HOW PROBIOTIC FERTILIZERS IMPROVE IRRIGATION EFFICIENCY, BUFFER SALTS, AND REDUCE NITRATE INFILTRATION INTO GROUNDWATER

Kenneth R. Martin Robert Ellsworth, Ph.D.

ABSTRACT

Since the advent of chemical fertilizers there has been a loss of humus in most agricultural soils and a diminishing of the vital biological dynamics which were present in less intensive chemical farming. The loss of healthy top soil is well documented. Salt problems are significant in virtually all irrigation areas, and the deterioration of soil structure with resulting reduction of irrigation efficiency is well-known.

Probiotic technology, which takes into account the biological potential of soils, can reverse these trends and enables the farmer to use "environmentally friendly" fertilizers which restore and build healthy soil by increasing the humus complexes in soils. The dramatic change in soil structure improves water infiltration and water release efficiency, and buffers harmful salts in water and soil.

University research has shown that nitrate fertilizers can be maintained in the root zone with less leaching of nitrate and other agrichemicals due to biological complexing and chelation. Probiotic technology enhances the natural processes in the soil while biodegrading the detrimental chemical residue that has accumulated in soil.

Humus is a biological soil derivative which has received insufficient research attention. The pressure to develop high production agriculture utilizing salt-based fertilizers and a host of chemicals has been the focus of most agricultural research. The residual of many of these compounds has been detrimental to the health and vitality of the natural biological systems. Soil conditions have generally deteriorated. This deterioration contributes to erosion which is responsible for significant losses in fertile soil every year.

EFFECT OF MICROBES ON SOIL STRUCTURE AND FERTILITY

There seems to be a limited amount of information on soil biological dynamics and how these dynamics affect irrigation efficiency, soil fertility, crop response, and farm profits which is available to the grower.

Soil scientist F. Lyle Wynd[1] (1963) has wisely stated, "The plant eats at the second table--the plant gets what the microbes give it!" The research literature confirms that the microbe is the superior competitor over the plant for nutrients in a nutrient-deficient environment.

To a great degree, plants are dependent upon microbes for balanced nutrition. Microbes need the same essential nutrients as plants. If the biological environment is not restricted by harsh chemicals or other detrimental practices, microbes are able to feed on nutrients needed for their metabolism.

Several nutrients including phosphate and potassium are usually chemically bound soon after application as fertilizer and are subsequently unavailable for immediate plant nutrition. As the biological community utilizes nutrients needed for microbial support, they are converted to nutrients which are ultimately available to the plants.

THE IMPORTANCE OF AEROBIC MICROBIAL FUNCTIONS

Wilson,[2] (1992) reports that most of the characteristics that we normally associate with a productive soil are either directly or indirectly associated with aerobic biological activity. Microbial activity determines the tilth of a soil through flocculation, aeration, and humus formation. A healthy soil is very much a living entity that is teeming with a wide variety of micro-organisms. However, many of our agricultural soils are not biologically healthy. Modern intensive farming often requires extensive use of agrichemicals and salt-based fertilizers. Large scale farming, which use heavy machinery to maintain timely planting and harvest schedules, often creates significant soil compaction. Compaction becomes a serious factor, reducing water infiltration and moisture retention. In addition compaction restricts free movement of water and salts downward, resulting in salt accumulation in the root zone of the soil.

Wilson further states that significant improvement in soil flocculation by the action of agricultural probiotics serves an important function in many agricultural soils. High alkalinity and salinity pose a serious problem in many coastal and arid areas. Sodium salts are especially damaging to both crop yield and soil structure. Probiotic fertilizers buffer salts by dissociation and organic chelation and immobilization of the component elements. Dissociated salts are far less damaging to crops and soil and remain dispersed in the soil profile rather than concentrating at the upper levels of the root zone. Multiple applications of probiotic fertilizers during the growing season is most effective in salt management.

Probiotic technology which takes into account the biological potential of soils can reverse detrimental trends in soils and establish an "environmentally friendly" agrichemical relationship which restores and builds healthy soil by increasing the humus complexes in soils. Growers using probiotics report a dramatic change in soil structure which improves water infiltration and water release efficiency while buffering harmful salts in water and soil.

PROBIOTIC FERTILIZERS

Probiotic fertilizers are composed of natural biological systems, buffers, organic acids, nutrients, and energy systems which are formulated to balance the soil and enhance the indigenous microbial soil population which is usually at low levels in modern agriculture. Probiotic fertilizers are formulated by complexing plant nutrients with probiotic compounds forming more environmentally friendly fertilizers.

Probiotics help bio-degrade chemicals and other substances that are detrimental to biological activity and add energy and nutrients needed for optimal microbial activity. The complete degradation of these harmful substances yield carbon dioxide, water, and humus. When enhanced with probiotics this microbial reservoir becomes a vital source of available nutrients for plant life.

As the humus fraction develops it provides an organic reservoir of complexed nitrogen and other nutrients which are organically stabilized. This reduces the nitrogen solubility,enabling the soil to retain this nitrogen which would otherwise leach past the plant root zone and become a potential groundwater contaminant.

As organic residues and probiotic fertilizers are added to soil, the microbes utilize the fertilizer to provide the energy to convert organic matter to humus developing a rich organic bank of nutrients which crops can access when needed.

> ***The balance of this paper consists of University research and field trials which demonstrate the effect of probiotic fertilizers on water infiltration, irrigation efficiency, nitrogen fertilizer efficiency, reduction of nitrogen leaching, and buffering of salts in soil.***

EFFECT OF PROBIOTIC FERTILIZER ON WATER INFILTRATION

These field trials were conducted by Waldon Laboratories of Ripon, California in 1987.

Objective

To determine infiltration rate changes in a low organic and low cation exchange capacity soil following the application of "Lase", a probiotic fertilizer, which enhances humus formation and soil flocculation.

Materials and Methods

Probiotic Lase was applied at 1 ...

The test soil was Ripon sandy loam, (1% organic matter, with a Cation Exchange Capacity of 14). This soil has no noticeable water penetration problems.

Twenty-five furrows, 12 inches wide and 4 inches deep, were laid out on 30 inch centers 30 feet long. Irrigation tubing was placed along the end of the furrow with one 3 inch gate at each furrow. Water was supplied by a 500 gallon tank, gravity fed.

The soil was allowed to air dry to 12 inches then the water was applied to one furrow at a time to a depth of 3 inches until all 500 gallons were used. The total number of feet of furrow watered were measured.

The soil was allowed to air dry again and the Lase was applied to the test areas and all furrows were watered to allow normal penetration and action.

The soil was allowed to air dry again then 500 gallons of water was applied as in the first irrigation. The total number of feet of furrow was again measured.

The rate and time of flow was constant for each irrigation based on constant gate openings and water head.

<u>Results</u>

The final irrigation, untreated control, covered 390 feet with 500 gallons. The final irrigation, Lase treated, covered 240 feet with 500 gallons of water. This represents an infiltration rate increase of 38% (390 feet minus 240 feet divided by 390 feet), expressed as water absorbed per foot of row. The control absorbed 1.28 gallon/foot of row while the Lase treated absorbed 2.08 gallons/foot of row for a 62.5% increase.

<u>Conclusions</u>

The single Lase application produced a substantial increase in water infiltration rate in this soil. Experience has shown that as probiotics improve water infiltration, they also improve water retention and release to the plants. This results in improved irrigation efficiency.

PROBIOTIC EFFECT IN IRRIGATION WATER REDUCTION

Using probiotics to develop a humus-rich soil provides improved water efficiency. The following chart shows the improved efficiency reported by the Visalia Country Club in Visalia, California.

When given the challenge to reduce water consumption, West[3] investigated methods to accomplish water reduction while maintaining excellent playing conditions. In 1990, it was necessary to water the turf 7 days per week for 15 minutes twice daily to keep the grass from water stress. Even then puddles of water formed on the course and water runoff occurred.

West was introduced to Huma Gro probiotic fertilizers in November of 1990. He applied the probiotic "Thatch" to improve water penetration and absorption. By spring of 1991 the soil "black layer" was dissipating, plant root depth and mass had increased from 3" to over 12", and the water was penetrating the soil profile.

Fig. 1

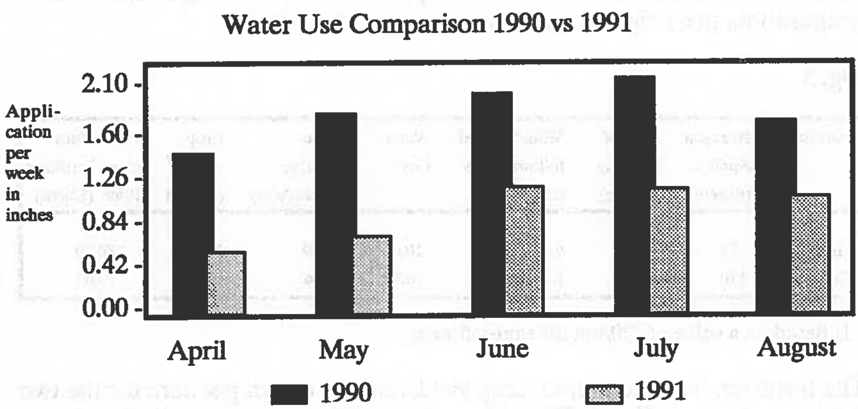


Fig. 2

	Weekly Water Application 1990	1991	Inches of Water Reduction for the month
April	1.35	.50	3.4
May	1.74	.75	4.95
June	2.03	1.00	4.12
July	2.10	1.06	4.16
August	1.870	1.00 (1st week's data)	4.00 (est)
		Total reduction Y.T.D. 20.63 inches	

Due to the increased water infiltration, the irrigation pattern in 1991 was changed to 3 days per week resulting in a significant reduction in water applied, greater root depth and mass, and little or no puddling of water and/or runoff. This resulted in a turf with excellent playing conditions and easier maintenance. Water savings with less stress to the turf resulted from the use of Huma Gro probiotic fertilizers.

PROBIOTIC FERTILIZERS ALLOW REDUCED WATER AND NITROGEN REQUIREMENTS

A field trial conducted by Culver and Ellsworth[4] demonstrated the effect of probiotic fertilizers on water and nitrogen usage.

Water / Nitrogen Usage Study

Location: Lemoore area, Kings County, California.
Crop: Wheat

History of both plots were similar with previous crops of silage corn. Soil preparation, pre-irrigation, and planting were also similar.

Fig. 3

Fertilizer	Nitrogen Applied (lb/acre)	Cost of Fertility ($/acre)	Water applied following pre-irrigation	Water Cost	Yield of silage (Tons/Acre)	Crop value1/ ($/acre)	Net Return aboveFertilizer Price ($/acre)
Huma Gro	54	41.50	0.5 Acre Ft.	10.00	11.59	231.80	180.30
Conventional	170	44.20	1.5 Acre Ft.	30.00	7.66	153.20	79.00

1/ Based on a value of $20/ton for winter forage.

The fertilizer, irrigation input, crop yield, and net return per acre for the two fields are shown in Fig. 3. Fifty-four units of nitrogen were applied in the Huma Gro probiotic fertilizer field, compared to 170 units of nitrogen in the conventional fertilizer program field. One post-plant irrigation was necessary in the Huma Gro field, compared to three in the conventional field.

The net return over fertilizing cost was $180.30 per acre in the Huma Gro field, compared to $79.00 per acre in the conventional field resulting in an increase of $101.30 for the Huma Gro field. The water savings of one irrigation in the Huma Gro field ($10.00) compared to three in the conventional field ($30.00) was an additional economic advantage, as well as irrigation labor savings.

Improved water absorption and release to the crop contributed to improved irrigation efficiency in the Huma Gro field. As a result of the positive changes in the soil structure that occurred in the Huma Gro field, post-harvest ripping of the soil was not necessary in preparation for planting the following crop of silage corn. Ripping was necessary under the conventional fertilizer program.

The Huma Gro probiotic fertilizer provided the following advantages:

a) Increased yield
b) Comparable fertility costs with reduced nitrogen application
c) Reduction in irrigation costs
d) Reduction in tillage costs.

NITROGEN EFFICIENCY AND LEACHING FIELD TRIALS

In Othello, Washington in the Columbia Basin Region, field trials of growing potatoes were conducted including one at Washington State University research station near Othello and in a commercial grower's field, comparing Huma Gro probiotic fertilizers and conventional fertilizers.

Washington State University Potato Trials

During the 1989 planting season near Othello, Washington, the Huma Gro company authorized and supported a field trial of its probiotic fertilizers on the production of *Solanum tuberosum* "Hilite" potatoes. One function of the testing procedure was to check the level of post-harvest residual soil nitrate. Hiller and Ellsworth[5] reported the design and results of the test.

For the function in question, the test-plots were replicated three times on a fine sandy loam soil. The Huma Gro probiotic fertilizer program was compared to a conventional fertilization program. One test plot was treated with the Huma Gro probiotic fertilizers the prior fall season.

"Hilite" potato seed was planted on all test plots and grown for the entire season. Tillage practices on all plots were identical. One plot fertilized conventionally received 312 lbs per acre of nitrogen fertilizer while the other plot had 193.5 lbs of Huma Gro complexed nitrogen.

Tests were made both during and after the growing season for residual soil nitrate levels. Soil samples were taken at harvest from both treatments and tested for NO_3 levels. Test results are shown in Fig. 4.

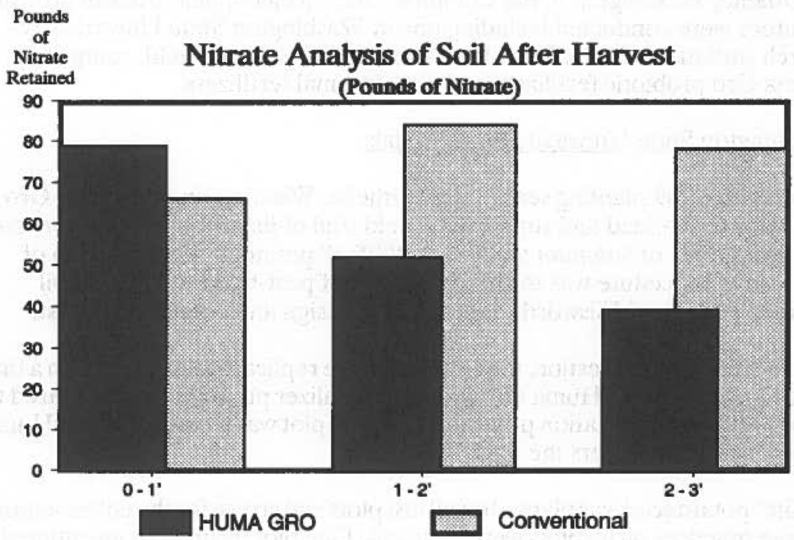
Fig. 4

Nitrate Analysis of Soil Following Harvest

Depth	HUMA GRO plots lbs NO_3 per acre	Conventional plots lbs NO_3 per acre	% Difference
Top Ft.	79	66	19.7
2nd Ft.	52	84	(38.1)
3rd Ft.	39	78	(50.0)

Figure 5 was derived using the data from Fig. 4. It should be noted that Huma Gro nitrates remained closer to the soil surface than the conventional fertilizer. With the conventional fertilizer, nitrates remaining after the growing season were spread throughout the soil profile. Huma Gro nitrates on the other hand, remained primarily in the top of the soil profile. The concentration of Huma Gro nitrates decreased as the depth of soil increased.

Fig. 5

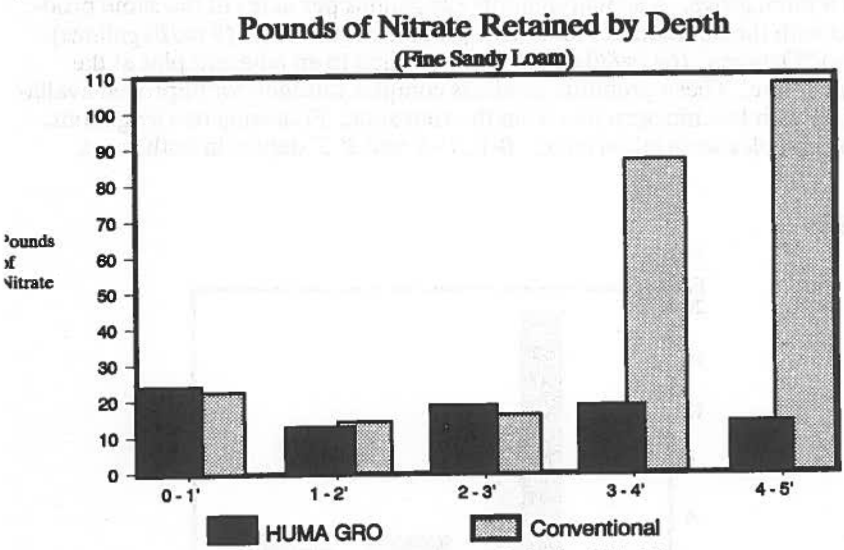


1989 planting season near Othello, Washington

Soil Nitrates Comparison Washington Field Trial

Soil samples were obtained and analyzed for residual NO_3 from two adjoining fields following potato harvest near Othello, Washington in 1989. Samples were taken to represent the first foot, the second foot, etc., down to the fifth foot. Results are shown in Fig. 6. As in the WSU plots the residual levels of NO_3 in the soil from the Huma Gro fertilizer were higher at the 0 to 3' level and lower at the 4' and 5' level than the conventional fertilizer plots. The nitrates from the conventional fertilizer plots appear to be moving deep into the soil profile raising some serious questions about potential ground water contamination.

'ig. 6



1989 planting season near Othello, Washington

Conclusions

'n this test, Huma Gro nitrates remained within the root zone to a greater extent than did those from conventional fertilizer practices. The conventional plots nitrate levels at the 3-4' and 4-5' depths indicate greater nitrate leaching than the Huma Gro plots.

SLOWING NITRATE LEACHING IN FARM SOILS

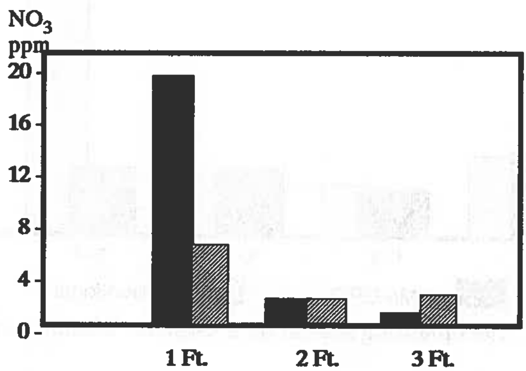
Ellsworth,[6] conducted field demonstrations showing the effectiveness of Huma Gro probiotic fertilizer in reducing nitrate leaching in farm soils near Fresno, California. The following is a description of the field trial with resulting graphs showing how probiotics kept the nitrogen in the root zone, reducing the opportunity for nitrogen to be leached into the groundwater.

A field trial comparison analysis between two equal soil conditions was conducted near Fresno, California in 1991 to evalute nitrate stability in the top three feet of soil.

Procedure

Twenty-five gallons of Calcium Ammonium Nitrate was applied to one plot in a plum grove. A similar quantity (25 gallons per acre) of the same product with the addition of Huma Gro probiotics "Octavol" (8 oz/20 gallons) and "Octagen" (64 oz/20 gallons) was applied to an adjacent plot at the same time. These probiotic products complex nitrogen for improved availability with less nitrogen loss from the root zone. Following two irrigations, soil samples were taken from 0-1', 1'-2' and 2'-3' depths in both areas.

Fig. 7



Conventional CAN 17 = 44#/Ac Nitrogen in 3 ft.

Huma Gro Complexed CAN 17 = 88#/Ac Nitrogen in 3 ft.

Total Applied Nitrogen = 43.55#/Acre

Results & Discussion

The results shown in Fig. 7 demonstrate the feasibility of holding applied nitrogen in the plant root zone. The complexed CAN 17 (Huma Gro) plot contained 3 times more nitrogen in the top foot of soil (the primary root feeding area) than the non-complexed CAN 17 plot. The total nitrate nitrogen in the three foot range shows nearly a 2 to 1 (84-44) advantage for the complexed plot. The short term economic advantages are immediately apparent. The long term decrease in nitrogen leaching can significantly reduce aquifer contamination.

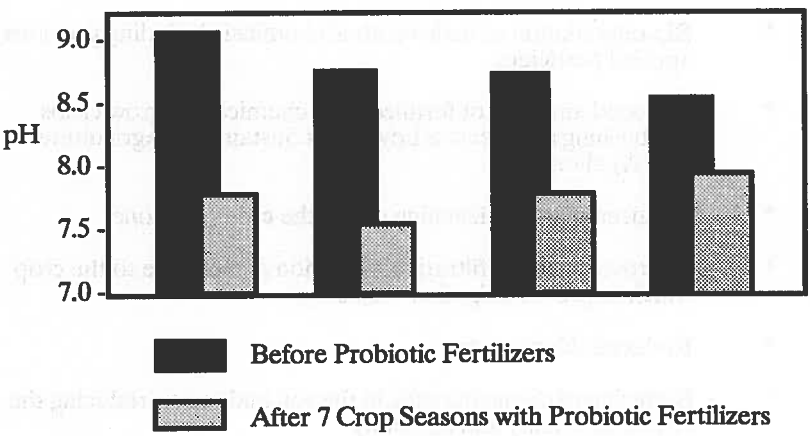
Huma Gro probiotic fertilizers preserve the nitrogen availability while protecting the environment.

PROBIOTICS BUFFER SALTS IN SOIL

Ralston[7] of Triple R Farms of Maricopa, Arizona has been using Huma Gro probiotic fertilizer since 1979. Soil samples were analyzed from four fields in February 1979 prior to using probiotic fertilizers. These same fields were analyzed in October 1985 after 7 growing seasons utilizing probiotic fertilizers, showing a significant reduction of soil pH without the use of gypsum or other products generally used to alter soil pH. The following graph shows the pH before and after 7 growing seasons of probiotic soil treatment.

Fig. 8

Soil pH Analysis on Four Fields
Triple R Farms, Maricopa, Arizona



The surrounding desert soil is very low in organic matter. Most farms in this region have soils which analyze .5% to .8 % organic matter.

During this same period noted in Fig. 8 the organic matter analysis increased from an average of .5% organic matter in 1979 to an average of 2.3% organic matter in 1985 after 7 cropping seasons. This increase in organic matter occurred in a crop program of cotton without rotation. The probiotic fertilizers provide biological activity for decomposition of cotton stalks and roots forming humus which provides a buffering of salts and reduction of pH.

SUMMARY

The far-reaching effects of replacing conventional fertilizer with probiotic fertilizers offers encouragement that many of the soil and water problems in irrigated agriculture can be reversed.

Harnessing the natural power of the soil microbes by utilizing probiotic technology as prescribed by Huma Gro is now a practical reality. Growers utilizing probiotic fertilizers report significant improvement in soil and farming conditions as follows:

* Improved structure and tilth of soil
* Increased levels of humus in the soil
* Reduced disease and pathogen incidence
* Bio-degradation of toxic residual chemicals including previous applied pesticides
* Reduced amounts of fertilizer and chemicals to grow crops establishing an effective Low Input Sustainable Agriculture (LISA) alternative
* Reduced nitrogen leaching out of the crop root zone
* Improved water infiltration, retention and release to the crop which improves irrigation efficiency
* Reduced tillage costs
* Buffering of damaging salts in the soil and water, reducing the effects of salinity and alkalinity

There is a possibility of treating irrigation water at the water district level to improve soils for improved water efficiency. Probiotics encompasses technology utilizing both organic and inorganic chemistry. Probiotics softens the impact of agrichemicals on soil while enhancing the biological potential in the soil. Soil biochemistry and microbiology offer a great hope for further improvements in the field of probiotic fertilizers.

REFERENCES

1/ Wynd, F. Lyle, 1963, *The Living Soil*

2/ Wilson, Norman, 1992, *Huma Gro Blend in The Growing Edge,* Vol. 3, March . 2 - 4.

3/ West, Rick, 1990, Visalia, California Country Club, *Water Efficiency Evaluation With Probiotic Fertilizers*

4/ Culver, Dennis, 1990, Ellsworth, Robert , Ph.D., *Effects of Probiotic Fertilizers on Water & Nitrogen Efficiency*

5/ Hiller, Larry, 1991, Ellsworth, Robert, Ph.D., *Potato Field Trials with Probiotic Fertilizers*

6/ Ellsworth, Robert, 1991, *Effects of Probiotic Fertilizers on Nitrate Leaching.*

7/ Ralston, Bob, 1986, *Probiotics Buffering of Salts in Soil.*