

RLF TECHNICAL BULLETIN

Rhizodeposits and Farm-grown Humic Substances versus imported Humic Substances

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WHAT'S IN THIS BULLETIN

This Technical Bulletin discusses the definition and composition of rhizodeposits and their benefits and quantification. It also looks into the benefit of foliar-induced humic substances (HS) versus the cost of imported HS.

DEFINITION AND COMPOSITION OF RHIZODEPOSITS

Rhizodeposits refer to all the materials lost from plant roots, they are placed in the following groups:

1. Water-soluble organic exudates:

These include organic acids, amino acids, fatty acids, sugars and sugar-phosphates. These compounds are exudated passively or actively from living plant roots and are rapidly taken up and metabolized by rhizosphere microorganisms; thereby providing soil microorganisms with carbon and energy for their growth and reproduction, eventually resulting in HS.

2. Large particles and polymeric organic molecules:

These are constituents derived from plant roots or autolysis of root cells, they include sloughed cells, root hairs, fine roots and lysates. Lysates result from autolysis (breakdown) of root cells and include Mucilage, polysaccharides, polyphenols, proteins and enzymes.

3. Inorganic nutrients such as phosphate, potassium, sodium, bicarbonate (CO_3H^-) and proton (H^+) that are lost from roots passively or actively.

4. Gases such as ethylene and Carbon Dioxide (CO_2), the latter a product of root respiration.

BENEFITS OF RHIZODEPOSITS

Rhizodeposits have the following benefits:

(a) Contribution to soil organic matter and Humic Substances:

Humic substances (HS) are polymers of phenolic substances with free radicals, (Jörg Gerke, 2018, MDPI Agronomy) they have a unique ability to incorporate a variety of organic and inorganic molecules and elements, including amino acids, peptides, sugars, lignin fragments, pesticides and surfactants.

Humic substances have important physical and chemical functions in soil, among them a high Water-holding capacity, a high cation exchange capacity, and the ability to adsorb or complex cationic nutrients such as K^+ , Ca^{2+} , $Fe(III)$, and $Cu(II)$, and to immobilize heavy metals such as lead and Cd, increasing the availability of Phosphate in soil. Thus, HS are the major components of soil organic matter that form water-soluble and water-insoluble complexes with metal ions and hydrous oxides in soil.

(b) Feeding soil microbiota:

Benefits of rhizodeposits in survival and reproduction of soil bacteria is better appreciated when we realize that about half of gross photosynthetic products(GPP) that are transported to underground plant parts is lost as Rhizodeposits.

(c) Keeping soils moist:

Mucilage and various polysaccharides facilitates water and nutrient movement especially in dry conditions (Zarebanadkouki et al 2019). Mucilage secretion in root tips eases root penetration and elongation in soil.

(d) Exclusion of pathogenic organisms from root zone:

Various chemoattractants and poisons are exuded from plant roots; these include benzoxazinoids (BXZ), malic acid, and flavonoids that attract plant-beneficial rhizobacteria to the root, or reduce pathogens due to their toxicity. A single BXZ produced in maize and wheat can be toxic, repelling, or attractive, depending on the particular species. (MDPI Agronomy 2018, 8, 143; doi: 10.3390/agronomy8080143).

Some beneficial bacteria such as *Bacillus subtilis*, *Agrobacterium*, *Arthrobacter*, *Azotobacter*, *Azospirillum*, *Bacillus*, *Burkholderia*, *Erwinia* and nitrogen-fixing bacteria (that colonize roots) exclude pathogens from the root.

(e) Increased nodulation and mycorrhizal association

Plant Growth Promoting Rhizobacteria (PGPR) also induce rhizobia and nodule formation in legumes and stimulate mycorrhizal symbiosis in plant roots.

(f) Increasing plant resistance to abiotic stresses such as cold, heat, drought and salinity

X-F Huang ([dx.doi.org/10.1139/cjb-2013-0225](https://doi.org/10.1139/cjb-2013-0225)) reviewed a number of soil microbes that are able to alleviate plant stress responses by lowering plant ethylene levels thus increasing the plant ability to resist diseases and abiotic stresses such as drought and salinity.

Ethylene is a plant hormone that generally functions as anti-auxin; thus, lowering level of ethylene allows normal plant growth to proceed.

QUANTIFICATION OF RHIZODEPOSITS

Dozens of publications have dealt with Rhizodeposit quantification in the laboratory using sterile conditions and radioisotopes such as C^{14} , C^{13} and P^{32} in order to trace carbon and organic compounds formed in photosynthesis and separate these from pre-existing similar molecules. The use of different carbon isotopes has been essential in sorting out the three sources of CO_2 , namely a) root respiration; b) microbial respiration using exudates and c) microbial respiration using original (pre-existing) carbon source in soil.

Differences in soil type, plant species, plant growth stage and plant age that affect variation of rhizodeposits along the root length result in large variations in such rhizodeposit measurements to be between 30 and 90 percent of the carbon transferred to the belowground plant parts.

In young plants of wheat or pasture grasses, 20 to 50 percent of GPP is transferred to belowground components; half of which (10% to 25% of GPP) is estimated to be released as soluble organic exudates (Cheng and Gershenson, in *The Rhizosphere*, Science Direct, 2007).

The result of 43 articles reviewed by Christophe Nguyen (September 2009, DOI*: 10.1007/978-90-481-2666-8_9) showed that on average 17% of GPP was lost as rhizodeposits (12% recovered as rhizosphere respiration and 5% as soil residues.)

The review of 281 data sets by Pausch and Kuzyakov in 2017 <https://doi.org/10.1111/gcb.13850> showed that grasses allocated 12% more carbon to below ground than crops.

Fewer researchers have quantified rhizodeposits in field; but importantly, often in studies that continued for many crop cycles (e.g. Wang et al 2017; and Zhu et al 2020). Such published field trials show similar or higher percentages of rhizodeposits (17% of GPP or more) that was observed under laboratory conditions using radioisotopes.

It is therefore reasonable to assume that short-term laboratory studies and long-term field measurements conclude that the organic exudates of roots (referred to as rhizodeposits) is 17% of GPP in annual crops and 20% of GPP in permanent crops and pastures.

BENEFIT OF FOLIAR-INDUCED HS VERSUS COST OF IMPORTED HS

It has been estimated that 65 to 75% of the organic matter in soils consists of HS, that is, humic acid, fulvic acid, and humin (M. Shnitzer 1983 <https://doi.org/10.2134/agronmonogr9.2.2ed.c30> Agronomy Monographs). The remainder is primarily composed of various polysaccharides and protein-like substances.

Considering the cropping and pasture soils have 1% organic matter in the top 0–10cm and assuming a soil density of 1, the organic matter in the top 10cm of soil per hectare is $0.01 \times 1000,000\text{kg}$ or 10,000kg or 10t/ha. At 65% HS, the 0–10cm of soil has $10\text{t} \times 0.65 = 6.5\text{t/ha}$ of HS. This quantity of HS is underestimated since most soils have a bulk density higher than 1.

It is therefore a waste of money to buy and import HS into a farm given that most soils have at least 6500 kg/ha of HS for every 1% of soil organic matter at 0–10cm profile, to which is added with every crop cycle some 20% of GPP/ha.

Martin and Merckx 1992 ([https://doi.org/10.1016/0038-0717\(92\)90065-6](https://doi.org/10.1016/0038-0717(92)90065-6)) showed that some 38 to 42% of radioactive carbon was fixed under wheat crop in 63 days as HS and humin free from carbohydrates and protein; therefore, HS and Humin are formed by bacterial acting on rhizodeposits during one crop cycle, there are published work showing this conversion can occur over a week or two.

I have recently calculated the annual, in-home production of humic substances under a vineyard in Griffith yielding 14t/ha and compared it with the actual money spent on RLF Viticulture plus vs the cost of imported Humic Substances by the grower. The following steps can be used for any annual or perennial crop to calculate seasonal production of HS using harvest index (HI) of the particular crop and yield increase by RLF foliar fertiliser that is well documented by replicated independent trial to be around 10% in field crops, pastures, viticulture and horticulture.

The steps that I used for Griffith vineyard below can be applied to other crops using specific parameters of the chosen crop.

1. The grape yield of Griffith was 14t/h, at 25% HI, this is equal to $14/25 \times 100 = 56$ t fresh matter/ha per season as GPP.
2. Calculate the dry matter equivalent of 56t fresh matter assuming 80% water and 20% dry matter, this comes to $56 \times 0.20 = 11.2$ t/ha GPP.
3. Calculate Rhizodeposits at 20% GPP which is $11.2 \times 0.20 = 2.24$ t/ha of dry matter.
4. Assuming RLF program increases yield by 10%, (as observed in Shiraz trial in Barossa by Dr Michael McCarthy), then extra exudate produced is $2.24 \times 0.10 = 0.224$ t/ha or 224kg extra exudate.
5. Take HS to be 40% of the exudate, this comes to $0.40 \times 224 = 89.6$ kg HS/ha
6. Calculate the equivalent litre of humic substances that farmer purchased at 12.5% (W/V) HS or 125 grams/L, or 0.125kg/L which is $89.6/0.125$ kg = 716.8 litre of HS.
7. Calculate the value of 716.8 litre of HS in \$A assuming \$10.00/L which comes to $716.8 \times \$10 = \7168
8. Deduct the cost of RLF program from the value found at No 7 above, the result is the farmer loss had he used his standard practice + RLF foliar rather than his standard practice+ HS. The cost of 3 foliar sprays of RLF each at 5L/ha is around \$150.00 per ha, the net loss of farmer buying this amount of HS is $\$7168 - \$150 = \$7018$.
9. The cost of 10% extra grape yield (1.4t/ha of grape) and any loss in grape quality seen in Barossa trial should be added to the \$7018 to get the total loss per hectare.

Abbreviations used:

*DOI	Stands for Digital Object Identifier
HS	Stands for Humic Substances
GPP	Stands for Gross Photosynthetic Production
NPP	Stands for Net Photosynthetic Production (GPP minus respiration).
Rhizodeposit	Total products derived from living plant roots. Rhizodeposit In quantitative studies (as described in this article) refers to water-soluble organic molecules exuded from living root passively or actively.

About the Author of the Report

Dr. Hooshang Nassery | International Technical Director

EARLY YEARS

Hooshang Nassery was born in Tehran. He graduated from Tehran University with a B.Sc. in biology and a M.Sc. in Botany. His academic career started in Shiraz University as a demonstrator in Biology.

He was granted a British Council Scholarship to continue his studies towards Ph.D. in Plant Nutrition in the Botany Department of Sheffield University under the guidance of Professor J L Harley FRS, Professor H W Woolhouse and Professor I H Rorison. After his Ph.D., he returned to Shiraz University as Assistant Professor where he lectured and researched in the field of Plant Physiology and Plant Nutrition advancing to the posts of Associate and then full Professor in 1972.

MOVE TO AUSTRALIA

Dr Nassery moved to Australia in 1984 as a visiting professor in the School of Agriculture, University of Western Australia and researched in salt and flood tolerance at the university of Western Australia and WA Department of Agriculture for one year.

He moved to Adelaide and continued his career working with fertiliser companies in Australia. He was Director of Research and Development in Australian Mineral Fertilisers from 1986 to 1992. After working as a consultant for farmers and fertiliser industry for a couple of years, he joined Rural Liquid Fertilisers in 1995 to the present in the roles of National Technical Manager and currently as Global Technical Director. His role includes formulating and developing RLF products, the training of field staff, writing technical notes and insights and advising growers and corporate clients.

TODAY

Dr Hooshang Nassery lives in Adelaide and works as RLF Global Technical Director. In this role, he coordinates research and trials, develops products, writes technical bulletins, conducts training courses for RLF staff, agronomists and farmers and advises clients and corporations in Australia and overseas.



Areas of research and publications:

1. Phosphate response in plants from habitats of different phosphate status.
2. Root and root hair growth response to low phosphorus status.
3. Structural and physiological mechanism of salt tolerance.
4. Role of pH, calcium and other cations in membrane permeability and integrity.
5. Interaction of sodium and potassium uptake in plant roots.
6. Impact of salt and osmotic stress on root nutrient uptake.
7. Retention of sodium in stem as a mechanism of salt avoidance in plants.
8. Exclusion of sodium at the endodermal layer of root as a mechanism of salt avoidance.
9. Role of ATPase in nutrient uptake and radial transport in root.
10. Role of Pinocytosis in ion uptake and subcellular localization.
11. Mechanism of flood damage and flood tolerance in plants.

Co-authors and co-workers in research and publications:

- | | |
|----------------------------------|--------------------------|
| 1. Professor J L Harley FRS | 9. Dr M A Rezaian |
| 2. Professor J F Sutcliffe | 10. Dr Gen Ogata |
| 3. Professor I H Rorison | 11. Dr F. Didehvar |
| 4. Professor Dennis A Baker | 12. Dr Ed Barret Leonard |
| 5. Professor Wolf Dieter Jeschke | 13. Dr Tim Setter |
| 6. Dr Hank Greenway | 14. Mr. A. Valamanesh |
| 7. Dr Eugene Maas | 15. Mr. R L Jones |
| 8. Dr Richard Nieman | 16. Mr. Clive Malcolm |

Association with academic institutions:

Dr Nassery held research and teaching positions in the field of Botany, Plant Physiology and Plant Nutrition in the following universities and institutions, the results of his research work were 22 major refereed publications plus numerous abstracts, short communications and technical notes that are cited by researchers in 364 publications.

1. Tehran University, Iran.
2. Shiraz University, Iran.
3. Sheffield University, England.
4. Sussex University, England.
5. Wurzburg University, Germany.
6. University of California, Riverside.
7. University of Western Australia.
8. Flinders University of South Australia.
9. US Department of Agriculture Salinity Laboratory, Riverside, California.
10. Western Australian Department of Agriculture, Western Australia.

