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AREAS OF BIOTECHNOLOGY RESEARCH WITH POTENTIAL APPLICATIONS TO AGRICULTURE: A LITERATURE SEARCH

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TITLE PAGE

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Areas of Biotechnology Research With Potential Applications to Agriculture: A Literature Search

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Recently there has been increased attention paid to biotechnology and how it might be applied to agriculture. It therefore seems appropriate to review some of the major areas of research which may have agricultural applications. The following discussion, which is by no means comprehensive, attempts to focus or some of the major areas of current research and give some evaluation of how realistic is commercial application before the end of this century.

Biotechnology is a term without a clear cut definition but has commonly come to mean biological research which includes techniques such as recombinant DNA, cloning and monoclonal antibodies. Recombinant DNA involves cutting the native DNA strand of a cell at selected points and inserting a piece of foreign DNA into that strand. Cloning involves massive replication of identical organisms (cells) often containing the inserted DNA. Monoclonal antibodies are a revolutionary new immunological tool which involves fusing antibody producing cells (usually spleen cells) with a tumor cell to produce a hybridoma capable of producing a single specific antibody. This specificity is what makes monoclonal antibodies much more useful than antibodies obtained by traditional immunological methods.

Within the last 10 years, tremendous strides have been made in these areas. A major intended application is to use the information learned to increase agricultural productivity. This is essentially the same as with traditional breeding techniques, but it is hoped that the new technologies will allow more selectivity and greater control over outcome, reducing the level of uncertainty of traditional methods, and also that the time required to bring about improvements will be shorter.

Some of the more interesting plant research attempts to change photosynthetic efficiency and to enable non-legumous plants to fix nitrogen. Unfortunately, these processes are very complex and under the control of multiple coordinated genes. They are also intimately associated with the plant's morphology (size and shape) and therefore are not areas which are likely to yield commercial applications any time soon.

It does appear likely that herbicide resistance is controlled by a single gene (i.e., there is one gene responsible for a crucial metabolic enzyme, and changing that gene produces an enzyme which is no longer inhibited by herbicides). Introduction of herbicide resistant strains of corn and possibly cotton will probably occur soon.

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While research continues to try to understand basic physiology and genetic control of these processes, many non-genetic techniques to increase productivity are being studied as well, and it is these techniques which will come on the market sooner. These techniques strive to (1) increase the output of the individual organism or (2) increase output of a given geographical area either by (a) extending the range in which an organism can live and grow, or (b) by decreasing variation of output per unit of time.

On the animal side, two promising areas of research to increase individual organism productivity include growth hormones and related products, and auto-immunization techniques in which the animal produces antibodies to chemical compounds which it itself produces. These can include testosterone (auto-castration) and somatostatin (a compound which in a process not well understood, appears to have a negative feedback effect on compounds which promote growth).

Animal and plant productivity are affected by weather, pests, and diseases. These serve both to increase variation of output over time, and to prohibit an organism from being adapted to an area. One has the option of either changing the environment or changing the organism's response to the environment. For the most part, it is impractical to change the environment, although introduction of genetically modified Erwinia bacteria to control frost damage and pheromones for pest control are attempts to do so. Most adaptions will be by altering the response of the organism itself. Plant growth regulators can be useful in moderating plant responses to stressful conditions, particularly those related to weather. As for disease detection, monoclonal antibodies are being used to identify both plant and animal pathogens and hold considerable promise of yielding information unobtainable by traditional immunological methods. This research has currently led to the development of vaccines for calf scours and foot and mouth disease.

Basic research will enable scientists to know more about the genetic and physiological processes involved, but it is also essential that more be learned about the techniques necessary to apply that knowledge commercially.

Once the genetics of a physiological process are understood, there has to be a consistent means of inserting new genes into an organism, in the proper position, so that the organism is still viable and capable of reproduction. It is hoped that research into tumor inducing (Ti) plasmids will yield such a vector. Ti plasmids are carried by Agrobacterium tumefaciens, a bacteria which causes crown gall tumors. Unfortunately, this bacteria naturally infects only dicotyledonous plants and therefore may not be useful for grasses.

Traditional plant breeding which requires several backcrosses is a very time consuming procedure. It is hoped that tissue culture methods can speed up this process. Included under tissue culture is protoplast fusion and related techniques (i.e. callus culture and plant regeneration), haploidization (fusion of gametophyte cells), and hybridization (somatic cell fusion). The actual regeneration of a completely viable plant with tissue culturing is routinely used in the orchid industry, but there seems to be many difficulties in applying these techniques to the major grains.

On the animal side, superovulation and embryo transfer are means of increasing the speed by which desirable characteristics are spread throughout a given animal population. This procedure has been practiced for some time, but is time consuming and expensive. There is also the problem of embryo sexing, but in this regard, monoclonal antibodies may yield new techniques.

Besides trying to directly affect productivity of an organism, research is also being conducted to use byproducts of organisms. Work in these areas include processing peanut shells into cattle feed, using tobacco protein in a manner similar to soybean protein, biomass energy conversion, and artificial sweeteners to replace sugar. Finding expanded uses for an organism or elimination of a large part of its market will surely affect the mix of agricultural products produced.

Following is a list of current research areas which may yield agricultural applications. Each major heading includes several subheadings of particular areas of research. These particular areas are often used synonomously with the major heading.

Also included is a bibliography of books and articles which discuss agricultural applications of biotechnology research.

Our intent is to use this information in the selection of a specific case or cases of biotechnology application which appears to have high economic priority. Then we will apply an "economic feasibility" type of analysis to test both the evaluative framework and the application under consideration. One cannot determine whether a specific application will be successful, but, one can evaluate, at least in a partial sense, the costs and economic consequences of a successful application.

Research Areas with Potential Agricultural Applications

I. Plant Research

A. Photosynthesis

1. Photorespiration
2. Leaf and whole-plant senescence
3. Photosynthate translocation

B. Nitrogen Fixation

1. Nif gene
2. Hup gene
3. Nitrogen fixing microorganisms such as Rhizobium, Azospirillum, Azotobacter, Mycorrhizae, Cyanobacteria and Azolla

C. Storage Proteins

1. Phaseolin genes
2. Zein gene
3. Lysine rich corn

D. Growth Regulators

E. DNA Vectors

1. Ti plasmids (Agrobacterium tumefaciens, grown gall tumors)

F. Organelle Transfer

1. Mitochondrial hybrids (Mybrids)
2. Cytoplasm hybrids (Cybrids)
3. Chloroplast hybrids (Chlybrids)

G. Tissue Culture

1. Meristem Culture
2. Embryo Culture
3. Protoplast Fusion
4. Callus Cultures

H. Haploidization

1. Anther, Pollen, Ovule, Shoot Tip, Inflorescence Cultures

I. Hybridization

1. Asexual, somatic, or wide hybridization

J. Frost Damage

1. Erwinia herbicola; Pseudomonas syringae
2. Plant membrane fluidity (phospholipids, choline, ethanolamine)

K. Pheromones

II. Animal Research

A. Monoclonal Antibodies

1. Hybridomas
2. Vaccines from Monoclonal Antibody Research
   a. Neonatal Diarrhea
   b. Africa Swine Fever
   c. Foot and Mouth
   d. Trypamosomiasis
   e. Rinderpest
   f. Scours

B. Auto-Immunization

1. Somatostatin
2. Autocastration

C. Bovine Growth Hormone

1. Double muscle gene

D. Animal Reproduction

1. Superovulation and Embryo (ova) Transfer
2. Twinning
3. Oocyte Fusion
4. Sex Regulation

III. Miscellaneous

A. Energy

1. Rice hulls, sawdust, bagasse, sacchrafication, cattails, etc.

B. Cheese Making

1. Genetically engineered bacterial rennet

C. Food Additives

   1. Tobacco Protein and Peanut Shells

D. Artificial Sweetners

   1. Aspartame (Nutra Sweet) and Acesulfame

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