



Modern concepts of agricultural research : Ripples and options for conservation agriculture and resource use efficiency

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ABSTRACT

India witnessed self sufficiency in food production by shifting from the traditional organic to chemical-industrial agriculture in the second half of the past century. The production levels plateaued and several challenges of soil-health, crop production and environment have become critical in the new millennium. This need paradigm shifts in agricultural practices and research priorities. Systems Rice intensification conserves water, but it is difficult to practice. Organic farming is eco-friendly but, organic source of nutrients are not sufficient to meet the nutrient requirement of crops and the yield reduction is substantial. It has little scope for farmers to export the produce to developed countries after meeting the standards of trade and cumbersome procedures. The integrated supply of nutrients is potential to sustain the crop yields and restore the soil-health. The transgenic crops opened new vistas in agricultural production. But, such genetically modified crops are frequently unstable and inactivated. They lose the newly acquired traits due to gene silencing. The cell and tissue culture techniques may substitute the traditional crops for the production of food like starch, protein and fats in fermentation tanks. The nanotechnology is likely to revolutionize the agricultural production system. Nutrition with desired elements and flavor stored in the capsules burst open in the stomach and deliver the nutrients in quantities needed by the organ. Similarly, they release the toxins in the stomach of the harmful insects of crop plants. Nano-sensors will alert the farmers before the occurrence of the pest, disease or nutrient deficiency and damage to the crops. The resource conservation technologies for anaerobic crops after the harvest of aerobic rice save expenses and time for land preparation. This will facilitate early sowing of the crops after the harvest of rice on the carry over soil moisture or a shallow irrigation. The use of heavy machinery for sowing may compact the soil in the long run. The residue on the soil surface add organic matter but, it is also likely that it may hinder proper seedling growth. The rice stubbles may harbour the harmful pests and disease inoculums, refuge the rats and invite the snake problem.

Key words : Systems rice intensification, Organic farming, Integrated nutrient supply system, Nano technology, Transgenics, Conservation technologies.

Modern agriculture is scientific. Man imitated nature, maneuvered the soil fertility and productivity, crop architecture, developed artificial source of nutrients with large concentrations in small quantities and readily available form to the crops, pesticides, to protect the crops from pests and rodenticides and herbicides to turn down the competition of other vegetation with the crop. Several equipment and machineries were developed to till the land, sow the seed, plant the seedlings and apply fertilizers, spray the chemicals, harvest the crop and thresh the produce. The water-bodies were tapped to irrigate larger area of the crops. Dryland technologies were developed to utilize the natural resources efficiently, conserve the soil and reduce the runoff losses and minimize the risk of crop failures due to insufficient and irregular distribution of rainfall. Crops and cropping systems were identified for site specific situations. Thus the past extensive agriculture

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was transformed to the exploitative intensive agriculture.

The ancient agriculture was not sustainable. India encountered 14 famines from 11 to 17th century. There were 12 famines and 4 severe scarcities from 1765 to 1855. Several famines and scarcities again prevailed between 1860- 1908. Hunger and malnutrition was destined even in the first half of the 20th century. The human population was low. A total of 238.4 million(m) people inhabited in 1901. The population increased exponential in the second half of the century and crossed an ever record of 1,000 m by 2000.

Transformation from old to new concepts of agriculture in India

The modern concepts of agriculture in India commenced during 1950s. The food grain crops were cultivated on an area of 97 m ha producing 50.8 m tones(t) in 1950. The per caput availability of food grains was only

395 g/day. To sustain the need of food for the increasing population, their cultivation was extended to 124 m ha by 1970. Increase in irrigation was another effort to meet the increasing food requirement. The gross irrigated area increased from 22.5 to 37.0 m ha by this time. The fertilizers were introduced and 69,000 t were applied to the crops in 1950. Their consumption increased to 2.18 mt in 2 decades. The high-yielding fertilizer responsive wheat varieties were introduced in 1963 from Mexico and rice varieties from IRRI in 1964. These interventions more than doubled the food grain production to 108 mt in 1970. Thus the population increased by 21.7%, while food grain production increased by 115% during this 20 year period. This revolutionary achievement relaxed the country from the clutches of dependence on other countries for import.

Thomas Malthus (1798) predicted disaster due to adverse imbalance between human number and their capacity to produce food, when global population was only 360 m. The Paddock brothers predicted doom's day for India due to recurrent famines. Several foreign experts in 1960s concluded that India has no option except to become the home of serious and recurrent famines. The famous economist Paul eldritch in 1966 predicted that sometimes between 1970 and 1985 the world will undergo vast famines and millions of people will starve to death.

The modern concepts of agriculture disproved all these forewarnings and India achieved the Green Revolution. Indian food grain production increased progressively despite the cultivated area remained constant since 1970. This crucial limitation was fairly overcome by the modern technologies to increase the productivity/unit area and thereby the total food grain production. New ideotypes with canopy architecture to capture more sunlight and CO₂, the root mass with high CEC-effective to respond to the artificial nutrients through fertilizers and partitioning of more dry matter of the plant into grains vis-a-vis the increasing irrigation potential which made intensive cropping feasible added to increased level of food production to match the need for the increasing population until the turn of the century. The per caput availability of food grains raised to 460 g/day. The high-yielding varieties covered 97% of the area by 1997. The fertilizer consumption increased steadily to 20.94 mt and gross irrigated area to 82.68 m ha by 2005.

New challenges of modern agriculture

Currently, decline and deterioration of natural resources emerged as a serious concern for the sustainability of food production. The yield plateaus and several new generation problems of soils are considered as the silent ill effects of over exploiting the resources through the Green Revolution technologies. The soils have become sick for sus-

tained crop production and the environment unsafe for human health. Some of the widely recognized problems are the low nutrient status of the soils due to intensive cultivation. The crops are unhealthy with prominent symptoms of multi-nutrient deficiencies due to the indiscriminate quantities of fertilizers applied. The continuous and massive application of fertilizers without the organic manures have created lifeless and dusty soils which are more prone to erosion. The use of heavy machinery created the problem of soil compaction which reduces the ability of the soil to absorb water and reduce the crop yield. The water runoff the compact soil and contribute to erosion. The faulty irrigation practices led to the development of barren lands by accumulating salts to toxic level and creating water-logged conditions. The over exploitation of irrigation by shifting from centrifugal pumps to submersible tube well to extract water lowered the depth of water-table. The excessive tillage eroded the soils leading to loss of nutrients, reduced the organic carbon through the evolution of CO₂ destructed the stable aggregates and disrupted the void proportion for proper root growth and development. High nitrate content in ground-water has been detected in intensively cultivated rice-wheat system. The indiscriminate use of insecticides created resurgence with no satisfactory control of pests viz., *Helicoverpa armigera* on cotton and red gram, pod borer in rice etc. and tolerance to chemical toxicity of the herbicide Isoproturon to the weed *Phalaris minor* in wheat and butachlor to wrinkle grass in rice. The balance between the harmful insects and predators has disrupted. The pests continued to evolve and through the process of natural selection build up resistance to the chemicals. As a result yesterday's pests have become super-pests to withstand large doses of pesticides. Sometimes they have become cross resistant to 5 or more pesticides and are less likely to be troubled by the predators. Chemical residues in food increased the incidence of many types of cancer particularly among the farmers. Over 40,000 Third World farm workers are killed each year and upto one- million made ill or permanently injured due to over exposure or mishandling of the agro chemicals. Rodent control in the fields by the regular use of zinc phosphide @ 2% in cereal baits has become ineffective in Punjab and Haryana. These are some of the classical examples to cause severe yield losses in crops. The eutrophication of water-bodies due to the accumulation of excess salts in soil due to heavy dose of fertilizer applications rendered soils less productive for cultivation. The factor productivity for 1 kg fertilizer was 35 kg food grain during Green Revolution. This has come down to < 12 kg. Therefore, to get the same response to fertilizers as in the past, currently higher fertilizer dose is needed. Surekha (2007) reported that the soil fatigue in intensively culti-

vated irrigated rice lands led to the use of 40% more nitrogen to produce the same quantity of rice as 10 years ago. The cultivation of Bt cotton was over whelming to the farmers. The *Helicoverpa* larvae were fairly controlled until 90 days after sowing the crop. This technology saved the farmers from committing suicides. But, in 2007- 08, the pest became virulent early at 60 days in Andhra Pradesh. This threat appears to be due to the silencing effects of the genes. A hitherto major pest of custard apple, mango and red gram - the mealy bug infestation emerged as a new and serious pest on Bt or non-Bt cotton. The application of confidor lost its toxic effect on the sucking pests. There are several such examples that the modern technology is challenged and demand a revision of human intelligence to search alternative options.

Systems rice intensification

The resource conservation technology for rice cultivation was evolved by Fr. Henrie Laulanie at Madagascar during 1983. He migrated from France in 1961 and settled at Madagascar to practice and profess agriculture. The technology showed a dramatic improvement in rice yield to harvest 2-fold more grain with just half the water. Also, it conserved the seed. This yield improvement was possible with only 5-10 kg seed against convention of sowing 50-100 kg/ha. The technique is also eco-friendly. Since the fields are not flooded but kept moist 'methane' the major green-house gas is not produced. This was not known outside Madagascar until 1997 as it sounded too good to be true.

The farmers harvesting 2 t grain realized even 8 t/ha. Its potential was tested in China, Indonesia, Cambodia, Thailand, Bangladesh and Sri Lanka. The technology spread successfully in 18 districts of Sri Lanka. The first International conference on SRI was held in China in April 2002. It was known in India during 2000. In Andhra Pradesh, it was introduced in 2002. Several large-scale demonstrations were conducted in the farmers' fields. Systematic research was then conducted in the research farms. There was no appreciable increase in yield compared to the conventional method. However, water conservation was the advantage. To produce 1 kg grain 2,710 litres of water was needed through this novel approach in contrast to the 3,720 litres through the conventional method. The labour do not have the skill to pull the 8-12-day-old tiny and delicate seedlings from the nursery with the seed intact and soil adhering to the roots without damaging the root system. It was not possible to be extremely cautious to irrigate the field frequently and shallow to keep the soil moist without flooding or allowing it to dry to develop hair cracks. The high intensity rains in the *kharif* season may submerge the seedlings, uproot and wash them away eas-

ily. The frequent failure of electricity is not uncommon. This leads to drying of soil. The depressions and elevations due to imperfect leveling of field create water logged and dry patches. Most of the farmers who initially tested this concept shirked it off since 2006.

Organic farming

A network of experiments initiated in India to study the feasibility of reverting to organic from the chemical agriculture. The results of experiments conducted at three different ecological regions of Andhra Pradesh on maize-onion, turmeric-sesamum and rice - rice cropping systems are discussed.

The experiment on maize-onion cropping system at Rajendranagar (Table 1) indicated that the recommended dose NPK to maize (120:60:60 kg/ha) and NPKS to onion (150:60:60:40 kg/ha) produced more yield than the organic treatment by the application of FYM, vermi compost and neem cake each applied at 1/3 recommended rate of N. The integrated supply of nutrients through 50% RDF with 50% N equivalent through FYM in general produced yield similar to RDF. The soil recorded considerable improvement in OC, available P and K due to the external input of nutrients compared to the initial level after 4 year. The OC increased from the initial 0.36 to 0.49% due to the continuous application of fertilizers and also by the integrated supply of nutrients. But, high value of 0.70% OC was recorded by the organic source of nutrient supply.

The yield responses and the effect on soil fertility after 5 years of turmeric sesamum cropping system at Rudrur in response to different sources of nutrients (Table 2). The rhizome yield of turmeric and seed yield of sesamum reduced due to the continuous addition of organic source of nutrients in all the 5 years. The application of 50% RDF with 50% N equivalent through FYM largely compensated the yield loss due to the organic nutrients alone. Maximum yield was realized by continuous application of fertilizers @ 180:75:120 kg to turmeric and 30:60:40 kg/ha NPK to sesamum. The organic carbon content was maintained to the initial level even after 5 years of continuous fertilizer additions while, it reduced due to the organic farming.

The production trends in rice-rice cropping system in the coastal ecosystem at Maruteru and the effect on soil fertility are given in Tables 3. The organic treatment did not support yield similar to those due to continuous application of fertilizers @ 60:40:40 kg/ha NPK in *kharif* and 120:60:60 kg/ha during *rabi* in any one of the 5 years. But the integrated supply of nutrients by the application of 50% RDF and 50% N equivalent through FYM was almost equally productive as due to the application of fertilizers alone. The organic carbon content improved by the cultivation of crops through the external input of nutrients.

But, there were no distinct variations due to the source of nutrients.

By and large the experiments conducted elsewhere in the country do not provide evidence that the organic farming is more efficient to increase the production or the soil organic carbon, available P and K compared to the chemical fertilizers. It is not possible for all the farmers to raise organics on the farm in sufficient quantities to supply the needed nutrients to the crops. If purchased, the costs are prohibitive. Nonetheless, organic farming is highly profitable despite severe reduction in yield, if the produce is certified for export after cumbersome processes of international standards and heavy investments. It is not applicable to all the farmers who cannot afford to invest high nor ready to lose the yield substantially. It is estimated that about 30 m t of nutrients are removed by the crops annually in India. The nutrient addition has reached 22 m t by 2006. Still there is a gap of 8 m t. All the organic sources of nutrients pooled do not exceed 6 - 8 m t. They will be sufficient to supply 1/5 nutrient requirement of crops in the country, if agriculture is to be shifted from fertilizers to organic. Therefore, this concept has no scope to flourish in future. Awareness to combine every organic source with the fertilizers will help in the physical improvement of soil, better water retention and thereby better fertilizer use efficiency for high yield.

Integrated plant nutrient supply

The decline in productivity of rice-wheat cropping system due to over exploitation of natural and indiscriminate use of chemical inputs in South Asian countries was the turning point to integrate the plant nutrient supply system and conserve the soil-health by improving physical, chemical and biological properties for sustained production of crops. The appropriate combination of mineral fertilizers with organic manures, crop residues, green manures, composts, rotation with N-fixing crops, bacterial cultures that fix-nitrogen, solubilize the fixed P in the soil and micorrhizae etc. varies with the system of land use, ecological, social and economic conditions. Therefore long-term experiments were initiated in rice based and other cropping systems throughout India in the early 1980s. The concept help in avoiding soil degradation and deterioration of water and environmental quality by promoting carbon sequestration and checking the losses of nutrients to water-bodies and atmosphere. The organic source of nutrients act as slow release fertilizer as it synchronizes the nutrient demand set by the plants (Gill and Brar, 2005). The 20 years search in this direction from a rice-rice system in the alfisol at Rajendranagar in Andhra Pradesh showed that the green manuring with *Glyricidia maculata* which is locally available in plenty is the best

source to sustain the crop productivity and conserve the soil health. The incorporation of *Glyricidia* @ 60 kg N equivalent on dry-weight basis in the soil about 2 weeks before planting of rice in *kharif* and fertilizing the crop only with 60:30:30 kg/ha NPK produced grain and straw yield similar to the effect of the recommended dose of kg/ha NPK (120:60:60). The soil organic carbon was more than the initial value and as much due to inorganic cultivation. The substitution of 50% NPK fertilizers with Farm-yard manure improved the organic carbon to a maximum of 0.70% compared to the initial value of 0.54% (Table 4).

In the tank irrigated medium deep soils at Rudrur, the rice – mustard cropping system also confirmed the usefulness of integrated supply of nutrients. The substitution of 50% N fertilizer dose to *kharif* rice with FYM or *Glyricidia* green leaf manure incorporation sustained the yield with the recommended dose of NPK (120:60:40 kg/ha) to rice and to mustard (80:40:30 kg/ha) supplied sole through the fertilizers during 14 years of study. The soil organic carbon improved even in the unfertilized crop after 5 years. This was probably due to the incorporation of organic matter through harvested stubbles and the fallen leaves that were incorporated into the soil every season. The organic carbon was more due to the integrated nutrient management treatments over the continuously fertilized soil (Table 5). The soil available P and K increased after 14 years of cultivation of rice – mustard cropping system with different treatments.

In Maruteru, the integration of green leaf manure with *Sesbania aculeata* or FYM replacing 50% NPK fertilizer dose during *kharif* in rice- rice cropping system sustained yield on par with the continuous application of fertilizers. The organic carbon content of the soil did not change substantially either by the cultivation of the crops with fertilizers or through integrated nutrient supply after 15 years (Table 6). There was a substantial reduction in the level of available potassium compared to the initial value.

The results obtained from a wide net work of experiments in the country from several long-term experiments has set a sound confidence that the soil can be conserved from degradation of its physical and chemical properties without serious yield reduction in rice- based cropping systems by adopting the integrated nutrient approach. These results indicated that there should be a surge of renewed interest to decompose every farm waste and incorporate into the soil and conserve its structural properties and improve the water and nutrient use efficiency for better productivity.

Transgenics

The transfer of an unrelated desired gene from one organism to another or non- crossable species is called

Table 1. Influence of source of nutrients on yield (t/ha) in maize – onion cropping system soil chemical properties after 4 years and at R' nagar.

Treatment	2004 - 05		2005 - 06		2006 - 07		2007 - 08		pH		EC d S/m	OC %	Av. P kg/ha	Av. K kg/ha
	Maize	Onion	Maize	Onion	7.6 Maize	0.55 Onion	0.36 Maize	24.0 Onion	293					
50% NPK – 50% N FYM	3.15	14.37	2.20	15.14	4.17	9.33	4.36	18.48	7.4	0.35	0.49	33.3	349	
1/3 N FYM + VC + N C	1.90	8.77	1.62	9.20	1.94	6.31	2.18	9.02	7.4	0.36	0.70	34.6	377	
RDF	4.29	10.86	2.23	14.41	3.39	10.23	4.78	19.58	7.2	0.39	0.49	34.6	358	
Initial														

Table 2. Influence of source of nutrients on yield (t/ha) in turmeric – sesamum cropping system and at Rudrur.

Treatments	2003-04		2004-05		2005-06		2006-07		2007-08		pH	EC dS/m	OC %	Av. P kg/ha	Av. K kg/ha
	Turmeric	Sesamum	Turmeric	Sesamum	Turmeric	Sesamum	Turmeric	Sesamum	Turmeric	Sesamum					
50% NPK + 50% N FYM	5.02	0.79	2.70	4.8	4.31	5.0	4.02	0.51	4.10	0.52	7.8	0.34	0.41	35.8	230
1/3N FYM + VC+ NC	4.52	0.65	2.31	3.9	4.02	4.1	3.28	0.45	3.42	0.46	7.7	0.30	0.30	45.6	242
RDF	5.43	0.76	3.05	7.6	4.43	7.6	4.23	0.58	4.57	0.60	7.8	0.47	0.47	41.4	246
Initial											7.3	0.48	0.46	41.0	225

Table 3. Influence of source of nutrients on yield (t/ha) of rice- rice cropping system at Maruteru

Treatments	2003-04		2004-05		2005-06		2006-07		2007-08		pH	EC dS/m	OC %	Av. P kg/ha	Av. K kg/ha
	<i>kharif</i>	<i>rabi</i>	<i>kharif</i>	<i>rabi</i>	<i>kharif</i>	<i>rabi</i>	<i>kharif</i>	<i>rabi</i>	<i>kharif</i>	<i>rabi</i>					
50% NPK – 50% N FYM	4.50	3.92	5.39	5.41	4.36	6.40	3.86	4.80	5.09	5.55	5.8	0.76	0.80	340	179
1/3N-V FYM +VC+NC	4.46	3.16	5.13	5.08	4.01	5.01	3.45	3.77	4.21	4.37	6.6	0.41	1.03	357	171
RDF	4.87	3.42	5.26	5.83	4.78	6.52	4.23	5.30	5.30	5.32	5.7	0.29	1.06	382	170
Initial											6.6	0.37	1.00	310	184

*VC: vermicompost; NC: Neem cake; RDF: Recommended dose of fertilizers

transgenic. The transgenic plants or animals so derived are called genetically modified organisms. Such varieties of crop plants are now emerging as strong tools for yield security because of their promise to resist the damage due to pests and diseases, tolerance to the herbicides, high level of salinity, alkalinity and aridity etc.

In India, cotton is grown on 9 m ha *i.e.* 20% of the area in the world. But, its tyranny is that the boll worms and sucking pests cause severe economic damage. The cotton growers often commit suicides. The pest *Helicoverpa armigera* has developed a high level of resistance to several pesticides. The transgenic Bt cotton were introduced for commercial cultivation since 2002 in India amidst several skepticisms of tolerance of the insect even to this bacterial gene effect. It was also known that the *Helicoverpa armigera* has the capacity to develop resistance to the protein Cry 1 AC in 7-8 generations. The conventional varieties progressively made a way for the Bt varieties. The farmers were comfortable. The larvae of *Helicoverpa* were fairly untraced until 90 days after sowing. But by 2007, the Bt cotton is infested with this pest by 60 days. It is also

severely infested by hitherto a negligible pest – the mealy bugs. The story of miseries turned around. The risks of this tremendous and potential technology are now seen in 5 years. Several research workers already cautioned that the gene silencing may occur in transgenic plants and the transgenes cease to function. The emerging biotechnology can erode the biodiversity increasing uniformity in production and imposing intellectual property right to turn life forms into private property (Rethinam and Sreedhar, 2000). Desirable new phenotypes created by introducing foreign DNA into plants are frequently unstable leading to loss of newly acquired traits. This genetic instability is due to the inactivation of transgene referred as gene silencing. Resistance problems are likely to develop in Bt crops. The continuous expression of toxin create a strong selection pressure. They are also likely to affect non target organisms and neighbouring fields that share similar pest complexes ending up with resistant insect population colonizing their fields. Genetic engineering in agriculture will do nothing to stave off world starvation. On the other hand, it is likely to do much to increase such problems (Anuradha,

Table 4. Influence of integrated nutrient management treatments on soil fertility after 20 years at R'nagar.

Treatment	pH	EC (dS/m)	OC %	Average P (kg/ha)	Average K (kg/ha)
No Fertilizers	8.06	0.45	0.55	30.07	159
RDF	8.01	0.47	0.67	48.56	166
50% N <i>Glyricidia</i> + 50% N fertilizers	8.03	0.55	0.57	36.71	165
50% N FYM + 50% N fertilizers	7.67	0.46	0.70	40.69	158
50% N Paddy straw + 50% N fertilizers	8.02	0.47	0.59	32.97	171
Initial	8.50	0.24	0.54	34.00	224

Table 5. Influence of source of organic nutrients combined with fertilizers on soil fertility after 14 years of rice-cropping system.

Treatments	pH	EC (dS/m)	OC %	P (kg/ha)	K (kg/ha)
No fertilisers	7.63	0.58	0.59	25.47	328
Recommended dose of fertilisers	7.77	0.64	0.59	26.73	338
50% N <i>Glyricidia</i> +50% N fertilisers	7.60	0.65	0.64	28.10	316
50% N Farmyard manure + 50% N fertilizers	7.73	0.62	0.64	26.80	320
50% N Paddy straw +50% N fertilisers	7.67	0.64	0.67	26.83	326
Initial	8.10	0.37	0.52	18.00	304

Table 6. Influence of source of integrated nutrient management on soil fertility after 15 years rice-rice cropping system at Maruteru.

Treatments	pH	EC (dS/m)	Organic carbon %	Average P (kg/ha)	Average K (kg/ha)
No fertilisers	6.05	0.34	0.83	32.17	220
Recommended dose of fertilisers	5.98	0.36	0.89	34.47	174
50% N <i>Sesbania</i> + 50% N fertilisers	5.96	0.33	1.01	35.23	169
50% N FYM +50% N fertilisers	6.15	0.35	0.89	33.07	168
50% N paddy straw + 50% N fertilizers	6.11	0.32	0.86	32.65	214
Initial	5.10	0.38	0.90	38.00	344

2000). To overcome this challenge integrated gene management along with precision farming is suggested. Cysgenesis is now considered to open new options for second Green Revolution in India. It can be used directly for the improvement of existing varieties which already proved to be safe for use in the market (Jacobsen and Nataraja, 2008).

Crop substitution

It is possible in the near future that the traditional food crops can be substituted with factory produced foods *viz.*, starch, proteins and fats grown in fermentation tanks by the use of modern techniques of cell and tissue culture. This will replace some of the agricultural crops such as vanilla, sugar or oilseeds to be grown at current production levels.

NANO technology

It is the manipulation or self assembly of individual items, molecules or molecular clusters into structures to create materials and devices with new or vastly different properties. The prefix 'nano' is the greek word meaning dwarf. One nm corresponds to the millionth part of a mm. Nanotechnology utilizes structures of 0.1 to 100 nm in size. The application of this technology to agriculture and food industries was first addressed by a United States Department of Agriculture road map in September, 2003. It has a potential to revolutionize the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection and enhance the ability of plants to absorb nutrients etc. Nano-structured catalysts will be available to increase the efficiency of pesticides and herbicides with lower doses. Smart sensors and delivery systems will help agricultural industry combat viruses and other pathogens (Joseph and Morrison, 2006). The low-cost sensors are developed to detect the presence of food borne pathogens, filters to remove undesirable compounds from foods and beverages and nano-particles to store flavours and nutrients inside foods and release them at designated organs in the body when they are needed. Sensors also detect low levels of molecular signals of spoilage and food borne pathogens within minutes of exposure. The packaging materials for food products can also be structured at the molecular level. Plastics can be manufactured with different nano- structures to gain various gas and moisture permeabilities to fit the requirements of specific products, *viz.* fruits, vegetables, beverages and wine. This will improve the shelf – life, flavor and colour preservation of the products. Food safety is also ensured by nano- structured films and packaging materials that prevent the invasion of pathogens and other micro-organisms.

A range of smart agricultural inputs and products are developed *viz.*, nano-seed varieties with inbuilt pesticides that release under certain environmental conditions. Molecular food manufacturing appears to be the future achievement for food security and safety. The nano-capsules make it possible to alter the nutritional composition, flavor and other attributes of food to match consumers' personal tastes, psychological requirements and smart food for packaging able to detect the presence of pathogens. These capsules respond to the body's requirement. They remain dormant in the body and release the nutrients to the cells more efficiently and when needed. The addition of nano-particles to the existing food increase the absorption of nutrients. Tuna fish oil, a source of omega 3 fatty acids has been successfully encapsulated to incorporate in the bread in Australia. These capsules break open only in the stomach and thereby avoid unpleasant taste of the fish oil.

Nano-scale devices with novel properties could be used to make agricultural system smart. They can be used to identify plant health issues before they become visible to the farmer. They will be capable of responding to different situations by taking appropriate remedial actions. If not, they will alert the farmer to the problem. Thus the smart devices act as both a preventive and an early warning system. They deliver the chemicals in a controlled and targeted manner. The encapsulation and controlled release methods have revolutionized the use of pesticides and herbicides. The formulations contain nano-particles within 100-250 nm size range that dissolve in water more effectively than the existing ones thereby increasing their activity. The manufacture of nano-emulsions – suspensions of nano- scale particles are: water or oil-based containing uniform suspensions of pesticidal or herbicidal nano-particles in the range of 200-400 nm. They can be easily incorporated in various media like gels, creams and liquids. They have multiple applications for preventive measures, treatment or preservation of the harvested product.

A few examples of nano-technology are : The application of growth regulator 'Primo MAXX', if applied prior to the on-set of stress *viz.*, heat, drought, disease or traffic, strengthen the physical structure of turf grass and allow it to withstand on-going stresses throughout the growing season. The encapsulated product 'Karate ZEON' is a broad control spectrum on primary and secondary insect pests of cotton, rice, peanuts, and soybeans. It contains the active compound - cyhalothrin – a synthetic insecticide-based on the structure of natural pyrethrins. It breaks open to release its contents when it comes into contact with alkaline environment, *viz.* the stomach of certain insects. Nano-products are also under preparation to tailor them in such a way that they release the chemicals slowly or

quickly in response to different signals *e.g.* magnetic fields, heat, ultra sound and moisture etc. Nano-technology can also be used to clean ground-water. The aluminium oxide nano fibres of 2 nm dia are used as water purifiers. Filters made from these fibres remove viruses, bacteria and protozoan cysts from water.

Conservation Agriculture

The concept of conservation agriculture was developed in USA during 1974. This was due to the necessity. The price of oil increased steep. To cut down the exorbitant expenses on tillage machinery, Government imposed minimum disturbance of soil. Essentially, it has 3 components *viz.*, minimum disturbance of soil, surface cover with crop residues and suitable crop rotations.

Impact of conservation Tillage in Andhra Pradesh

Intensive tillage is necessary after the harvest of rice. The primary tillage to open the soil and secondary tillage to break the clods and make a soft seed bed has become common practice. This is followed by a secondary tillage to prepare a congenial seed bed in the conventional system. This is illustrated with the data on performance of rice - groundnut cropping system to planting technique of rice and tillage requirement of groundnut in Andhra Pradesh (Table 7).

The results showed that in all the 4 years transplanted rice produced more yield than the direct dry seeded crop.

The data on yield of groundnut in response to different tillage practices in rice field sown in puddle and unpuddled soil Table 8 showed that results are clear that the groundnut require intensive land preparation by ploughing twice followed by running the rotavator to prepare fine tilth. The performance was better after dry than the transplanted rice continuously for 3 years. The sub-surface compact layer in the puddle soil was not optimal for better root development and was perhaps more compact for the growth and development of pegs and pods. However, due to the intensive cultivation for 4 years a better tilth was obtained in the previously puddle than the unpuddled field.

In Andhra Pradesh rice is cultivated on an area of 4 m

ha hectares. Out of this 3.8 m ha is transplanted in the puddle while rest is sown direct. In the coastal regions black gram is grown as a relay crop before the harvest of rice on the residual soil moisture. Sesamum and mustard are also relay cropped to a limited extent. This is a zero till cultivation. It saves expenditure on land preparation and yield about 2 t/ha of black gram seed. The fodder is highly valued for its high protein and palatability to the cattle. The yellow mosaic virus infestation has become a serious yield limiting disease since 2005-06. It devastated the entire crop during 2007-2008. This challenge compelled the farmers to search for alternate cropping system. In 2005-06 farmers attempted exploratory efforts by sowing maize between the stubbles of harvested rice at optimum moisture for good germination.

The canal water is usually released in July and withdrawn in February. Rice nurseries are raised in June-July for about a month and transplanted. The crop is harvested in October-November. Soil moisture is retained for a long time in the heavy black soils. The evaporation is slow due to the cold weather with low temperature, high humidity and low wind velocity. Therefore land preparation becomes difficult. About 2-3 weeks time is needed for the implements to work. There is little time for this operation. If land preparation is delayed, the soil become hard and develop cracks. If ploughed under over moist conditions heavy clods are exposed. Maize mature in 4 months unlike black gram in 80-90 days. Therefore, time of sowing for maize is critical. Farmers recognized the need to sow the crop early to match with the availability of water until the grain filling stage. They skipped of the tillage practices to create a soft seed bed. Seeds were dibbled 2-3 days after the harvest of maize in the moist sub-surface layer. The moisture was adequate for good germination and to produce healthy seedlings without stress until 3 weeks. This practice saved the expenses for land preparation, water for 1 irrigation and advanced the time of sowing by about 2-3 weeks. The weeds are usually less due to the sub-merged conditions of puddle fields. Therefore weed control with the herbicide sprays was very effective until the crop canopy covered the ground area and suppressed their growth. The herbicides mixture of Paraquat @ 5 ml and atrazine @ 4 g/litre was sprayed on the soil surface and stubbles of harvested rice within a couple of days. There was no rejuvenation of the rice stubbles and the newly emerging weeds were controlled. The light and medium soils were disturbed with the blade harrows after 3-4 weeks of sowing with bullock drawn blade harrows to break the capillaries for aeration and fertilizer is added. This is followed by irrigation. In heavy black soils fertilizers are dissolved in water and applied along the rows through the perforated poly vinyl chloride pipes. Seed is

Table 7. Influence of planting techniques of rice on seed yield (t/ha)

Treatments	year			
	2003	2004	2005	2006
Dry seeding	2.83	2.08	1.52	1.72
Transplanting	3.92	3.87	4.38	3.51
<i>In-situ</i> green manuring and transplanting	3.81	4.02	4.55	4.06

also sown behind the plough by opening a furrow in light textured soils. This reduce expenditure on 25-30 labour for dibbling while 8-10 labour is sufficient to sow and fertilise behind the plough. This is not possible in heavy black soils.

In the Nagarjuna Sagar command area, rice-rice is the predominant cropping system. Maize, sunflower, groundnut and cluster bean are the alternate crops to rice in *rabi*. The water is released for cultivation in the 4th week of July to 1st week of August until the 4th week of April. Rice nurseries are raised dry with rainwater in June-July. Seedlings are transplanted in August-September and the crop is harvested in November-December. Rice nurseries for the *rabi* are raised 2-3 weeks before the harvest of *kharif* crop. The land preparation is done within 10-15 days and the seedlings are transplanted during December – January.

Hail storms common in April – May coincide with the maturity stage and seriously damage the crop. This necessitated the farmers to search alternate crops. Maize was the best option. The seeds on the cobs are well protected with the layers of husk. Hence the seeds are not in direct contact with the hail. It requires less water and the cultivation expenses are less. This was the turning point for the farmers during 2005 to grow maize by dibbling the seed between the rice stubbles with the help of ropes. Several demonstrations were conducted by the agronomist of the Agricultural Research Station – Kampasagar to sow the seed with zero till fertilizer drill developed at Pantnagar. Currently the sowing methods followed by the farmers are hand dibbling, opening a small furrow with the country wooden plough, Zero till fertilizer drill, Zero till drum seeder and a local devise developed by the farmers to

Table 8. Influence of tillage practices in rice fields on pod yield of groundnut (t/ha)

Treatment	Year			
	2003	2004	2005	2006
Dry seeded rice-ploughing once and harrowing twice	1.921	1.940	2.150	1199
Ploughing twice and harrowing thrice	2.299	2.075	2.275	1267
Ploughing twice and rotavator twice	3.240	2.210	2.362	1460
Transplanted rice-ploughing once and harrowing twice	1.723	1.505	1.780	1068
Ploughing twice and harrowing thrice	2.200	1.680	1.676	1271
Ploughing twice and rotavator twice	2.884	1.775	1.984	1335
Green manure and Trans-ploughing once and harrowing twice	1.809	1.730	1.950	1468
Ploughing twice and harrowing thrice	2.283	1.865	2.073	1566
Ploughing twice and rotavator twice	3.033	1.990	2.174	1619

Table 9. Relative seed and labour requirement for sowing maize with different methods after rice.

Input	Method of sowing maize				
	Conventional	Zero till drill	Zero till drum	Dibbling	Behind the plough
Seed (kg/ha)	15 - 20	25	12 - 15	12 - 15	20
No. of Labour/ha	10	2 - 3	15	15	6 - 8

Table 10. Cost of uncommon operations for zero till maize cultivation (Rs/ha).

Operation/Input	Method of sowing maize				
	Conventional	Zero till drill	Zero till drum	Dibbling	Behind the plough
Land preparation	2,500				
Sowing	1,200	2,500	3,000	3,000	1,500
Weeding	3,000				
Harrowing	500				
Glyphosate		875	875	875	875
Gramoxone		940	940	940	940
Atrazine		525	525	525	525
Seed	1,500	2,500	1,200	1,200	2,000
Total	8,700	7,340	6,540	6,540	5,840
Cost of machine		35,000	8,000		

move the wheel of a cycle embedded with spokes to make holes in the soil at desired spacing. The seeds are sown in the soft and moist sub-surface layer within 7-10 days after the harvest of rice in light textured soil in the low lying areas but within a week in the ridge areas where the moisture is lost quickly. In heavy clay soils, the seed is sown 10-15 days after the harvest of rice. The soil is irrigated immediately after sowing. Some farmers believe that the seed sown after a light irrigation is more beneficial. The germination is uniform and the plant population is well established. A pre-emergence herbicide spray of gramoxone @5 ml and atrazine @ 4 g /l water is the common practice to manage the weeds. The young seedlings develop a sickly appearance of nutrient starvation. Fertilizers are applied on the surface of the soil and irrigated during the 3rd week after sowing.

The farmers are convinced with the effective operation of sowing and fertilizer application with the zero till machine. Sowing is rapid. It covers 1 acre area/hour. The depth of seeding is uniform unlike in dibbling. Though many farmers cannot afford to purchase this drill at the cost of Rs 35,000, there is a surge of interest to hire and sow the crop. However, farmers observed some limitations which need to be addressed in future. The height of 35 - 40 cm stubbles after the harvest of rice with combine machines come in the way of swift movement of the machine. In the low-lying patches, the soil stick to the tines and clog. The seeds do not drop until cleaned and leave gaps. The plate which pick and drop the seed need refinement. Only 1 seed is dropped at a time, if the seed is bold and uniform in size. But 1-3 seeds are dropped when they are of small size. This add extra burden of high seed rate on one hand and labour for thinning.

The zero till-cum-fertilizer drill fabricated by the ECF agronomist Dr M. Govardhan at the Agricultural Research Station, Kampasagar, is less expensive and gaining popularity with the farmers. It costs < 10,000 rupees. As the drum moves, the spokes make holes for dibbling the seed and fertilizer application simultaneously adjacent to each other. This require more labour for sowing and fertilizer application but less seed of 12 – 15 kg compared to 25 kg/ha by the zero till drill. There are no gaps and no need for thinning as there is no over seeding. One transparent set back is that the soil stick to the spokes after making the holes. This need cleaning. To overcome this problem, reduction in angle of the spokes on the roller is under consideration. The labour requirement and the seed rate of maize/ha for sowing by different methods is presented in Table 9.

The economics of maize cultivation due to the resource

conservation technologies for uncommon operations are presented in table 10.

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