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Can chemical-free farming alone achieve sustainability? - A review

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Abstract

With the rising population, the demand for food, fuel, fiber, and timber is increasing and to meet out these ever-increasing demands farming systems all around the globe has become more intensive to be in pace with these demands. Soils around the world are being subjected to more chemical inputs in form of chemical fertilizers and amendments which are reducing their productivity and plants are being treated for diseases and insect-pests through a variety of chemicals which are entering into the food chain and contaminating water resources. Forests are being leveled to bring more area into agriculture, grazing area is shrinking and habitats of various species are destroying which is causing loss of biodiversity. Moreover, climate change is causing threatening impacts on current agriculture practices which include decreasing yields, the occurrence of new diseases and natural disasters. Considering the present scenario, it has now become utmost necessary to shift from industrialized agriculture to organic farming where sustainability must be the prime objective; where soils are allowed to rejuvenate to their natural potential. However, millions of people around the world still suffering hunger especially when industrialized agriculture is considered as most productive; at this situation, a major shift from conventional to organic farming has raised the question "can organic farming alone achieve sustainability"? Considering the above facts present review inculcated various published research of national and international repute that claims the capability of organic farming to achieve sustainability and the loopholes where it lacks adaptability over conventional farming.

Keywords: fertility, organic farming, productivity, soil conservation, sustainability

Introduction

The population of the world is increasing at a faster rate and it is estimated that by 2050 the world's population will increase by two billion or three billion and as a consequence, it will double the demand for food, fuel, fibre, and shelter. The demand will also rise due to better income that will increase purchasing capacity of people around the world, they will eat more processed food which will need more raw food and energy. Consequently, more area available for forest and pastures will be levelled for intensive agriculture for crops to be grown with more capital inputs and hence the food will be expensive and become less accessible especially to rural people of developing countries. Moreover, intensive agriculture has been causing deteriorating effects on soil health and crop environment which results in yield reduction and hence demand additional expense on crop growth, soil amelioration and mechanization; these additional expenses causing additive effects in price rise as well as undesirable for livelihood of rural people especially in developing countries where they rely mostly on agriculture and possess small land holdings. Also, the crops under modern agriculture are being grown by the intensive addition of fertilizers, pesticides, herbicides and various biocide chemicals which are causing their entry into the food chain as well as contaminating the natural and ground water resources which are an unavoidable serious issue. The present situation has led the researchers and world leaders to question whether current agriculture must be abandoned or not and if yes then what will be its impact on global food security? Also, a big transition from industrialized agriculture to organic agriculture will be fruitful or not? However, some successful examples still available in favour of organic agriculture but those were carried out on small scale; considering them as sufficient evidence to adopt organic farming globally will raise question "whether organic farming alone achieve sustainability?"

However, the solution to every problem depends upon how the problem is perceived. Our goal is to achieve sustainability in farming systems that will ultimately meet out our food security objectives. Food security is basically "when all people, at all times, have physical and

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economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). In a broad sense, this definition implies that availability of cheap nutritious food at all times will bring food security but as far as present agriculture practices are concerned the food so produced is neither healthy (in many quality parameters) nor cheap.

Moreover, present food production and distribution systems are not making a significant contribution to addressing food insecurity among rural people. Various other missing links are also preventing food security to establish. First, approximately 800 million people are food insecure globally, the majority of which living in central Africa and south Asia. Especially when current food production has enough calories and protein to feed everyone; it is just because the food divided unequally due to corrupt governments, political turmoil, civil wars and periodic droughts. The world has enough food for everyone but the political and logistical events prevent adequate production and stopping aid to reach and hence hundreds of millions of people starve to death. Second, the majority of food insecure people live in rural areas of developing country which have small land holdings and not literate enough to either get a job or adopt new technology in their agriculture practice. Hence, their income is not sufficient to access basic health and social services for their products possess the quality to influence the market and ultimately, they are becoming poorer from poor. Thus, national food security does not guarantee food for all as demonstrated by the fact that India has been among largest food exporters in the world whereas approximately 212 million Indians are food insecure (FAO, 2006) ^[15]. Third, the green revolution of the 70s helped enhanced crop yield particularly in Asia owing to the agro-ecological conditions, soil response to chemical inputs, population per unit area, ability to invest in agriculture and better extension services but it is very difficult to replicate in Africa especially in sub-Saharan regions where such advantages never exist. Thus, use of synthetic fertilizers has remained low and the crop yields per hectare have barely increased over the last 40 to 50 years in Africa as a whole, and remain very low (less than one metric ton per hectares for most crops according to FAO STAT, 2007) ^[16]

Therefore, a more comprehensive and practical approach is needed that takes into consideration various aspects of agriculture that involves enhancement of the natural environment, natural resource sustainability, maintenance of livelihood including social and cultural traditions of the people (Markwei *et al.*, 2008) ^[30]. We have seen all the advantages and drawbacks of modern agriculture as well as various unavoidable consequences of modern agriculture that have hazardous impacts on human and animal health and natural resources. Considering the present scenario, we are left with no other choice in favor of present conventional agriculture practice and we must adopt an alternative. If we follow certain examples available in favor of organic farming that proves its capability to achieve sustainability then organic farming could be that alternative. But, as described in the facts above that organic agriculture could not be adopted on a large scale in developing countries so it should be a

sustainable alternative in the developed world on large scale. Through organic means, the output must be continuously improved per unit area as well as social and environmental needs must be facilitated. Organic farms must combine multiple crops to facilitate maintenance of soil ecology, biodiversity, and yield stability; we need to further improve organic farming to meet out emerging needs of food, fiber, biofuel and climate conditioning. Thus, there will be great need of significant inputs of resources for research, including agronomical and soil science based principles along with physical, chemical and biological methods together act synergistically to maintain desired results from organic food production system.

However, neither the conventional agriculture was zero disadvantageous practice nor organic farming; it is because we have explored every corner of conventional agriculture and when its drawbacks became apparent then we are trying to shift to an alternative which is organic farming. But, organic farming is still not under practice on a global scale hence neither its benefits nor drawbacks are fully explored that's why its adoption is questionable. That's why we have thoroughly studied various international literature which favors organic farming as well as those which criticize it and a detailed study has been presented here to facilitate readers with comprehensive knowledge about various drawbacks in conventional agriculture as well as limitations in organic farming and what needs to be done to achieve sustainability.

Drawbacks in Conventional Agriculture

Agriculture is at a crossroad now, where choosing the right path will define our future. Approximately one sixth of the world's population is in danger of starvation (UN, 2008). The situation differs from region to region, and changes with time as economic and political conditions change, but in general, over much of the world, there is a serious problem of food security. Agribusiness executives, agricultural and ecological scientists, international agriculture experts, agronomists working at the field level, as well as economists and political analysts in multi-national banks, development agencies, and non-governmental organizations agree that action must be taken to stave off immediate problems of hunger and believe that a large-scale shift to organic farming would not only increase the world's food supply, but might be the only way to eradicate hunger (Kiers *et al.*, 2008; Stokstad, 2008) ^[24, 49]. Majority of people advocate in favour of "Second Green Revolution" based on inorganic fertilizers, pesticides, and genetically modified crops as utmost necessary to feed the world (Borlaug, 2007; Pennisi, 2008; Brown and Funk, 2008) ^[3, 36, 5] whereas other oppose it as being not sustainable practice of crop production due to following reasons:

- It is highly dependent upon petroleum to synthesize the fertilizers, pesticides, and herbicides, and for fuel for transportation of these chemicals. Since petroleum supply is erratic and limited (Kerr, 2008) ^[23], agriculture based on these compounds is not sustainable. With the increase in petroleum price, prices for agricultural chemicals will increase and it will cause less fertilizer usage and hence greater soil degradation and declining yield of agriculture (Scherr, 2003) ^[41].

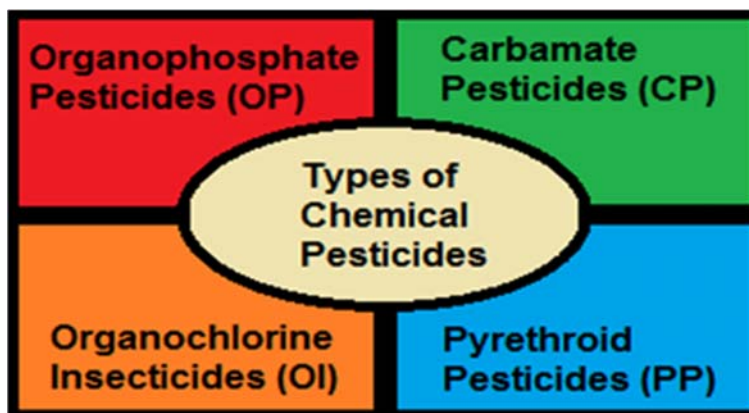


Fig 1

- Use of genetically modified crops can increase yield (Le, 2005). However increasing yield requires an energy trade off against the ability to resist pests, and compete with weeds for nutrients and water. Genetic engineering does not increase the photosynthetic energy available to plants. It just redirects it (Jordan, 2002)^[22].
- Use of genetically modified crops can put the farmer under the control of international corporations that own patents on the crops. As the use of these crops spreads, the world's food supply becomes increasingly dependent on the economic goals of a handful of corporations and not on the needs and desires of consumers (Then, 2000)^[51].
- The simple, vertically integrated economic food chain common in industrial agriculture can be highly susceptible to disturbances (Striffler, 2005)^[50]. For example, terrorists can disrupt the world's food supply by introducing pathogens and other biological weapons into a few key links in the food chain (NDU, 2002; FAO, 2008)^[51].
- Industrial agriculture is leading to a depletion of water resources. For example, center pivot irrigation has led to a significant depletion of the Ogallala Aquifer in the western U.S. (Soule and Piper, 1992)^[47].
- Prevalence of monocultures in industrial food production systems leads to loss of genetic diversity (Soule and Piper, 1992)^[47]. Low genetic diversity increases the risk of disease or insect outbreak (Real, 1996)^[40].
- Inorganic nitrogen leached from fertilizers spread on agricultural fields enters waterways and causes hypoxia that results in the killing of fish, crustaceans and other marine life (Rabalais *et al.*, 2002)^[39]. Dead zones have been reported from more than 400 regions throughout the world (Diaz and Rosenberg, 2008)^[10].
- Nitrogen volatilized from fertilizers enters the troposphere and poses direct health threats to humans and causes substantial losses in agricultural production (Galloway *et al.*, 2008)^[17].
- Animal waste lagoons and spray fields near aquatic environments can significantly degrade water quality and endanger health (Mallin, 2000)^[29].
- Overuse of antibiotics in the livestock industry has resulted in increased resistance of pathogens (Mlot, 2000)^[32].
- Increasing resistance of weeds to a single type of herbicide is resulting in the need for an expensive series of herbicides (Service, 2007)^[42].
- Use of pesticides kills beneficial insects that can help control pest species (Soule and Piper, 1992)^[47].
- Plowing and other methods of tillage that disrupt the structure of the soil result in erosion that is destroying croplands throughout the world (McNeil and Winiwarter, 2004)^[31].

PESTICIDES: HITTING YOU ALL OVER	
Pesticides	Toxic impact
Chlorpyrifos	Nerve damage
Endosulfan-T	DNA mutation, hormone disorders, neurotoxicity
Heptachlor	Nervous system and liver damage
Quinalphos	Developmental, reproductive, neurological damage
Aldrin	Cancer, infertility
Chlorfenvinfos	Developmental, reproductive, neurological damage
Chlordane	Affects nervous system, lungs, liver, kidneys, eyes
DDT	Cancer, hormone disorders, infertility

Fig 2

Considering the above facts, opponents of industrial agriculture argued that current agriculture practice must be replaced with organic agriculture which is based upon natural

processes, humans should learn and understand how nature works, and take advantage of the services of nature to produce food and fiber (Jordan, 1998)^[21]. We must modify

conventional agriculture, modern agriculture, and industrial agriculture into new terms such as organic farming, sustainable agriculture, biodynamic agriculture, alternative agriculture, ecological agriculture and regenerative agriculture.

Limitations in Organic Farming

Global food production increased by 70% from 1970 to 1995, largely due to the application of modern technologies in developing countries, where food production increased by 90%. However, global food production must grow to the same extent in the coming three decades, to meet human demand (Bruinsma, 2003; Cassman *et al.*, 2003; Eickhout *et al.*, 2006) [6, 7, 12].

To achieve this demand two possibilities have been identified: first is that we go for industrial agriculture where intensification of agricultural production on existing cropland or plowing up the natural land into cropland, *i.e.* clearing pastures and rangelands, cutting forests and woodland areas is to be done. Some experts have a positive view that food production can be greatly increased if high-yielding production is widely applied (Bruinsma, 2003) [6], and the expansion of arable land in the world is expected to only slightly increase from 1400 Mha in 2006 (FAO, 2007) [16] to 1600 Mha in 2030 (Bouwman *et al.*, 2005) [4]. The other possibility is to adopt organic farming which is not yet adopted on a larger scale. However, recent research claims that sufficient food can be produced by organic agriculture (Woodward, 1995; Vasilikiotis, 2000; Leu, 2004; Tudge, 2005; Badgley and Perfecto, 2007) [57, 55, 28]. Various arguments have been put forward against organic agriculture out of which most appealing are following three:

- Organic agriculture mainly depends upon leguminous plants for nitrogen fixation hence a larger land area is to be utilized by legume crops, particularly grain legume. So, a change in the diet based mainly on vegetables and legumes provide food for all or not (Woodward, 1995) [57].
- In rural areas of developing country people need low-cost and readily available technologies and practices of crop production, whereas the organic farming cause additional cost to the overall expenditure as well as a biocontrol of insect-pest has very few advantages over chemical control and results are not always promising (Pretty *et al.*, 2003) [38].
- Organic agriculture demands additional area for raising green manure crops, or various manures, composts *etc.*, which is a major limitation for poor farmers (Leu, 2004) [28].

These arguments confuse the original scientific question with other realities interacting with food sufficiency, such as a change in dietary composition, poverty, finance, markets, distribution system, etc. However, the basic scientific question remains the same about the authenticity of organic farming as promising as it is assumed to be. Various other arguments also put forward that questions the sustainability accomplishment where neither industrial agriculture nor organic agriculture is a cause. Such as:

- Land area is still decreasing as it is being taken over for the industrial and urban purpose (Blum *et al.*, 2004) [2].
- Global warming may reduce the potential for higher yields irrespective of what agriculture practice is being adopted (Parry *et al.*, 2005) [35].

- Considerable areas of land especially forests has been used for fuel and timber production that competes with food production systems (Nonhebel, 2005) [34].
- Cropland simply cannot be expanded, due to a shortage of suitable land as well usage of land against the land suitability classification. On the other hand, current yield increases appear to be falling below the projected rate of increase (Cassman *et al.*, 2002) [8].

To ascertain the beneficial as well as negative aspects of organic farming some refined researches had been carried out. The evaluation of organic yield data in those researches was evaluated through sophisticated means. The important points of the results can be summarized as:

- Yields of organically grown crops in Europe are in most cases significantly lower than those of conventional crops (Blum *et al.* 2004) [2].
- High organic yields, as reported in certain studies in the USA, are not relevant for comparisons with conventional yields, since they rely on the purchase of large amounts of animal manure (Smolik *et al.* 1993) [43].
- Average organic yields from rotations based on green manure are misleading unless years with crops not yielding exportable products are included in the calculations (Smolik *et al.* 1993) [43].
- Organic yields are limited by both nutrient shortages and high weed populations, and they are more difficult to increase through on-farm manures and exclusive use of untreated minerals as compared to the industrialized agriculture practices (Kirchmann *et al.* 2008) [25].
- Organic agriculture uses cropland less efficiently and requires more cropland to produce the same crop yields. There is a good reason to believe that a large-scale conversion to organic agriculture would lead to severe food shortages (Halberg and Kristensen, 1997) [18].

Salient Features of Organic Farming

Switching to organic farming would have different effects according to where in the world you live and how you currently farm since it is broadly a natural practice of raising crops and hence depends largely upon agro-climatological features of an area. Furthermore, it depends upon the eco-friendly technology incorporated and expertise involved. Although organic farming has certain limitations over conventional farming, it still possesses significant salient features that could guarantee safe and sustainable crop production for coming future. Such beneficial features of organic farming have been studied and summarized as:

- **Yield benefit:** Research by the University of Essex in 1999 found that, although yields on US farms that converted to organic initially dropped by between 10 and 15 per cent, they soon recovered, and the farms became more productive than their all-chemical counterparts (Pretty *et al.*, 2003) [38].
- **Energy efficient:** Studies by the Department for Environment, Food and Rural affairs over the past three years have shown that, on average, organically grown crops use 25 per cent less energy than their chemical cousins. Far from being simply 'energy-lite', however, organic farms have the potential to become self-sufficient in energy or even to become energy exporters (Defra, 2005) [9].



Fig 3

- **Mitigate greenhouse gas emissions and controls climate change:** The production of ammonium nitrate fertilizer, which is indispensable to conventional farming, produces vast quantities of nitrous oxide with a global warming potential some 320 times greater than that of CO₂. In fact, the production of one ton of ammonium nitrate creates 6.7 ton of greenhouse gases (CO₂ equivalent) and was responsible for around 10 per cent of all industrial greenhouse gas emissions in Europe in 2003 (EEA, 2003) ^[11].
- **Efficient use of water:** Agriculture is officially the thirstiest industry on the planet, consuming a staggering 72 per cent of all global freshwater at a time when the UN says 80 per cent of our water supplies are being overexploited (Weis, 2007; UNESCO, 2006) ^[26, 53]. Organic agriculture emphasizes on healthy soil structure, organic farming avoids many of the problems associated with compaction, erosion, salinization and soil degradation, which are prevalent in intensive systems (Lampkin, 1990) ^[26]. Organic manures and green mulches are applied even before the crop is sown, leading to a process known as 'mineralization' – literally the fixing of minerals in the soil. Mineralized organic matter, conspicuously absent from synthetic fertilizers, is one of the essential ingredients required physically and chemically to hold water on the land.
- **Localization of produce:** The organic movement was born out of a commitment to provide local food for local people, and so it is logical that organic marketing encourages localization through veg boxes, farm shops, and stalls. Between 2005 and 2006, organic sales made through direct marketing outlets such as these increased by 53 per cent, from £95 to £146 million, more than double the sales growth experienced by the major supermarkets (Soil association, 2006) ^[44]. As we enter an age of unprecedented food insecurity, it is essential that our consumption reflects not only what is desirable, but also what is ultimately sustainable. While the 'organic' label itself may inevitably be hijacked, 'organic and local' represents a solution with which the global players can simply never compete (Defra, 2005) ^[9].
- **Reduced use of pesticides:** According to the World Health Organization an estimated 20,000 accidental deaths occur worldwide each year from pesticide exposure and poisoning (WHO, 1990). More than 31 million kilograms of pesticide were applied to UK crops alone in 2005, 0.5 kilograms for every person in the country (PAN, 2007) ^[37]. Organic farmers, on the other hand, believe that a healthy plant grown in a healthy soil will ultimately be more resistant to pest damage. Organic systems encourage a variety of natural methods to enhance soil and plant health, in turn reducing incidences of pests, weeds, and disease. There are in fact only four active ingredients permitted for use on organic crops: copper fungicides, restricted largely to potatoes and occasionally orchards; sulfur, used to control additional elements of fungal diseases; Rotenone, a naturally occurring plant extract, and soft soap, derived from potassium soap and used to control aphids. Herbicides are entirely prohibited.
- **Impact on the ecosystem:** Since 1962, farmland bird numbers have declined by an average of 30 per cent. During the same period, more than 192,000 kilometers of hedgerows have been removed, while 45 per cent of our ancient woodland has been converted to cropland (Spencer and Kirby, 1992) ^[48]. By contrast, organic farms actively encourage biodiversity in order to maintain soil fertility and aid natural pest control. Mixed farming systems ensure that a diversity of food and nesting sites are available throughout the year, compared with conventional farms where autumn sow crops leave little winter vegetation available (IFOAM, 2003) ^[19].
- **Nutritional benefits:** In 2001, a study in the Journal of Complementary Medicine found that organic crops contained higher levels of 21 essential nutrients than their conventionally grown counterparts, including iron, magnesium, phosphorus and vitamin C. The organic crops also contained lower levels of nitrates, which can be toxic to the body (Worthington, 2001) ^[60]. Other studies have found significantly higher levels of vitamins as well as polyphenols and antioxidants in organic fruit and vegetables, all of which are thought to play a role in cancer-prevention within the body (Soil association, 2008) ^[46].
- **Saving of seeds:** The UN FAO estimates that 75 per cent of the genetic diversity of agricultural crops has been lost over the past 100 years (FAO, 1997) ^[16]. Traditionally, farming communities have saved seeds year-on-year, both in order to save costs and to trade with their neighbors. As a result, seed varieties evolved in response to local climatic and seasonal conditions, leading to a wide variety of fruiting times, seed size, appearance, and flavor. More importantly, this meant a constant updating

process for the seed's genetic resistance to changing climatic conditions, new pests and diseases.

- **Employment generation:** According to a 2006 report by the University of Essex, organic farming in the UK provides 32 per cent more jobs per farm than comparable non-organic farms. Interestingly, the report also concluded that the higher employment observed could not be replicated in non-organic farming through initiatives such as local marketing. Instead, the majority (81 per cent) of total employment on organic farms was created by the organic production system itself. The report estimates that 93,000 new jobs would be created if all farming in the UK were to convert to organic (ISEC, 2002) [20].

Solutions to Achieve Sustainability

After studying the above facts which are based on scientific experiments it is now clearly understood that we should not continue producing crops through industrialized agriculture due to various drawbacks discussed above as well as organic farming also have limitations. From the evidence of various experiments discussed above it has been found that promoting organic agriculture does not increase the food security problems, but is part of the solution - especially because it leads to improvement in productivity of local food systems and access to food. But realizing this potential on a larger scale is presently hampered by major challenges that include lack of significant research and technical support. As compared to industrialized agriculture, organic agriculture and the agro ecological methods are knowledge intensive, requiring training and continuous access to information and extension services. Considering the limitations and advantages of both industrialized and organic agriculture certain solutions to achieve sustainability has been postulated as:

Stop expansion of agriculture land

Expansion of agriculture land should be slowed down and ultimately stop, particularly into tropical forests and savannah. The demise of these ecosystems has far-reaching impacts on the environment, especially through lost biodiversity and increased carbon dioxide emissions (from clearing land). Slowing deforestation would dramatically reduce environmental damage while imposing only minor constraints on global food production. The resulting dip in farm capacity could be offset by reducing the displacement of more productive croplands by urbanization, degradation, and abandonment.

Yield enhancement

To double global food production without expanding cropland, we must significantly improve yields of existing farmlands. Which can be done in two possible ways: first, we can boost the productivity of our best farms through improved crop genetics and management and second, we can improve the yields of the world's least productive farms. The first option will enhance the total yield of the farm whereas the second option provides the largest and most immediate gain especially in regions where hunger is most acute.

Efficient Resource Use

To reduce the environmental impacts of agriculture, both low and high yielding regions must practice agriculture with

vastly greater efficiency: far more crop output per unit of water, fertilizer, and energy.

Change Eating Habits

We can dramatically increase global food availability and environmental sustainability by using more of our crops to feed people directly and less to fatten livestock. Globally, humans could eat up to three quadrillion additional calories every year which is almost 50 percent more from our current supply by switching to all-plant diets. Naturally, our current diets and uses of crops have many economic and social benefits, and our preferences are unlikely to change completely. Still, even small shifts in diet, say from grain-fed beef to poultry, pork or pasture-fed beef can pay off handsomely.

Reduce Food Waste

A final, obvious but often neglected recommendation is to reduce waste in the food system. Roughly 30 percent of the food produced on the planet is discarded, lost, spoiled or consumed by pests. Although completely eliminating waste from farm to fork is not realistic, even small steps would be extremely beneficial. Targeted efforts especially reducing waste of the most resource – intensive foods such as meat and dairy could make a big difference.

Conclusion

Persisting agriculture practices has many drawbacks which are causing unavoidable harmful impacts on the environment, soil and living beings. Apart from these prevailing issues current agriculture practices are no longer productive and require additional expenses which are not desirable for the rural people especially in developing countries and hence it has been found that our goals of food security and sustainability could not be accomplished by industrialized agriculture.

On the other hand, organic agriculture is a most discussed alternative against industrialized agriculture owing to its salient features. Though organic agriculture also has certain limitations; after long term experimentation, it was found that the results are desirable but locally acceptable. However, with no other choice, organic agriculture is definitely the demand of time. But organic agriculture alone could not achieve sustainability rather it is our responsibility that along with organic agriculture we must change our lifestyle by changing food habits, conservation of energy and natural resources, controlling food wastage and informing others to do same.

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