Scientific Proof of Mokichi Okada's Nature Farming Theories

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***Abstract** : About sixty years ago, when chemical farming just started to spread in Japan, many farmers and agricultural scientists believed in chemical fertilizers and pesticides, with which pests would be exterminated and starvation would end. Contrary to the common opinions, Mokichi Okada proposed nature farming with his systemic theories. However, it has been questioned up to now whether Okadaís philosophy on nature farming is capable of scientific proofs. In this report, the author shows his own research data as proof of Okadaís nature farming philosophy on soil pollution, plant diseases, pest insects and food quality as follows.*

1. ***Fertilizers pollute the soil and weaken its power of productivity.*** *The data showed that excessive nitrate pollutes the soil and decreases soil microbial quantity and quality.*
2. ***Pests would breakout from the excessive use of fertilizers.*** *Disturbed metabolism makes nitrogen intermediate compounds, such as nitrate, amino acids and amides, to accumulate in leaves, weakens the leaves morphologically and as a consequence results in pest invasions and pathogen infections.*
3. ***The difference in disease incidence between resistant and susceptible plants is attributed to nutritional conditions inside the body.*** *The data shows that the susceptible varieties contain more nitrogen mediate metabolites than the resistant ones even under the same soil nutrition. The nitrogen mediate metabolites are favorable for pathogens.*
4. ***Vegetables and fruits produced by nature farming taste better than those by chemical farming.*** *The data shows that vegetables and fruits contain more soluble sugars, organic acids and vitamin C, which account for the deliciousness.*

With above-mentioned data from several experiments, the theories of Okada's philosophy are perfectly proved in scientific ways. This suggests that Okada's philosophy is of extractions from the nature.

Introduction

When chemical fertilizers spread in Japan more than 60 years ago, many farmers and agricultural scientists blindly believed in chemical fertilizers and pesticides, that pests would become extinct and hunger would be exterminated by chemicals. Actually, the tragedy of human beings caused by chemicals started from this time. At this moment, Mokichi Okada, an orient philosopher, warned people with an opinion contrary to others (Okada, 1941). Among his sharp opinions, four examples are selected here.

1. Fertilizers pollute the soil and weaken its power of productivity. This theory can be found in one of Okada's poems:

2. Pests would outbreak from the excessive use of fertilizers.
3. Nutrition favorable for pathogens causes disease susceptibility.
4. Vegetables and fruits produced by nature farming taste better than those by chemical farming.

Up to date, because of large uses of chemical fertilizers and pesticides in agriculture, environment degradations and food pollutions are leading to many serious problems in our society. Therefore concerns over the food safety and environmental protection have prompted our scientists and policy-makers to re-evaluate the modern agricultural practices. In many countries over the world, a lot of people suffer from difficult healthy problems and the financial input to medication increases steadily year by year. At this moment, many people may recall Okadaís warning. However, it is important to show the people whether or not Okadaís philosophy on nature farming can be proofed with modern scientific theories and experiments. In this research, several scientific experiments were conducted in accordance with Okada's philosophy to proof some of his opinions on nature farming.

1. Fertilizers Pollute the Soil and Weaken Its Power of Productivity.

First, one of Okada's poems is recommended here.

> "What a foolish thing! Today's man is polluting. The earth's precious soil.
> Which produce the treasure. Vitally important food"

Here, "polluting" means the soil degradation that the original power of the soil is destroyed and the physico-chemical and biological properties are declining due to the excessive use of chemicals. According to the present experimental results, the soil nitrate concentration is higher in chemical farming fields than in nature farming fields (Table 1). This is one of the soil pollutions indicated by Okada. When the soil is polluted by excessive uses of chemical fertilizers, the first thing that occurs is a reduction in microbial quantity (Table 1, Dehydrogenase activity). At the original, nitrate nitrogen is transformed to biomass state or ammonium state that are stored in soil of the ecological system if the nitrate-nitrogen is in excessive status, without excessive supply to the plant and without leaching from the soil (Roger et al., 1993). As Okada (1941) wrote in his articles , this is the natural power of the soil. However, the natural power of the soil loses because of excessive uses of chemical fertilizers for a long time. Excessive supply of nitrate-nitrogen from the soil to the plant weakens the disease resistance of the plant. Therefore, the nitrate-nitrogen is the nutrition favorable for pathogen propagation as indicated by Okada (Okada, 1941).

Table 1. Phytophthora Infection on Tomato Plants Grown with Different Fertilization

Fertilization	Infection	Intensity	Dead Plant	Leaf			Soil	
	(%)	(leaflet)	(%)	NRase	Nitrate	Amino	Dhase	Nitrate
Chemical	88.2	2.43	88.3	5.47	2.7	2.33	21	224
	±12.3	±0.29	±9.6	±0.51	±0.19	±1.2	±4.4	±21.5
Organic	60.5	1.57	63.7	7.34	1.9	1.64	81	174
	±7.2	±0.17	±8.2	±0.53	±0.08	±0.09	±5.6	±5.2

Mean±SD. Nrase, nitrate reductase activity; Amino, Amino acids; Dhase, dehydrogenase activity.

With the above experimental data, Okada's opinion on disease resistance is confirmed. However, it is necessary to elucidate the detailed mechanisms. The pathogen examined in this experiment is *Phytophthora infestans* and the disease is a serious problem for tomato production. The leaves, petioles and even the stem rotted very fast when the tomato plant is infected by the phytophthora pathogen. Even now, it is not clear whether the phytophthora infection in tomato is associated with soil and plant nutrition. About 60 years ago, Mokichi Okada, a Japanese philosopher, warned people that more use of the chemical fertilizers, the more the infections of diseases and pest insects. Now, the scientists have known that resistance of pathogens and insects to chemicals increase steadily and more poisonous chemicals are needed. However, it is not clear whether the imbalance of the plant nutrition metabolisms is associated with disease infections. From examinations on tomato plants and phytophthora infection, it is found that concentrations of nitrate and amino acids are higher in leaves of chemical fertilized tomato plants than in leaves of organic fertilized tomato plants. The high concentrations of nitrogen metabolism intermediates may be favorable to propagation and infection of the pathogens. It is necessary to understand what is the reason for the low concentrations of nitrate nitrogen in leaves of organic fertilized plants. First in considerations is nitrate reductase in addition to the supply quantity of nitrate nitrogen from the soil. The data show that nitrate reductase activity is higher in organic fertilized tomato plants. The high nitrate reductase activity accounts for the low nitrate concentration in the leaves. Not only in the leaves, but also in the soil, the nitrate reduction activity shown by the hydrogenase activity is higher in the organic fertilized plots. The nitrate nitrogen, especially in excessive status, is reduced to ammonium nitrogen or organic nitrogen, resulting in a balanced supply of nitrogen nutrition to the plants and a stable storage of nitrogen in diverse status in the soil. Moreover, balanced nutrition including micro-elements would also contribute to the enzyme activities in organic fertilized plants and soil. However, the plant growth and photosynthetic rate before phytophthora infection are not lower in chemical plots than in organic plots (data not shown). This suggests that phytophthora resistance is not associated with plant physiological activities. The nitrogen nutrition metabolism is the ultimate reason for the infection resistance.

2. Pests Would Outbreak from the Excessive Use of Fertilizers

It has been observed in a fertilization experiment that aphids infect only the chemical fertilized cucumber plants even the plants are arranged in a Latin Square design. When an organic fertilized pot with a cucumber plant is placed in the chemical plot, the plant still keeps away the aphids. Examinations show that nitrate nitrogen concentration is lower in organic fertilized cucumber plants (Data not shown). Usually, nitrogen metabolism mediates, such as nitrate, amides and amino acids, are favorite to aphids. This phenomenon confirmed Okada's opinion that "Pest insects well up due to fertilizer application".

3. The Difference in Disease Incidence Between Resistant and Susceptible Plants is Attributed to Nutritional Conditions inside the Body

Okada (1941) has indicated that 'the difference between resistant and susceptible plants is the existence of the nutrition favorite to pathogens'. What is the nutrition favorite to pathogens? As mentioned in the previous paragraphs in this article, this nutrition includes nitrogen metabolism intermediates, such as nitrate and amino acids. Several experiments

have been done with powdery mildew resistant and susceptible varieties of cucumber. The resistant variety (*Cucumis sativus* L.cv. INFRC C-1) shows its lower concentrations of nitrate and amino acids and higher nitrate reductase activity than the susceptible variety 'Nankyoku-1' (Table 2). This resistant variety is bred and selected in strict field conditions of nature farming without any applications of chemical fertilizers and pesticides. The variety has adapted to low nitrate soils with a good fruit yield in organic conditions although the fruit yield is a little low in conditions of chemical fertilization. The high powdery mildew resistance of C-1 might be attributed to low nitrogen substance concentrations, which are due in turn to the high nitrate reductase activity (Table 2).

Table 2. Powdery Mildew Infection and Nitrogen Metabolism in Tomato Varieties with Different Resistance

Variety	Infection (%)	NO_3 Leaf pl^{-1}	NO_3 (g kg^{-1} DM)	Amino ($mmolkg^{-1}$ DM)	NR-ase ($\mu molkg^{-1}FM$)	Soil NO_3 ($mgkg^{-1}DM$)	Fruit yield (kgm^{-2})
Nankyoku	100±0.1	7.6±0.9	2.9±0.19	2.1±0.1	6.5±0.49	119±18	1.487±0.17
INFRC C-1	15±9.6	0.2±0.1	2.1+ 0.1	1.6±0.2	8.9±0.49	116±5	1.162±0.1

Vegetable crops such as cucumber are easier to be infected by pathogen when the nitrogen nutrition is high in addition to high humidity conditions. However, the mechanisms are not clear enough. The previous research with tomato shows that an unbalanced or disturbed nitrogen metabolism accounts for the phytophthora infection (Wang et al., 2000). Tomato plants with organic fertilization show higher phytophthora resistance than chemical fertilized plants.

4. High Quality of Leafy Vegetables Grown with EM Bokashi

Okada (1941) has indicated that "Vegetables produced by nature farming are much more delicious than chemical fertilized ones". Why are vegetables produced by nature farming more delicious? What accounts for the deliciousness? To elucidate the questions, an experiment was conducted in greenhouse with two kinds of leafy vegetables. Growth of these two leafy vegetables. Leaf concentrations of sugars (sucrose, glucose and fructose) and vitamin C (ascorbic acid) are significantly higher but nitrate concentration is lower in organic-fertilized than chemical-fertilized vegetables. High concentration of vitamin C and low concentration of nitrate are indications of high quality of vegetables. Similar results have been reported elsewhere (Wang et al., 1999).

Table 3. Concentration of Vitamin C and Nitrate in Leaves of two Brassica Leafy Vegetables

	Sugars (g kg^{-1})				Vitamin C (mg kg^{-1})				NO_3-N (g kg^{-1})				Vitamin C / NO_3-N			
	Out	Mid	Inner	Picked	Out	Mid	Inner	Picked	Out	Mid	Inner	Picked	Out	Mid	Inner	Picked
Brasscica campestris L. cv. Kairyo																
Org	1.3	5.8	11.9	8.1	148	190	210	189	5.4	4.8	3.2	3.2	27.4	39.6	65.6	60.0
Che	0.7	3.9	11.1	6.0	104	130	175	158	7.5	6.3	3.7	4.5	13.9	20.6	47.3	35.5
Brasscica campestris L. cv. Shinbansei																
Org	5.7	12.5	20.0	15.3	150	170	210	207	6.1	5.3	1.5	3.6	24.6	32.1	140.0	56.9
Che	2.6	8.1	18.5	11.5	127	135	150	171	7.7	6.7	3.8	4.6	16.5	20.1	39.5	37.6

Out, Mid and Inner means the1st to 3rd leaves, the 4th-6th leaves and the 7th-9th leaves, respectively, from the outmost

Conclusions

With above data from several experiments, the theories of Okada's philosophy are perfectly proved in scientific ways. This suggests that Okadaís philosophy is of extractions from the nature. The most important theories on nature farming of Okada are summarized as follows.

1. Fertilizers pollute the soil and weaken its power of productivity. For example, scientific data show that the excessive nitrate pollutes the soil and deceases soil microbial quantity and quality.
2. Pests would outbreak from the excessive use of fertilizers. Experimental data show that disturbed metabolism makes nitrogen intermediate compounds, such as nitrate, amino acids and amides, to accumulate in leaves, weakens the leaves morphologically and as a consequence results in pest invasions and pathogen infections.
3. The difference in disease incidence between resistant and susceptible plants is attributed to nutritional conditions inside the body. The data show that the susceptible varieties contain more nitrogen mediate metabolites than the resistant ones even under the same soil nutrition. The nitrogen mediate metabolites are favorable for pathogens.
4. Vegetables and fruits produced by nature farming taste better than those by chemical farming. The data shows that vegetables and fruits contain more soluble sugars, organic acids and vitamin C, which account for the deliciousness.

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