Effect of Organic Matters on Higher Plants

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In a series of studies of the interaction between higher plant and soil microorganisms, it was revealed that organic matters applied to soils exerted various effects on higher plants with the intervention of activities of soil microorganisms[1~4].

Good organic matters caused soil microorganisms to multiply, inducing them to excrete low molecular nucleic acids, amino acids, fatty acids, vitamins and hormones[1,5,7]. Higher plants, absorbing these excretions directly or indirectly, were greatly affected[8,9]. When, for example, uracil and cytosine among bases of nucleic acids and proline among amino acids were absorbed by higher plants at the reproductive stage, they promoted the turnover in metabolic pathways for flowering, fertilization and growth of fruit of the plants, resulting in the increased yield[1,4,7]. It was also found that they exerted favorable effects contributory to quality improvement, that is, improvement in the taste and luster of the harvest.

Results of these studies will be described briefly in this paper.

Growth of rice plants and variations in the number of microorganisms in the rhizosphere

Shown in Fig. 1 are the growth of rice plants and seasonal variations in the number of microorganisms in the rhizosphere.

Variations in the number of the characteristic microorganisms of the microbial flora will be described. In the period from the latter part of June to the early part of August, that is, the vegetative stage of rice

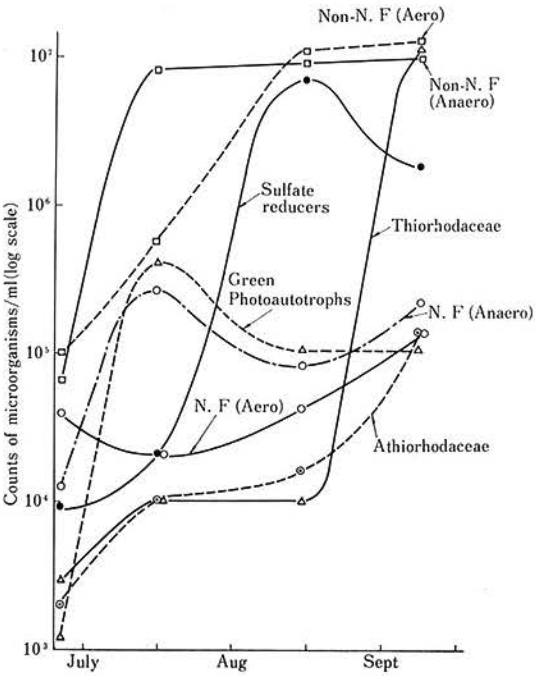

Fig. 1. Seasonal changes of microbial counts in rhizosphere of rice plants
Non-N. F.: Non nitrogen fixing microorganisms
N. F.: Nitrogen fixing microorganisms
Aero: Aerobic condition
Anaero: Anaerobic condition
Thiorhodaceae: Sulfur purple bacteria (photosynthetic bacteria)
Athiorhodaceae: Non-sulfur purple bacteria (photosynthetic bacteria)

plants, algae grew well, but in the reproductive stage which began in the early part of August, the rhizosphere fell into an anaerobic condition, when the sulfate reducing bacteria grew actively with the formation of hydrogen sulfide which inhibits markedly the metabolism of plant roots. However, it was found that from about the middle part of August, the photosynthetic bacteria which utilize the so accumulated hydrogen sulfide grew very well. The Thiorhodaceae and the Athiorhodaceae given in Fig. 1 are photosynthetic bacteria, and it was shown that their maximum multiplying stage coincided with the young panicle stage of rice plants in the early part of September, and then their multiplication slowed down. The study of such an interaction between soil microorganisms and higher plants led to new studies set out one after another as described below.

Application of photosynthetic bacterial cells as an additional fertilizer to rice plants at the reproductive stage (about three weeks before heading) resulted in an increased number of grains. (Table 1).

In a study on metabolic pathways of amino acids and nucleic acids of rice plants, it was disclosed that the requirements of plants at the reproductive stage for proline among amino acids and uracil and cytosine among bases of nucleic acids were increased scores of times as high as the requiremenst at the vegetative stage as given in Table 2.

Table 1. Growth and yield of rice plants as influenced by supply of photosynthetic bacteria, as an additional fertilizer at the reproductive stage

Treatment	Aug. 6		Sept. 19		No. of ear	Grain No./ear	Wt. of ear, g	Total Wt. of ear, g
	Height, cm	No. of tillers	Height, cm	No. of tillers				
NH_4Cl+NH_4Cl (control)	64. 0	25. 6	103	28. 0	28	66. 8	1. 54	43. 1
NH_4Cl+Chlorella	65. 0	28. 0	101	27. 0	23	71. 6	1. 75	40. 3
NH_4Cl+PSB*	63. 6	26. 3	102	23. 3	23	87. 9	2. 04	46. 9

* PSB: Photosynthetic bacteria.

Table 2-A. Uptake of ^{14}C labelled amino acids by rice plants at the reproductive stage as compared to seedling stage

^{14}C-amino acids	Uptake of ^{14}C-amino acids as percent of glutamic acid			Uptake of ^{14}C-amino acids at reproductive stage as percent of seedling stage	Uptake of ^{14}C-amino acids by young panicles as percent of seedling stage
	Seedling stage	Reproductive stage	Young panicles		
Aspartic acid	133. 2	49. 0	35. 4	35. 5	25. 6
Glutamic acid	100. 0	100. 0	100. 0	100. 0	100. 0
Threonine	10. 8	51. 0	76. 7	470. 0	710. 0
Proline	13. 0	123. 0	87. 7	711. 0	487. 0

Table 2-B. Incorporation of ^{14}C labelled nucleic acid bases into reproductive stage plant and young ear of rice as compared to seedling stage

^{14}C-nucleic acid bases	Uptake of ^{14}C-nucleic acid bases as percent of adenine			Uptake of ^{14}C-nucleic acid bases at reproductive stage as percent of seedling stage	Uptake of ^{14}C-nucleic acid bases by young panicles as percent of seedling stage
	Seedling stage	Reproductive stage	Young panicles		
Adenine	100	100	100	100	100
Guanine	236	336	300	142	127
Cytosine	22	216	216	981	980
Uracil	26	247	1354	950	5200

Absorption of amino acids and nucleic acids and its effects

In absorption experiments with ^{14}C-labelled compounds and by microbe-free culture, it was revealed that, after the multiplication of soil microorganisms, amino acids, nucleic acids and lower fatty acids were excreted into the soil (Table 3) which were then absorbed by the roots of higher plants[1,8].

Metabolic incorporation of ^{14}C-labelled amino acids prepared from photosynthetic bacterial cells into chlorophyll and proteins of rice plants is shown in Table 4. Evidences were also obtained of the fact that such direct absorption and metabolism occurred with low molecular nucleic acids and lower fatty acids, too.

As shown in Table 5, the application of proline and uracil, the requirements for which are highest in the reproductive stage of plants as described above, are resulted in the markedly increased number of grains of rice plants, as compared with the number of grains of rice plants to which only inorganic fertilizers were applied[1,7]. When uracil and proline were applied to tomato plants, the number and size of fruit were increased markedly.

It was further proved in the subsequent experiments conducted for applying the findings to practical use that such effects of uracil and proline supply were a common

Table 3. Contents of amino acids, nucleic acids and lower fatty acids in paddy soils (Kyoto University)

(mg/1,000 g dried soil)

Amino acids	51
Nucleic acids	8
Lower fatty acids	45

Table 4. Incorporation of ^{14}C-amino acids into buffer soluble protein and chlorophyll fractions in rice plant leaves

Time	Light				Dark			
	Fresh weight	Total counts	Protein	Chlorophyll	Fresh weight	Total counts	Protein	Chlorophyll
	g	$\times 10^2$ cpm	$\times 10^2$ cpm/mg	$\times 10^2$ cpm/mg	g	$\times 10^2$ cpm	$\times 10^2$ cpm/mg	$\times 10^2$ cpm/mg
1 hr	1.04	1.50	0.65	1.46	1.05	1.32	0.85	0.45
3 〃	1.05	3.30	1.25	4.00	1.03	2.98	2.30	0.95
5 〃	1.12	8.50	2.72	7.50	1.01	6.44	3.60	1.07
7 〃	1.00	15.30	4.10	7.54	1.10	9.20	2.50	1.60

Total activity of ^{14}C-amino acids supplied: 2.0×10^5 cpm

Table 5. Effect of proline and uracil on yield of rice plants and tomato

Treatments	Rice plants				Tomato		
	No. of grains/pot	Weight of grains/pot g	Ripening percentage*	Yield increase over control %	Total no. of fruit	Total weight of fruit g	Yield increase over control %
Control	866	22.32	79	—	3	46.29	—
Proline	1001	23.12	88	3	5	64.50	40
Uracil	1026	24.93	89	11	10	60.90	32
Proline+Uracil	1679	32.59	92	46	15	256.98	455

* Percentage of grains which sink in NaCl solution with specific gravity of 1.06 (60 g of NaCl dissolved in 1 litre of water).

phenomenon with all plants. Especially in the phytotron culture of strawberry in winter, for example, the foliar supply of these compounds resulted in the twice or more increased yield.

Effects of photosynthetic bacterial cells as organic fertilizer

It is possible to collect a large quantity of photosynthetic bacterial cells from the disposal facilities of sewage[9,10], although the bacteria are distributed widely in nature[6].

Because the bacteria undertake photosynthesis, they contain a lot of carotenoid pigments in their cells. It was observed that when the photosynthetic bacterial cells were applied to the carotene-containing plants such as tangerine trees, persimmon trees, tomato plants and corn plants, carotene contents in their fruit and grains were largely increased. The results of this fertilization test with persimmon trees are shown in Table 6.

It was observed that when the photosynthetic bacterial cells were applied as an organic fertilizer to persimmon trees in sand culture, not only the yield increased but also the sugar degree and luster of the fruit were improved, as compared with the trees in control plot where inorganic fertilizers only were applied. As shown in Table 6 B, persimmon contains a pigment of the same structure as lycopene which is rich in photosynthetic bacterial cells, and it was of interest that lycopene content in the fruit from the trees to which the photosynthetic bacterial cells had been applied was increased in particular, as compared with the contents of other pigments in the same fruit. The ^{14}C-labelled photosynthetic bacterial cells were applied to persimon trees in order to observe the absorption of ^{14}C-labelled compounds. As shown in Table 7, the pigments in the photosynthetic bacterial cells were once decomposed by soil microorganisms into lower molecular substances, absorbed in that forms by the roots of the trees, and then resynthesized into pigments in the fruit[9].

Table 6-A. Weight and chemical components of persimmon fruit

	Total no. of fruit	Total wt. of fruit	Average wt./fruit	Fruit* colour H.C.C.	Water contents	Degree of sugar in Brix	Acid contents	Reducing sugar contents	Non-reducing sugar contents	Total sugar contents
		kg	g		%		%	%	%	%
Control (Inorganic fertilizer)	32	7.1	222	12	84.7	14.7	0	10.82	2.34	13.16
Treatment (Organic fertilizer)**	43	8.2	191	13	83.3	16.4	0	12.56	2.57	15.13

* Fruit colour: 12 Orange
: 13 Saturn red
** Photosynthetic bacterial cells.

Table 6-B. Contents of carotenoid pigment in persimmon peel

(mg/100 g fresh weight)

	β-carotene	Lycopene	Cryptoxanthin	Zeaxanthin	Total contents of carotenoid pigment
Control (Inorganic fertilizer)	3.108	2.773	13.018	7.682	26.581
Treatment (Organic fertilizer*)	2.929	4.237	15.667	8.970	31.803

* Photosynthetic bacterial cells.

Table 7. Incorporation of ^{14}C in persimmon fruit from ^{14}C-labelled photosynthetic bacterial cells

	^{14}C-activity incorporated cpm
Fruit	3.0×10^4 (100)
Pigments	3.4×10^3 (11.3)

Remark: Contents of carotenoid pigments in persimmon fruit are 0.026~0.032% (see Table 6-B)

Conclusion

Organic matters accelerated the multiplication of soil microorganisms, and the amino acids and nucleic acids excreted from the microorganisms were proved greatly influential to the metabolism of higher plants. The application of uracil and cytosine, the bases of nucleic acids, and proline, an amino acid, to plants at the reproductive stage was found effective in promoting flowering, fertilization and growth of fruit.

It was revealed that the application of photosynthetic bacterial cells to the plants bearing the carotenoid pigment-containing fruit (such as persimmons, tangerines, tomatoes) resulted in an increase of pigment contents in their fruit.

It has been said that the application of compost and other organic manures of good quality is effective not only in increasing yields but also improving taste and quality of the harvest, unlike the application of inorganic fertilizers. The author and his co-workers believe that their studies have provided theoretical grounds to the elucidation of the effects of organic matters on higher plants.

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