POSSIBLE FUTURE USE OF BACTERIAL INOCULANTS IN INDIAN AGRICULTURE

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[This article is based on the results of a study tour undertaken for two months during summer 1960 through the various Eastern European countries to learn about bacterial fertilizers where their use is in full swing.]

THE problem of proper fertilizer use exists worldwide, but it is more acute in a country like India where continued cultivation of soil for centuries has resulted in low levels of nitrogen and organic matter. The use of bacterial inoculants may overcome the shortage of plant nutrients thus increasing soil fertility and consequently food production. Before any mass scale step is taken very careful research is needed. In U.S.S.R. and other Eastern European countries the use of bacterial inoculants is already increasing and has resulted in raising the yields of wheat, cotton, lucerne, maize and other vegetable crops.[2,3] Such a venture may prove to be worthwhile in India where the soil productivity is quite low in comparison to U.S.A., Japan, U.S.S.R., Canada, Netherlands, etc.

Increase in soil fertility is directly related to the micro-organisms present in the soil. Activity of these microbes is governed by a set of environmental conditions including pH, moisture, organic matter, temperature, food supply, etc. These soil micro-organisms decompose organic matter, produce "humus" and render the mineral constituents into forms more available for the plant. Hence the introduction of micro-organisms involved in the processes of "nitrogen transformations" and "rhizosphere activity" would be logical in order to raise soil productivity.

Azotobacter spp. is non-symbiotic, aerobic, nitrogen-fixing bacteria which is reported to fix yearly about 40–50 lb. of atmospheric nitrogen per acre.[10] Kostychev[8] was the first to suggest the manufacture of "Azotogen" or "Azotobacterin" from *Azotobacter*. He recommended its use on wheat, rye, oats, barley, potatoes and sugar-beets where its application brought about increases in the crop yields from 10 to 15%.[8] Inoculation of such organisms into soil seems logical but there have been conflicting reports[1] about the inoculation of *Azotobacter* increasing crop yields. Such differences have been explained by Russian workers mostly on the ecological factors and lack of proper agro-techniques when pointed out by the author. In Roumania the report of the "Bacterial Fertilizer Experimental Station"[2] indicated increases of 10% in grain, 65% in straw with the use of "Azotobacterin" alone. When it was applied in combination with N, P, K an increase of 92% in grain and 101% in straw was obtained. The director of this experimental station warned about the proper use of media and number of inoculants. The inoculation of 150-750 million bacteria per c.c. was satisfactory. There have been conflicting reports as to the amount of nitrogen fixed by *Azotobacter* and Meiklejohn[6] emphasized the importance of *Clostridium butyricum* which is non-symbiotic, anaerobic nitrogen-fixer. This bacteria is reported to fix as high as 60 lb. of nitrogen yearly in one acre. If soil conditions were such that both organisms flourished, inoculation of that soil with these organisms might be twice as beneficial.

Rhizobium is a symbiotic nitrogen fixer which inhabits the root nodules of legumes. The quantity of nitrogen fixed by the various species of this organism is reported to be from 60 to 100 lb. in an acre yearly. The increase in yield by the use of inoculation of *Rhizobia*, popularly known as "Legume culture", has shown increases all over the world. In U.S.S.R. and U.S.A. this inoculant is called "Nitragin" and a concentration of 80–100 million *Rhizobia* per gram gave better results. However, locally isolated strains for lupine and lucerne are reported to be effective in Ukraine.[4]

Bacillus megatherium var. *phosphoticum*, a spore-former, is used for the production of "phosphobacterin". This group of bacteria was discovered by Menkina.[7] This bacteria can decompose organic phosphorous compounds present in soil and accumulate phosphorus necessary for plant growth; the heavy inoculum having 6-8 billion bacteria per gram employs kaolin as a carrier. It is distributed to farmers for use with proper instruction to apply at a nominal cost. Roumanian, Bulgarian and Polish workers mentioned the increase in yield by the use of "phosphobacterin" up to 20 40% in many crops. Roumanian workers cautioned that

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strains of *Bacilius megatherium* differed in their capability to produce effective inoculant and in their ability to mineralize the amount of phosphorus. These workers[2] did find 22° to 30° C. to be the optimum temperature for sporulation and that molasses was better than glucose as a source of carbohydrate. The recent reports by Smith, Allison and Soulides[9] showed that the use of "phosphobacterin" as soil inoculant would be beneficial for vegetable crops. Where commercial fertilizers are available in abundance it would not be beneficial to accelerate the oxidation of soil organic matter in order to release phosphorus, but in India this situation is reversed and for this reason these bacteria may increase the amount of available phosphorus.

Silicobacteria alexendrov is used to produce "silicobacterin" which is used to increase the availability of potassium in soil. This bacteria is autotrophic and derives its energy from *alumino*-silicate of the soil. This organism was also isolated by Alexendrov in 1940.[2] The inoculation, having 40 million bacteria per gram, showed increases of 27 — 28% in exchangeable K.

There is also another bacterial inoculant known as "Lactobacterin" which is used to hasten the silage-making, and is produced from *Lactobacillus* spp. The use of "lactobacterin" decreased the spoilage of silage caused by moulds on the walls of silo and improved the palatability of silage.[2]

Use of bacteria in quick retting of fibres, production of mycorrhiza and mycelium of mushroom (*Psalliota compestris*) have shown encouraging results and in the very near future would be in manufacture stage. In increasing the efficiency of such inoculants the polyculture has proved more useful, mixed fertilizers brought about increase in yields of tomato, potato and other field crops.

The mechanism of the action of "bacterial fertilizers" is discussed in more detail by Cooper[5], however, it is still a matter of speculation. Several hypotheses are put forward by Cooper,[5] *i.e.*, a provision of growth factors, destruction of soil toxins, acceleration of normal soil processes, stimulation of other microbes and antagonism towards other pathogens. All these hypotheses are plausible but there is a growing need to establish the validity of them. An application of 50 p.p.m. of gibrel (a potassium salt of gibberellic acid) increased the activity of autotrophes involved in sulfur oxidation and nitrification in 9 different Oregon soils.[5] These results suggest that the "bacterial inoculants" may liberate substances which may increase the efficiency as well as the number of the bacteria involved in such processes.

It can be said in summarization that after a tour of two months in the countries where "bacterial inoculants" are being used, the writer found a widespread faith in their ability to increase the yields of many crops. This confidence was exhibited by the farmers on the collective farms as well as the scientists engaged in their production and developments and agrotechnologists who test their effectiveness in field trials and other research workers. However, some scientists were hesitant to go along with their "wonder effect" and described them only as supplemental to the mineral fertilizers. Whatever the pros and cons may be of their application, their popularity suggests a definite need of research on "bacterial inoculants", and their widespread use in communist countries should not be discarded as mere "political stunts", "lack of proper statistics", "faulty technique" and "poor experimentation", etc. The scientists with an "open mind" should explore this newly developed field which can bring benefits in a country where the commercial fertilizers are not readily available. Their application alone or in combination with mineral fertilizers, use of proper media for their maximum efficiency, the right strength of inoculation and the proper strains responsible for maximal activity should be emphasized and explored further.

ACKNOWLEDGEMENT

The author expresses thanks to the University of Baghdad for providing the facilities which made this tour possible through these countries. Further, grateful thanks are due to the interpreters without whose genuine help this tour could not have been useful. Also my thanks are due to my colleagues Drs. J. D. Beaton and K. F. Nielsen for the criticism and suggestions to improve the manuscript.

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