMOs in New Zealand (NZ) are driven in large part by commercial interests in food production. The implication is that we need GMFs and GMOs. That implication has not been adequately demonstrated either. Furthermore our right to know, eg. the labelling of GMFs, has been resisted, even denied, and proof of safety has been effectively abdicated by government to the commercial interests themselves who refuse to accept any liability.

Health, safety and environmental aspects dominate the public concern. Conventional plant and animal breeding is GE (genetic engineering) but their slow historical development has effectively eliminated any adverse effects, at least as far as we know. GE in this context does not include conventional plant and animal breeding.

Government is reacting to, rather than leading, developments over which it should have sovereign control, control that it could be losing through the process of globalisation. The far from subtle commercial and political pressures forcing the issue are bypassing the wider debate about GE, where the potential for disastrous and permanent consequences in agriculture would seem to greatly outweigh the benefits. The risks to the wider environment from 'escapes' are effectively totally unknown, and perhaps unknowable. The precautionary principle aside, this paper argues that, at this stage, the interests of NZ, and perhaps the world, are best served by developing agricultural practices which ensure soil sustainability. There is certainly evidence GMOs could further impoverish the soil, whilst there is little evidence for productivity gains. The ontological dimensions of genetic engineering are then touched upon.

These deeper dimensions led to moratoriums on GE in NZ (late 70s) and the USA (mid 80s), but they appear to have involved only the scientific communities. The wider public discourse did not happen. Now, with food, we are all involved and it is appropriate that the public discourse on the ethics, benefits and risks of GMFs and GMOs and of GE generally can then take place in a measured manner. Ultimately, it is a discourse on the meaning of life. The possibilities of GE are awesome - that is they engender both wonder and fear. In our stupor, could GE in agriculture be obscuring our most fundamental need of agriculture, that it be sustainable, and could it be a Sorcerer Apprentice?

Agricultural Practices

Many traditional agricultural practices, at least in Europe, maintained (and often improved) the soil and its fertility. Around the beginning of this century, artificial fertilisers, pesticides and other chemicals began to replace the natural and local inputs, which together with more intensive farming, ushered in industrial agriculture, colloquially known as conventional agriculture. The soil quality began to decline, greatly accelerating after WW2 through the perceived necessity for the Green Revolution. The large increases in yields were mainly due to the advances in conventional plant breeding rather than the chemicals. The increased yields however have not reduced global hunger. The Green Revolution served primarily to highlight that hunger is about access to land or money, and the distribution of food, not its production (Cornerhouse 1998).

As the unsustainable nature of conventional agriculture on the soil itself and the vulnerability of uniformity in agricultural practice became apparent, the movements back to traditional (organic) methods and, more recently, forwards to biological agriculture began. Organic, biodynamic, biological, and IPM (integrated pest management) agriculture are not the same but they reflect a common desire - to use local and natural materials; for minimal artificial fertilisers and pesticides; for diversity; and to work with rather than against nature. These are known as alternative agriculture where the hallmark is not the conventional practices it rejects but the innovative practices it includes. Alternative systems are deliberately integrative and take advantage of naturally occurring beneficial interactions. There is much confusion over the term 'organic' which many nations are endeavouring to standardise, both nationally and internationally. GE is an anathema to organic if not all alternative agriculturists yet there are pressures in the USA to have GE crops classified as organic in the National Organic Program.

Agricultural Productivity

The dominant conventional agriculture lobby and large agricultural chemical and seed companies claim that alternative agriculture is less productive than conventional agriculture. But it depends on where you draw the boundaries. Perhaps a more relevant question is which is more sustainable?'. Agricultural sustainability should be expressed in physical rather than monetary terms, account for all the externalities, and be grounded ultimately on the sustainability of the soil. This is the realm of industrial ecology and life cycle analysis. In this context water sustainability is assumed.

Alternative agriculture is still very much at a re-discovery or re-development stage where the technologies and scale are not yet optimised. The Board on Agriculture in the USA commissioned the study Alternative Agriculture (NRC 1989). The report contains an extensive evaluation of the literature and 11 detailed comparative case studies. The major findings are that:

- alternative agriculture can lead to sustained economic and environmental benefits,
- government policies work against the adoption of alternative systems,
- a systems approach is essential to the progress of alternative agriculture, and
- optimal alternative systems are many and diverse for which farmers require informational and technical assistance.

Not surprisingly the report was controversial. Around the same time, Stanhill (1990) made 205 comparisons where, overall, alternative agriculture yields were 10% lower even though some alternative yields were greater. Unlike Alternative Agriculture Stanhill study did not address soil sustainability in any detail.

A literature search from 1990 conducted by the US Department of Agriculture for the writer comparing conventional and alternative agriculture came up 63 references, 40 of which could be categorised. Each study endeavoured to be internally consistent, ie. to have a common basis for comparison. Some were on experimental farms, others related to working commercial farms. Externalities were included to a variable extent. There was no consistency between studies of course. Ten indicated alternative agriculture as being more productive, whilst five favoured conventional agriculture. Ten had mixed results, depending on the chosen parameter or crop - for instance corn yields seem to be greater from alternative agriculture and potato yields greater from conventional. Fifteen were inconclusive. The comparisons are based mainly on yields, some on economic returns.

The definitive experiment however can be found in Cuba. The US economic blockade since 1960 has forced Cuba into alternative agriculture. Both imports and exports have decreased substantially, often by more than 50%. They have maintained one-third of the 11 million hectares of agricultural land on agrochemicals, turned another third fully organic, and kept the rest transitional' as half agrochemical and half organic. The yields per hectare of the fully organic are equal to the fully agrochemical, while the yields of transitional' fields are only half as much (Ho 1998).

The way of life has had to change too. Bicycles have replaced cars. Fields are ploughed with horses. Windmills, solar panels, and biogas generators have sprung up everywhere. Land has been re-distributed as cooperatives. Fortunately the extensive education and research programmes that had been in place in biological pest control in agriculture and in natural medicines in health have continued and have enhanced the quality of life. The diet of organically grown fruit and vegetables (and less meat), and a more physical lifestyle mean people are healthier. Life is more frugal but there is more vitality. The embargo has freed them from the conventional model of development. They have been forced to do what they, and perhaps all countries, should have done in the first place - to develop a model that is sensitive to their own country ecological, cultural, and economic circumstances, and which shows every sign of becoming sustainable (Zunes 1995).

Demand and Prices

The demand for alternative crops and animal products is growing at around 20% pa in the USA (Kimbrell 1998), 40% in the UK and 30 to 40% in NZ (Mason 1999). The 1996/97 year alone in NZ saw the demand for exported certified organic produce increase 67%, from $12 to $20m (DoS 1998). This demand invariably translates into higher prices which can be substantial (Dobbs 1998), eg. a 50% premium for certified organic rice (NRC 1989, 415). Watties NZ Ltd gross margin on organic corn was $1160/ha as against $740/ha from conventional corn - a premium of 57% (Mason 1999). Whether the demand and the price premium can be sustained is unknown of course, but the strength of the public opposition to GMFs and GMOs should give alternative agriculturists heart. Undoubtedly the demand for alternative produce has been influenced by the bovine spongiform encephalopathy (BSE) debacle in Britain and the injurious effects to cattle and people of bovine growth hormones (BGH) in the USA (Kingsnorth 1998). BGH is an example of a quite unnecessary evelopment' as there was surplus milk capacity to start with. The growth in demand for alternative produce can be expected to continue.

Nevertheless, the public perception in NZ is that organic produce is much more expensive than conventional produce - vegetables from 30 to 290 % and processed food from 30 to 130% more expensive (Consumer 1999). This margin reflects the largely cottage nature of organic farming in NZ around the urban centres, and the export orientation of the agricultural industry in NZ. One third of the production of The Organic Products Exporters Group (OPEG) is consumed domestically (Campbell 1999), whereas little agricultural produce of any nature is exported from the industrialised countries. We consume, on a per capita basis, one ninth the organic produce that the Germans do.

The fossil energy component of conventional agriculture is much greater of course, not only in the mechanised methods but also in the manufacture and application of the externalities, the chemical fertilisers, pesticides, and their downstream effects. For wheat it is 48% greater whilst the yields are 29% greater (Beradi 1977). Most of that energy comes from hydrocarbons which within 10 years are predicted to become much more expensive as demand outstrips supply. Even now, if all the externalities for the supply of petrol in the USA are taken into account, its real cost should be at least 5 and perhaps as much as 15 times the present price (ICTA). A tenfold increase in the price of petrol would have a very destabilising effect of course but ultimately would be more sustainable, not just for agriculture.

But it is not sufficient to make comparisons only in terms of yield or economic return. It must ultimately be on soil sustainability. Conventional agriculture makes no provision for depreciation of its real capital (the soil), even though it is depreciating. When provision is made for capital depreciation (soil deterioration) and current off-farm costs of soil erosion (to others or the environment) the economic viability of conventional agriculture changes dramatically (Faeth 1993). Net farm incomes may fall by 30% and net economic farm values may even become negative. Both alternative cropping and reduced tillage, practices of alternative agriculture, give slightly greater net farm incomes and mostly positive net economic values.

Soil Sustainability

A soil quality which has high nutrient availability and aeration, good infiltration and water retention, and is structurally stable and promotes a high level of biological activity, will lead to the sustained and productive growth of crops with minimal impacts on the wider environment. Soil is formed at a highly variable rate, from as little as 0.01 to 8 mm per year (Friend 1992). Between 3000 and 12,000 years are required to form sufficient soil to form productive land (Dailly 1995).

Prairie soils have been eroded up to 1m since the arrival of agriculture, most of that this century, ie. 10 mm/yr. Soil erosion on conventional farms in Berk County, Pennsylvania, can be 100 times its formation rate. Among them is a highly studied experimental and working farm in alternative agriculture which is losing soil at 10 times its formation rate (NRC 1989, 302). Reganold et al (1987) have made a long term study of soil erosion over 40 years of two adjacent farms at Spokane, Washington, producing very similar crops with comparable yields, one conventional the other organic since it was first ploughed in 1909. The soil profile of the organic farm is virtually unchanged. The soil on the conventional farm has been eroded 200mm (5 mm/yr) and the A2 horizon is almost depleted.

Here in NZ the rate of soil formation is less than 0.1mm/yr and we are losing 24 billion tonnes of topsoil each year (Beare et al 1997). Most of this is through deforestation and conversion to pasture in the high country and on steep slopes.

Soil therefore is not an infinite resource and not renewable within the time frames of current human expectations. Throughout most of the world today soils are being mined and can (many have) become unusable within a few generations. At least 25%, perhaps 80%, of the world agricultural land has been moderately to severely eroded. About 30% of the agricultural soils in the USA have been abandoned because of erosion (MfE 1997).

Organic carbon generally, the biomass that gives the soil structure or tilth, is declining. Conventional agriculture is destructive of structure. It depletes this matrix of organic carbon which provides the openness, thereby becoming more dense (aggravated through compaction from farm machinery), less healthy, less absorbent of water and prone to erosion. Alternative agriculture, on the other hand, retains and enhances the structure (see the many references in The American Journal of Alternative Agriculture AJAA).

Overviews in highly regarded and independent scientific journals are supportive of alternative agriculture, eg. New Scientist (Arden-Clarke and Hodges 1987), Scientific American (Reganold et al 1990), and Nature (Drinkwater et al 1998, Reganold et al 1987). Drinkwater et al (1998) have demonstrated there is greater retention of carbon and nitrogen in the soil when legumes and manure are used. Furthermore the organic matter in the soil has a sequestering effect on atmospheric carbon, which in the USA accounts for 1 to 2% of that released from fossil fuels, thereby helping global warming. The nature of the fertiliser is as important as the quantity.

Two of the five references that favoured conventional agriculture (the USDA literature search) conducted phosphorous or potassium balances or both (Lockeretz et al 1977, Penfold et al 1995). Alternative agricultural methods had negative balances. It does seem that the judicious use of chemical fertilisers and pesticides may be necessary in some situations in order to compete with conventional agriculture on yield or economic terms. Biological agriculture and IPM recognise the need for the minimal use of fertilisers and pesticides, at least in the transitional stage to fully sustainable practices, limiting the cropping if necessary.

Concern about the unsustainability of conventional agriculture led to the establishment of the independent Land Institute in Kansas in the 1970s. The prime intent was to reverse the declining fertility and erosion of Prairie soils (up to 10mm/yr). The objectives are to develop perennial grains through plant breeding techniques (preferably using indigenous grains), to avoid tilling and the use of artificial fertilisers, and to develop polycultures of crops to avoid (or at least minimise) the use of pesticides. After less than one human generation they are on the verge of success. Sustainable agriculture is imminent, when considered in terms of material and energy balances and soil sustainability, unlike monocultures of annual grains (Benyus 1997). We may however have to develop a taste for gamagrass bread, mammoth wildrye (a relative of wheat the Mongols used to use), Johnsongrass and grain sorghum, and Maximilian sunflower for vegetable oil. But it is only a beginning.

On another scale is the do nothing farming of Japan (Benyus 1997). The method mimics nature trick of succession and soil covering, developed over 30 years of observation of rice, rye and barley cropping. The self-fertilising and self-cultivating cycle repeats itself. No tilling is necessary. A quarter acre will yield 22 bushels of rice, and 22 bushels of rye and barley - enough to feed 5 to 10 people, yet it takes only 1 or 2 people a few days work to hand sow and harvest the crop. Similarly there is permaculture. These are on quite a different scale to commercial farming but have their place.

Little if any research has been conducted directly or indirectly on the impacts of GE developments on soil sustainability. We must therefore adopt the precautionary principle. There are no grounds, as yet, for believing soil sustainability will be enhanced and strong grounds for believing GE in agriculture is in effect an extension of conventional agriculture.

Biosecurity and the Advent of Genetic Engineering in Agriculture

The devastating effect of invasive species, often introduced with the best of intentions, on the indigenous NZ fauna and flora has been relatively recent (mainly post-European). The loss of NZ natural environment may now be irrevocable, despite some heroic and underfunded last ditch efforts. Paradoxically however we seem poised for a re-run where the invasion may come from within, through creating and releasing GMOs ourselves.

The report Alternative Agriculture (NRC 1989) was mindful of the potential benefits of GE and, although promoting and encouraging the research, it strongly advocated a precautionary approach. The possible adverse consequences on the soil of glyphosate (Roundup) and Bacillus thuringiensis (Bt) were first suggested in the early 80s.

The primary purpose of GE is increased production, produce that must draw its nutrients from the soil. Thus more chemical fertilisers will be required. Despite the claims of increased yields, a definitive comparative study of thousands of varieties of non-GE soya bean and Roundup-Ready soya bean over eight states found that the GE yields were from 4 to 6% less than the non-GE yields (Oplinger 1999).

Other purposes relate to pesticide resistance, and to processing, transport, storage and cosmetic considerations, ie. commercial advantage, not soil sustainability. The risks from GMOs however include the stimulation of pesticide-resistant 'superweeds' and 'superbugs'; the unwitting creation of new species of weeds, soil bacteria, and other species; the decline of beneficial insects; decrease in soil fertility; increasing water pollution and decreasing aquatic diversity (Rissler and Mellon 1996). Emphasis has been on mass, not on nutritional value. There is some evidence the nutritious value of GE crops can be inferior; indeed some animals prefer not to eat them (Sprinkel 1999).

Whereas pesticide resistance may lead to less use initially, the window of opportunity may be limited to a mere handful of years. Not only will the pests develop greater resistance themselves, but either heavier applications of pesticides or the development of more aggressive pesticides, when the old ones becomes less effective, will be required. Human antibiotic resistance is analogous, either directly or indirectly through animals fed antibiotics. Even the manufacturers of these pesticides acknowledge this, eg. Monsanto themselves admit that the associated weeds will develop resistance to Roundup. These concerns would appear to have been justified in the work of Creechio and Stotzky (1998) on the adverse accumulation of Bt in soil and that of Holmes et al (1998) on the genetic variants of the bacterium Klebsiella planticola.

There could already be and no doubt will be beneficial exceptions of GE in agriculture. At present though they would be coincidental exceptions. Should they then be determining exceptions? Here in NZ a weevil is playing havoc with white clover, advancing from infected areas at 30 km/yr. Red clover has a resistant gene which can be transplanted into white clover to give it the same resistance (Garnett 1999). Does the white clover still have the same function, and what are the other effects of inserting this particular gene? Are there other means to contain the weevil, eg. biological controls? Pasture sustainability however is not the same thing as soil sustainability. At present the advent of GE in agriculture therefore is essentially a continuation of the unsustainable practices of conventional agriculture.

We are prepared to spend millions to control or prevent accidental invasions (importations) of destructive species, whilst simultaneously running risks quite unnecessarily from introduced or self-developed GMOs. We should remember that farmers were the main advocates of the first invasions. Sarawitz

(1996) also reminds us that the scientists in the past have repeatedly got it wrong in their 'expert assessment' of the potential risks from introduced species.

There is much we have to learn about the impacts of GE, particularly in uncontained situations, as in agricultural practice. It is not sufficient to act in the absence of proof of harm. There is too much retrospective evidence of unseemly haste in the application of new technologies, eg. BSE, BGH. The precautionary approach is obligatory when it comes to damage that cannot be undone. This is more applicable to GMOs than to GMFs. But who can say certain GMFs may not introduce permanent hereditary effects. Even if not hereditary, what possible justification can there be for inflicting a single individual, say with an allergen, quite unnecessarily?

The Discourse on Genetic Engineering

At what stage does natural GE become artificial GE? Much animal and plant breeding is unnatural in that many developments would not have happened without man. Hybrids may be seen as a violation of the natural order as the plant has been diminished through having poorer, even sterile, seed and control has been taken from the farmer. The discomfort about GE comes when genes are inserted surgically, and is heightened as the modifications become progressively transgenic, plant/plant, plant/animal, animal/human. Distinctions are also made between GE developments for commercial purposes, at this stage largely for food, as distinct for altruistic purposes such as human health. Distinctions are also made between GE within a closed, tightly controlled environment, such as a laboratory or operating theatre, as opposed to an open environment, such as field trials, because of the risks of 'escapes'. There are no clear boundaries.

The Talking Technology Conference on Plant Biotechnology (TTC 1996) was held to address some of these concerns and was cautiously accepting of the technology. The panel advocated an open environment for its introduction so that people were informed and were able to make choices. That position was more or less reaffirmed at a follow up conference in May 1999, but where the panel felt that openness had not been a characteristic of the intervening years. Furthermore the panel were categoric about the need for clear unambiguous labelling - may contain was simply not good enough - and castigated government and industry for their tardiness in promulgating and responding to regulations. The public could be forgiven if it felt it had been treated contemptuously. Such treatment is reflected in the two unsuccessful attempts for a moratorium on field trials of GMOs and the deferral of the legislation on the labelling of GMFs.

The moratorium on GE in NZ in the late 70s was confined to scientists where even their understanding of the possibilities and consequences was extremely limited. The wider debate that was supposed to have happened in the USA during the four-year moratorium in the 1980s on recombinant DNA and foetal tissue research didn happen, possibly because the shadow sides were repugnant to too few people. With food we are all involved now. There is however an impatience, tinged with some arrogance, in both the commercial imperative and the well-intentioned enthusiasm of researchers, that wants to sidestep the wider discourse, even when sinister effects have already become apparent. The wide demand (over 90% in Britain, and now 69% in NZ) for the labelling of GMFs reflects not only a fundamental right to know about actions that could affect each one of us personally and irrevocably, but something much deeper.

The concern about genetic engineering is not simply a concern about technology. It is not wholly about ethics either for ethics have a cultural and temporal context. It is a debate about ultimate meaning - meaning in the purpose of life and of our role within it. The world we have created is quite different from the world of our forefathers. We are between stories. Traditional story, both mythical and religious, is no longer appropriate, for our understanding of the world has changed greatly.

Science is the application of reason - of empirical enquiry. Technology is the expression of science, and industry and business are the vehicles for that technology. Not all scientific discoveries are developed to technologies. Those that are, are progressed for one simple reason - they enable us to extend our control over nature or each other. That control is manifest in many ways of course, from warfare to monetary or competitive advantage, to the Faustian bargain of materialism. The control may have the potential to be universally beneficial (public water supply and sanitation, disease control), or it may be selectively beneficial (medical advances in fertility), or it may be consequentially insidious (motorised transport), or even overtly insidious (warfare).

The biosphere - Gaia - in which all species have their being, may be unique. Rationally it should not exist. At first sight, it even appears to defy the second law of thermodynamics. We must therefore use more than just our reason to understand the living world and to find meaning and purpose for our place within it.

Technology has undoubted benefits but it has unforeseen consequences, particularly when captured (Fricker 1997). Most new scientific discoveries are made within the public domain, that is with public money. The consequential technologies may be developed within the private domain for commercial development. The benefits and risks of technological development that is within the public domain tend to be shared equally. Development that is within the private domain tends to lead to private benefits and public risks. These are equity rather than ethical considerations. The benefits and risks of gene therapy are borne by the same person. The benefits for example of Roundup Ready soya bean however will be enjoyed by Monsanto, and perhaps the farmers, but the risks will be carried by the public and the environment. The implications go deeper.

Why is it for instance, that we in the West will make huge investments in medical genetic technology for the benefit of relatively few people whilst we make only paltry investments for the benefit of millions of disadvantaged people, thousands of whom may be on our own doorstep? Scientific curiosity therefore would appear to drive gene therapy developments - the compassion comes later when confronted with the suffering of those afflicted. Can we not turn that around and let compassion drive technological development. It surely does for some but not at the cash-register level.

Let go further, for gene therapy for minors goes beyond compassion, as the risks will be born effectively by a non-consenting party and the responsibility by parents and medical practitioners. Here it starts to become an issue about ultimate meaning - the answers to the collective existential questions of 'Who are we?' and 'Why are we?' etc. But should we not be considering ultimate meaning when it comes to altering any life form? The ancients were often better at this than ourselves for they would honour and respect the life surrendered to them in the hunt. We are part of nature in our interdependence with other species, even though we effectively control their existence and we ourselves are dependent on theirs. We have a huge responsibility to find meaning in the ultimate paradox .. *the essence of life is that living is about killing and eating* (Joseph Campbell). Meaning therefore should precede compassion which must itself precede technological development. Until we reverse the present order we shall continue on the path of unsustainability.

The capture or privatisation of technology began, in a really big way, 500 years ago with the enclosure of the commons, then the seas (the navies), other lands (colonisation), other people (slavery), knowledge (science as technology), the remainder of the public domain (energy, water, roads) and now life itself (genetic engineering) (Rifkin 1991). When technology begins to affect our very make-up, we the public must determine the direction of that development and its application, even though the development itself and the management may well be the preserve of the corporates, technologists and the bureaucrats (Fricker 1997). We ourselves must therefore claim ownership of technology if we are to find meaning. The Talking Technology Conference

(1996) is disappointing in this respect. It has rolled over somewhat lamely, lamenting that In a perfect world, the ownership of plants and their genes would be global .. this is not the case in reality. Plants can be owned by individuals and organisations ..".

NZ Unique Status

NZ is a sparsely populated and isolated agricultural country. We do not need the as yet unproven greater productivity of GE plants. We do however need our soils to be sustainable. We have the opportunity, now not later, to exclude GMOs in agriculture and the importation of GMF foods and ingredients. We could have excluded an undesirable natural GMO not long ago, the pitt bull terrier - it is too late now. We should be heading down the path of alternative agriculture, promoting and reaping the advantages of a GM-free industry. This is not isolationist. It is precautionary, rational and sensible. We can continue to share information and assist other nations who may, in time, be grateful for our stand. Meanwhile we can engage in the discourse of GE and gene therapy in a deep and meaningful manner.

NZ is the only country in the world that has embraced voluntarily the global free market. The benefits, if there ever were any, of that recede day by day. We did not embrace nuclear energy. We did not need it, and still do not need it. Our stand has brought us international respect. We need not embrace GE in agriculture - yet. The potential benefits in not doing so are clear (unlike the converse) and include international respect. At some future date when we are clear about our national meaning, our national being, we can embrace GE in agriculture. If and when we do however, the decision must be based on the sustainability of the soil, not on yields or economic returns.

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