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AGRICULTURE RESEARCH - 2000 A.D.*

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By year 2000 the Indian population of about 1 billion will require an agricultural output 50-60% greater than what it is today. Though the thrust of agricultural research will continue to be directed to finding quality food in adequate quantities in the wake of fast dwindling non-renewable resources and damage to ecology greater burden will have to be shared by agriculture in the other two basic needs, clothing and shelter as well as in improving ecological conditions. Before planning for the 21 Century it is relevant that we assess the situation from now to 2000 A.D. as the initial exercise. It has already been recognised that agriculture today comprehends animal husbandry, fishery and forestry all interacting at micro and macro levels in a human-animal-plant eco-system. In the light of the fast changing social and economic conditions, for a long term planning of agriculture research it will be more realistic to understand that the three basic needs of food, clothing and shelter will centre round. Grains, tubers, fruits, vegetables, animal, fish and their products as the source of food, natural and synthetic fibres as the source of cloth and dry matter of varying qualities as the source of fuel(energy) and timber, the core components of shelter and for improving ecology social and agro-forestry systems have to be developed even in annual cropped areas. Thus, integrated research efforts are called for producing not only adequate food but also enough dry matter keeping the ecological balance at safe levels.

Research efforts upto 2000 AD

Most investigators and leaders in agriculture expect that a revolution through genetic engineering to occur in agriculture it may take longer than 10-20 years since several break-throughs are required. As such research on high yielding new varieties of plants with resistance to many of the environmental and nutrient problems which face the present day agriculture adopting

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new approaches and involving the expected break-throughs in some of the biological processes such as transfer of symbiotic nitrogen fixing capability, C_4 mechanism of photosynthesis, reduction of loss due to respiration etc. have to be our major concern upto 2000 A.D.

1. Basic change in research strategy.

Research has little relevance unless the results obtained therefrom contributes to social benefit. It has to be admitted that the ongoing research efforts are isolated in nature and in many cases either not sufficiently important in relation to production or is not carried through to a stage of effective transfer to the field. This will mean that in future while planning research a variety of factors and their likely inter actions should be taken into account. Computerised inventories of the following interacting factors are therefore a must.

1.1 Human resources -

a) Research for which section of society - landless labour, marginal, small and large farmer, tribals etc.
b) Research by whom - Disciplines to be involved, whether competent persons are available.
c) Transfer of technology mechanism - Agencies and type of manpower required.

If a total picture on the above are available it will be possible for deployment of man power, continued interactions and develop an appreciation among the researchers that their efforts are likely to benefit at least those sections of the society for whom the programmes have been planned. While this is too generalised a situation, it will be possible even for specific problems of the nature of pests and disease control, factors to be looked into before initiating research keeping in view the above factual situation.

1.2 Present level of understanding of different areas of production

For a productive research the starting point has to be based on what has already been done not only in that particular

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field but also in the related areas which should be critically analysed by the research group and the work planned. The available research results should, therefore, be summarised and appropriate retrieval systems developed.

1.3 Genetic resources of animals, plants and microbes

Since exploitation of genetic diversity will continue to play vital role in enhancing/stabilising production an inventory of the genetic resources of animals, plants and microbes indicating conservation and in-situ centres of both indigenous and introduced materials indicating the possible/potential use of each must be prepared urgently.

1.4 Input requirements and constraints.

One of the major reasons for the limited flow of research results into the farmers' fields is the lack of understanding of the input needs and constraints that the farmer/extension agency will have to face if a given technology is to be adopted. These should be analysed and listed in advance and action initiated simultaneously.

The advantages of computerising such information are obvious. However, what is more important is whether answers/predictions can be obtained from a total analysis of the likely interacting factors that a research programme is likely to be socially beneficial and if so when and under what circumstances. If this answer could be provided, fixing priorities in research is bound to be much more meaningful.

2. Break yield barriers.

2.1. Multi-disciplinary revolution.

The green revolution achieved in wheat, rice and corn has been by and large the function of improved varieties cultivated under a set of limited conditions over specified areas. Still, the average yields of not only these crops but that of many others are far less than the averages realised by a number of farmers. A multi-disciplinary revolution in agriculture with greatly increased crop productivity is just around the corner. Multi-disciplinary revolution as the name implies is the efforts required to put all together into a unified or integrated system developed procedures which can improve crop yields. If we are to integrate the various independent pieces of know-how which already exist on how to improve crop yields, substantial increases in production are possible.

The following is the effect of management system on increasing crop yields.

Crop	Yield in MT	
	Average	Best realised
Wheat	2.5	20
Potato	3.7	100
Soyabean	2.0	7.5
Corn	6-8	22.5

The secrets of those who have attained the 20 MT per ha corn are inputs such as an appropriate hybrid seed, 90,000 plants, correct planting date, eliminating soil compaction, plenty of soil organic matter, 440 kg of nitrogen, 220 kg of phosphoric acid and 440 kg of potash, sufficient irrigation, sufficient ahd continued availability of soil moisture, control of weeds without injury to plants and protection against pests and diseases. If soil moisture becomes limiting, then the computer says that some of the nitrogen fertilizer should be withheld.

The exciting aspect of simultaneously overcoming several limiting factors to crop production is that additive effects are experienced (Wallace 1984). Correcting two limiting factors alone may result in a 20% yield increase for each. When both are corrected together the combined yield increase is more than 40%; it can be 44 or more per cent (1.20 x 1.20 = 1.44). When six, eight, ten or more limiting factors can be corrected simultaneously the total effect can be staggering. Often the combined effect of two corrected limiting factors is a synergism (Putnam and Penner, 1974). The combined effect then is much greater than the sum of the parts. Yields go up very rapidly with synergistic responses. An integrated approach to overcome limiting factors on sugar cane growth increased yield of the cane almost five times (Hussain, 1982). At this level inputs which normally give smaller incremental return will start giving higher responses.

Yields have not reached a plateau. Much improvement is still possible especially if the disciplines work together to eliminate more of the limiting factors. Examples of recent works to improve yields by overcoming multiple limiting factors have been reported by a number of workers (Anderson and Balser,1983; Brann and Alley,1983). This should therefore, become a great research goal. Integrated inter-disciplinary experiments to test the additive and synergistic effects of available production know-how and for obtaining information on critical areas of interaction for a computerised monitoring of the crop production will be greatly rewarding and should enable the easy accomplishment of human requirements of 2000 AD.

2.2 Tissue culture

Genetic variability of a population while it is an advantage, sets limitation in obtaining higher yields in the population unless efficient clonal multiplication techniques are available for the large scale propagation of any outstanding high yielding or otherwise desirable naturally occurring or synthesized plants. In coconut while the average yield of WCT is 60 nuts/palm/per year, elite single palms yielding 470 nuts and single D x T hybrid palm giving 180 nuts/year under rainfed conditions are available. There is no better method immediately available for breaking the yield barrier than adopting tissue culture technique under such situations provided adequate care is taken to include a wider genetic base in such materials used for multiplication. Where somaclonal variation is desired to be exploited a callus pathway and in cases where genetically uniform clonal populations are to be generated from elite selections direct embryogenesis and plant formation will be the useful tools. Research on the biochemical control of the process of somatic embryogenesis in crop plants where the technique is rewarding should be a priority area.

2.3 Manipulation of physiologic parameters

The overall conversion efficiency of crop plants depends to a great extent on the rates of dark respiration and photorespiration exhibited by them. Although a high rate of dark respiration reflects better growth of the plants some crops use large portion of the photosynthets for their maintenance through this mechanism. In C_3 plants intensive search for crop varieties/ individual plants which have higher efficiency in dark respiration as well as low photorespiration should be made so that the net dry matter production level is enhanced. Considerable efforts should also be made to locate C_4 system in individual plants among perennial species since some of them show outstanding yields which could possibly be due to C_4 pathways.

3. Biomass pathway

Calculation based on theoretical concepts have shown that the potential productivity of a crop in tropics under conditions of optimum management is 770 kg dry matter/ha/day which is equalent to an annual biological yield of 281.05 tons/ha (Loomis and Williams 1973). As against this the following is the situation in terms of dry matter production. (Hall 1976).

Yields of dry matter - T/ha/year

Tropical	
Napier grass	88
Sugarcane	66
Annual crops	30
Perennial crops	75-80
Rainforest	35-50
Temperate	
Perennial crops	29
Annual crops	22

The above yields are by and large from monocrops. There are definitely methods by which the total biomass production per unit area in unit time can be enhanced through high density cropping system approach. In such a system it was also possible to ensure that the basic needs of food, fibre, energy, timber etc. are also generated by an appropriate choice of the constituent crops. Considerable income generation also be ensured. Experiments conducted in Sri Lanka have shown that one such model involving over one dozen crops at a population density of 3606 plants/ha is capable of giving an income of over Rs.46000 per annum in addition to giving a variety of home needs and fodder for animals (Bavappa & Jacob, 1982) Recently high density planting in coconut taken up at Kasaragod has over 13,000 plants/ha where the normal stand of coconut was only 175. The dry matter production in all these cases is yet to be estimated. All the same, it is expected that in view of the maximum harvest of solar energy through the crop canopies of different crops under multi-layered system and better utilisation of soil mass the productivity of biomass could be pushed higher. Such an approach has many advantages such as minimum requirement of tillage, continued returns and better economic stability, higher generation and recycling of organic matter and nutrients and better ecological balance. A highly multi-disciplinary approach to understand crop compatibility, inter plant competition, nutrient balance, moisture requirement, soil micro-biological changes, ecological advantages, energy input and output, biomass production and economics of the systems involving annuals, perennials and animals in varying combinations is highly worthwhile.

4. Low cost technology

Most of the currently available technologies are neutral to scale but not to resources there by compelling the farmers to spend more on the inputs. Research should be oriented to developing technologies that do not cost much to the farmers.

4.1 Utilisation and convension efficiency

Photosynthesis

While photosynthetic efficiency of a particular crop is important, convension of solar energy through the photosynthetic apparatus of a crop community is more relevant in a tropical situation where mixed cropping patterns are being followed. Understanding of this convension capability is a primary need.

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4.2 Nutrients

Recent researches have shown that the ability of DxT coconut to exploit the native fertility of the soil as well as to use the applied nutrients is much higher compared to West Coast Tall.

Utilisation efficiency of nutrients

		Nuts yield/palm		
		WCT	DxT	TxD
	M0	23	31	17
	M1	51	75	60
	M2	67	76	61
		Nutrients (gms)		
Qty. of fertilizers to be applied to get 75% Mx. yield.	N	1025	140	170
	P	1025	140	170
	K	2050	280	345

Research to unearth this capability of the plants will be most rewarding.

4.3 Moisture

The fact that no crop production worth the name is possible without moisture, has shifted the search for drought resistant plants to those capable of doing well under stress (low moisture availability). Since moisture and nutrients have high interaction and also in view of the fact that moisture availability become limiting at least during certain periods of the year, search for stress tolerant varieties should receive priority.

4.4 Pests and disease resistance

In low cost technology research in this area is the most rewarding since the end result is a no cost technology. While search for resistance in the available populations should form part of any crop improvement programme, induction of resistance and transfer of resistant genes adopting DNA recombinant technique should be taken up.

4.5 Better adaption to environment

An analysis of major U.S. crops shows that there is a large genetic potential for yield that is unrealized because of the

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need for better adaptation of the plants to the environments in which they are grown. Evidence from native populations suggests that high productivity can occur in these environments and that opportunities for improving production in unfavourable environments are substantial. Genotype selection for adaptation to such environments has already played an important role in agriculture, but the fundamental mechanisms are poorly understood. Recent scientific advances make exploration of these mechanisms more feasible and could result in large gains in productivity.

4.6 Biological fertilizers, nitrogen fixation and nutrient systems.

Though the possibility of cheaper sources of nutrients through biological fertilizers and nitrogen fixation have been indicated this is yet to come to a level of commercial exploitation. While the pace of research in this area should be accelerated using modern biotechnology tools a more relevant area of immediate interest is the nutrient addition and conservation through cropping systems. Research on relay and mixed cropping systems for improving their self generating and conservation capability with regard to nutrients is a high priority area. Cocoa mix cropped with coconut in double hedge system has been observed to add 50 kg N, 11 kg P_2O_5 and 35 K_2O/ha/year. Much higher efficiency may be possible by appropriate choice of crops and supporting them further with proper biological agents such as arbuscular vesicular mycorrhizae, Rhizobium, free living fixers for nitrogen etc.

4.7 Slow release fertilizers

Recent research has shown that in coconut grown in sandy and sandy loam soils, up to 80% of the applied nitrogen is lost by leaching. Importance of slow release fertilizers in this context is most relevant for reducing the fertilizer input.

4.8 By-product utilisation

A number of agricultural byproducts if used in appropriate places can considerably bring down the cost of production. Coconut husk pith is ideal soil amendment for sandy soils. Rice bran and brewery waste in cattle feed could substitute wheat bran reducing the cost of production of milk by 35 paise/litre.

The research towards 2000 AD therefore, should not be simple trials but large experiments involving genotypes with variables for nutrients and moisture under an appropriate cropping system with a '0' control and a large interdisciplinary team working on at least the more important parameters of production and their interactions.

Innovations for 21st Century

1. Biotechnology research

Though considerable optimism is evinced in this area as a tool for enhancing production, it is evident that massive investment and expertise are required to achieve meaningful gains. Since very many easier approaches are still available at lesser cost for increasing production it is only logical that these should be first researched. All the same when a plateau in yields if is to come by the turn of the century, methods for breaking this barrier should be available. It is in this context that biotechnology research particularly becomes relevent.

1.1 Root nodule symbiosis

The property of atmospheric nitrogen fixation is now limited to leguminous plants, among higher plant species. Monocotyledonous plants provide no confirmed instances of nodule symbiosis. Although some of these may be induced to participate in rhizosphere, nitrogen fixation which leads to large gains in nitrogen, nodule symbiosis is considered to be the most efficient. Recently some workers have considered the possibility of imparting a faculty for nitrogen fixation to higher plants themselves. Rhizobia have been successfully fused with tobacco protoplasts and these cells, when cultured on a suitable medium is expected to give a whole plant with nitrogen fixing ability. These findings open up new and exciting possibilities of obtaining hybrids between legumes and perennial monocots which will eventually lead to enormous saving in nitrogen fertilizers.

1.2 C-3 C-4 hybridisation

C-4 plants in general are the most productive capable of producing high biomass and yield. Transferring a number of characters from C-4 to C-3 plants adopting normal breeding techniques have been done. However, transfer of the most important characteristic viz. C-4 pathway has not been achieved. Cellular hybridisation and monocular transformation should enable the transfer of C-4 mechanism to C-3 background.

1.3 Other areas of interest

Screening for resistance: In perennial crops screening for resistance especially to virus mycoplasma etc. is an exceedingly time consuming process today. In vitro culturing of pathogenic agents like mycoplasma and in vitro screening of the callus/embryoids obtained through tissue culturing technique should enable locating resistance much faster. In the case of disease problems like Root(wilt) and Thatipaka diseases of coconut, Yellow Leaf Disease of arecanut, research to standardise the basic technique should be undertaken. In this context the possibility of developing a vaccine for the plant mycoplasma on a cross protection technique may not be viewed as stretching the imagination too far. As a long term practical measure of immunising millions of coconut palms this is worth heavy investment.

2. Breeding new strains of bacteria

Single cell protein

Whilst agricultural research world-wide pursues yield improvement in food and forage crops in an attempt to keep pace with growing demand, alternative 'non-crop' protein sources have also been sought. Bacteria and yeasts have been shown to have the characteristics necessary for large-scale production of what has come to be known as single-cell protein. ICI's 'Pruteen', using a unique continous fermentation system, compares favourably with conventional protein feedstuffs. (Waterworth, 1981). Improving the quality of these bacteria adopting modern biotechnology techniques should enable massive production of edible protein for human consumption.

Biomass degradation

When biomass production pathway becomes a reality, the surplus dry matter can profitably be used only if the same is separated into fractions based on lignin, cellulose, hemicellulose etc. for further exploitation. Search for bacteria capable of such functions will have to be made and if required even evolved.

3. Hyponica

A recent report from Japan shows that plants giving exceptionally high yield can be grown without soil by placing a vinyl sheet in a water tank where ordinary seeds are put along with water and fertiliser running constantly and evenly. One tomato plant raised in this method is reported to have yielded 12000 fruits. Nozawa, an agricultural engineer who is the father of this innovation has already attracted the attention of agricultural experts from different parts of the world. Research to convent thousands of Km^2 of backwater, tanks, canals and rivers of Kerala into "vegetable factories" merits attention

4. Sky farming

During the twentyfirst century, at least in urban areas and in some of the thickly populated tracts the pressure on land will necessitate farming in the air space, roof tops and for that matter any area available for growing plants without directly coming in contact with land mass. This calls for research on production technology for farming without soil in media which are light and which can keep moisture and nutrients in a continuously available form, structures to support such media in space, mechanisms to feed them and breed plants with

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canopies and root systems fitting into this. Air space factories should be virtually possible for many crops. Research in this area has to make some beginning.

Research in 2000 AD while is challenging should also be novel and ingenious.

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