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PRESENT STATUS OF WOOD VINEGAR STUDIES IN JAPAN FOR AGRICULTURAL USAGE

T. Yoshimoto [1]

ABSTRACT

Growth of plants are usually accelerated when wood vinegar was drenched in field soil. The growth will be supposed to be induced by decreasing of nematode, mainly and partly by decrease of pathogenic fungus and scarcely by hormone influence on plants. There are growth inhibiting substances in wood vinegar but practically they will be usually absorbed on soil surface and chemically changed.

INTRODUCTION

Wood vinegar is used as important material of nature farming. Wood vinegar is obtained from the gas, which was produced by heating of wood under air less condition. The gas is cooled by air and the obtained liquor (upper layer) is collected as wood vinegar after leaving for 6 months. Production of wood vinegar in Japan is only 40 million liter per year. Half of them, however, is used for agricultural purposes (soil improving materials, pesticide and growth accelerating substances). The present author is summarizing some studies of wood vinegar for agricultural purposes in Japan.

CHEMICAL CONSTITUENTS OF WOOD VINEGAR

Chemical constituents of wood vinegar depend on wood species and gas temperature. Yatagai (1988) (Table 1) studied wood vinegar from 4 coniferous and 1 broad leaves woods and found that total organics ranged from 6 to 41%. The main components was methanol (54.4%) for larix and acetic acid (3.5~7.9%) for residual woods. However, Yoshimoto compared gas chromatographic patterns of commercial wood vinegar from 8 oaks and found that obtained similar pattern but had big difference on acetic acid contents (0.16~6.5%) and on methanol contents (0.03~0.49%), respective (Table 2). There are many other reports on chemical composition of wood vinegar and more than 200 compounds were found in them by Abe (1959), Kishimoto (1987), and Yasuhara (1987).

Table 1. Organic components of wood vinegars (%).

Tree species	*Pinus* sp.	*Quercus* sp.	*Larix* sp.	*Chamaecyparis*	*Eucalyptus* sp.
Total org.	8.1	16.2	41.3	6.4	28.8
Acetic acid	3.9	8.0	3.9	3.6	7.8
Methanol	0.7	0.9	22.4	1.0	0.0

[1] Nature farming foundation, Japan.

Table 2. Physical data of commercial wood vinegars.

Kinds	Spec. gravity	pH	Tar (%)	Acetic acid (%)	Methanol (%)
A	1.058	2..0	9.2	6..9	0.49
B	1.007	3.1	0.8	3.6	0.19
C	1.007	2.7	0.8	4.6	0.27
D	1.007	2.9	0.5	2.1	0.11
E	0.999	2.7	0.2	0.2	0.02
F	1.005	3.2	0.8	3.3	0.26
G	1.003	2.9	1.3	2.4	0.16

FIELD TEST OF WOOD VINEGAR FOR SOIL IMPROVING

Saigusa (1955) (Table 3) cultivated potatoes in nematode-rich field after treatment of original wood vinegar and found that weight of the leaves and roots increased at vinegar-treated field, comparing, comparing with non treated field. The effect was less than one of synthesized chemicals D-D.

Table 3. Effect of wood vinegar in nematode-rich fields (Yield, kg).

Treatment	Non treatment		20 ml		30 ml		50 ml		D-D	
fields	Leave	Potato	Leave	Potato	Leave	Potato	Leave	Potato	Leave	Potato
I	15	16	16	18	16	18	18	21	27	24
II	13	15	15	17	16	15	17	18	21	22
III	16	12	17	15	16	17	17	17	22	18
Average	15	14	16	17	16	16	18	19	23	21

Tuzuki (1989) investigated effects of soil treatment by mixture of wood vinegar and charcoal (1:4) as a basal dressing in growth and yield of rice at field and laboratory environment in 1987 and 1988. He found the number of panicle and grain yield increased in 1987 but was not changed in 1988. Isii (1990) investigated the effects in growth and yield of vegetables on three kinds of wood vinegars fractioned by gas temperature (Table 4). There fractions, lower (under 90 ℃), middle (90~150 ℃), and higher (upper 150 ℃) were used. Drenching in soil of middle and higher fractions gave good results at the middle and later season of growth, comparing with standard (non-treament).

The government agricultural research center recently (1992) began to investigate effect the of wood vinegar as a growth accelerating substance and as a pesticide for one of techniques in sustainable agriculture. The effects on two crops, radish (Tohoku district) and carrot (Kanto and Tokadi district) fields are being examined.

Table 4. Yields of tomato recorded by soil treatment with wood vinegar.

Harvest date	Apr. 26	May 31	Jun. 9	Jun. 11	Jun. 15	Jun. 23	Jun. 26	Jun. 30	Jul. 3	Jul. 7	Total
Standard											
Number	2	2	8	3	4	13	9	25	4	7	
Weight (kg)	0.32	0.19	0.39	0.43	0.50	3.29	1.51	4.79	0.40	0.83	12.65
Treatment											
Number	1	2	15	3	5	9	10	24	11	4	
Weight (kg)	0.31	0.30	1.95	0.39	1.06	1.67	1.70	4.33	1.88	0.74	14.33

INFLUENCE OF WOOD VINEGAR ON ORGANISMS IN SOIL

Saigusa (1992) found that addition of wood vinegar diluted 1/25 with water increased numbers of animals in soil, though number of nematodes did not increase (Table 5). It was also shown that nematocide D-D has ten times of killing power of nematode as much as one of wood vinegar. It was, therefore, assumed that the increased growth of plant can be induced by the interaction between plant, animal and fungi, and the decreased number of pathogens by wood vinegar.

Table 5. Number of micro animals and worms found before and after soil treatment with wood vinegar [1].

Disclosure	After treatment[2]	Before treatment
Nematode (sentyu)[3]	1,736	1,700
? (mizukemusi)	622	0
Turbellarian (uzumusi)	69	0
Rotifer (wamusi)	17	0
Ciliate (zohrimusi)	14	0
Iaterbear (kumamusi)	10	0

[1] 1 kg of soil was treated with 300 ml of 1/25 wood vinegar.
[2] 50 of soil was investigated on number of animal after air drying for 16 hours.
[3] Japanese name for the worms.

EFFECT OF WOOD VINEGAR AS A PESTICIDE

Fungi

Terasita (1957) found that wood vinegar diluted 1/5~1/25 with water effected as fungicide for 6 of pathogenic fungus in soil (Table 6).

Table 6. Effects of wood vinegar on the mycelia development of *Fusarium* sp. *Rizoctomia* sp. and *Rosellinia* sp. in wet soil.

Position of inoculum under soil surface	Concentration of wood vinegar	Development of mycelia		
		F. oxysporum	*R. solani*	*R. necatrix*
1 (inch)	1	+	+	+
	1/5	+	+	+
	1/25	+	+	+
0.5	1	-	-	-
	1/5	+	+	+
	1/25	+	+	+
0.25	1	-	-	-
	1/5	+	-	-
	1/25	+	+	+

Nohara (1960) compared effect of three pesticides wood vinegar, holside (75 l/m^2) and usbulun (dil. 800 liq. 8 l.m^2) on damping-off of seedlings of larches and found that wood vinegar had the best effect.

Miyamoto (1962) found inactivation of *Pellicular filamentose*, a fungus causing damping-off on warm beat, by treatment of original wood vinegar.

Torikosi (1990)found as effects in two *Hypcrea* of wood vinegar as a pesticide that spores were not killed by dipping for four hours but was killed after one week. Further, the growing of fungus was reduced by half at dipping in 1/10 wood vinegar.

Yoshimoto (Table 7) showed that wood vinegar of oaks diluted 1/50~1/100 with water exhibited similar fungicidal effects to one 1% aqueous solution of cycloheximide.

Table 7. Inhibiting effects of original wood vinegar to mycelium (Effect of 100 ppm of cycloheximid is shown as 100).

Kinds of wood vinegar	Genus of fungus			
	Fusarium	*Penicillium*	*Altermaria*	*Collectotrichum*
A	291	102	173	324
B	124	39	75	169
C	206	37	130	201
D	248	46	140	178
E	30	0	35	28
F	167	45	162	175
G	111	393	96	171

Bacteria

Tarasita (1960) found that the number of bacteria were reduced in the field of seedlings of conifer by spraying wood vinegar.

Virus

Miyamoto (1961) showed sterilized effect of wood vinegar for soil-born mosaics in soil drenched with its original or diluted ones (61/m^2) in several days before planting of barley seeds (Table 8). Acetic acid (a main constituent of wood vinegar) did not show so remarkable effect as wood vinegar on the diseases.

Table 8. Effect of wood vinegar and acetic acid in soil-born cereal mosaics at virus infested soil in glass house.

Dilution with water	Wood vinegar drenched		Acetic acid drenched	
	No. of plant*	*Growth*	No. of plant*	Growth
Original	0/164	+	25/172	+
2 times	6/176	+	29/191	++
4 times	10/180	+++	30/167	++
8 times	10/192	+++	26/182	++
16 times	22/177	++	33/155	++
Standard	63/168	++	-	-

* Infested plants/Total plants.

Growth inhibiting compounds in vinegar

Miyamoyo (1965) showed that formaldehyde was the most toxic substance in wood vinegar, because artificial wood vinegar containing 10 compounds showed killing effect only at the ones containing over 2.5% formaldehyed but in the ones containing under 0.5%. The same inclination was found at effect to tobacco mosaic virus.

Growth promoting compound for fungi in wood vinegar

Teeratani (1989) and Yosimura (1991) found that wood vinegar, especially 99.5~104.5 distilled compounds, promoted growth of Basidomycetes fungus and growth of *Pleurotus ostreatus* increased 1.7~9.2 times by addition of wood vinegar (Table 9)

Table 9. Mycelia growth acceleration effect on a fungus (*Pleurotus ostreatus*) of the distilled wood vinegar in a synthetic media.

Fraction	Concentration(%)	Mycelia growth	Ratio
Fr. 1	0.01	3.2±0.24	246
	0.1	7.2±0.24	554
	0.2	7.8±0.18	600
Fr. 2	0.01	4.1±0.19	315
	0.1	7.4±0.21	569
	0.2	8.1±0.26	623
Fr. 3	0.01	6.1±0.30	469
	0.1	11.5±0.27	885
	0.2	11.9±0.27	915
Control		1.3±0.05	100

Fr. 1: under 99°C ; Fr. 2: 99.0-99.5°C ; Fr. 3: 99.5-104°C

Yoshimura (1993) showed that the accelerating substance were 1~1,000 ppm of lactic acid, 2-methoxyphenol, terahydro-2-furylmethanol and 3,5-dimethylphenol. Mixture of those substances promoted growth of fungus of 1.7 times more than wood vinegar did, though addition of wood vinegar promoted them 4.3 times more than non addition.

INFLUENCE OF WOOD VINEGAR ADDITION ON GROWTH OF CROPS

Effect of wood vinegar in growing of crops

Itikawa (1982) found for addition of wood vinegar to increase the length of leaf sheath and shoot of rice (Table 10).

Tuzuki (1989) found that wood vinegar induced to from newly branched root and elongated roots and assumed the action to be hormonal, because of its low concentration.

Ishii (1990) inferred that the existence of growth inhibiting substances, such as middle fraction of wood vinegar, could give good change to the growth of old roots, formation of new branched roots and increment of amount of root at tomato water culture (Table 12).

Table 10. Effect of wood vinegar on growth and root activity of rice seeding.

Wood vinegar (g) per soil (40kg)	Length of shoot (cm)	Fresh wt. of top (mg)	Length of root (cm)	No. of new root	Fresh plant (mg)
0	13.8±0.2	165.3±3.4	4.46±0.16	4.8±0.2	134.2±2.8
4	16.6±0.2	152.8±3.7	4.61±0.12	5.3±0.2	155.7±2.4
8	17.6±0.2	163.0±3.7	4.25±0.12	5.4±0.2	144.1±2.1
20	18.5±0.5	163.0±3.4	4.25±0.11	5.5±0.2	158.4±2.9
40	19.3±0.2	151.3±3.9	4.81±0.12	6.2±0.2	162.2±2.2

Table 11. Effect of wood vinegar on growth and root branching of rice seeding.

Treatment	Length of shoot (cm)	Dry weight (mg) per two shoots		No. of root	Length of root
		Upper ground	Under ground		
No of treat.	26.9±4.9	51±9	9±4	5.2±2.4	5.6±3.9
Wood vine.	35.5±3.1	61±8	12±2	11.1±3.2	5.2±3.7

Med.=Medium; Sma.=Small; 0.1~0.5=Concentration of Wood Vinegar.

Influence of wood vinegar on germination of plant

Ishii (1990) examined germination of vegetables by each of wood vinegar which were obtained separately on the temperature, at which gases were fractionated (Table 13). Middle fraction (90~150℃) diluted into 1/1,000~100,000 with water was found to promote germination.

Table 12. Effect of tested wood vinegar on the growth of tomato root on water culture.

Treatment	Growth of old root	Development of new root	Amount of root	Color of old root
Standard	Medium	Medium	Med.~Sma.	White
Acetic acid	Medium	Med.~Big	Medium	White
0.1%*	Big	Big	Big	White
0.2%	Big	Big~Med.	Big	White
0.3%	Medium	Medium	Big	White
0.4%	Medium	Medium	Medium	Light yellow
0.5%	Med.~Sma.	Small	Med.~Sma.	Light yellow

*Percentage of wood vinegar.

Table 13. Effect of wood vinegar on germination of vegetable seeds.

Days after germination	3			4			5			8	
Concentration of wood vinegar (%)	0.1	0.05	0.1	0.05	0.1	0.05	0.1		0.05		
Standard	0		5		6		7				
Barassica pekinensis (Chinese cabbage)	3	3	5	11	10	11	14		11		
Standard	1		4		5		7				
Brassoca lapa (Komatuna)	5	2	19	17	19	17	20		17		

Yatagai (1987) found that the germination of radish seeds was accelerated by wood vinegar from 4 conifers but was not from broad leaf trees (Table 14).

Table 14. Effect of wood vinegar on germination of radish.

Source of wood vinegar	Dilution (Times)	Germination (%)		Growth rate (%)	
		After 1 days	After 4 days	Radical growth	Hypocotyl growth
Quercus acutissima	1,000	63.3	96.2	80.0±0.3	87.5±0.1
	10,000	83.5	100.0	93.3±0.4	94.2±0.1
	100,000	83.5	92.4	96.0±0.3	107.7±0.1
Pinus desifiora	1,000	118.8	96.6	113.3±1.4	75.3±0.1
	10,000	134.4	96.7	149.3±1.1	99.4±0.1
	100,000	143.8	100.0	144.4±1.2	80.2±0.1

Effect of chemical compounds in wood vinegar on germination and growth regulation

Wood vinegar is investigated on chemical compounds having bioactive effects. Yatagai (1989a) found that 5 acid used and neutral compounds tested inhibited germination and growth of radish and other plants at 1~0.1% concentration (Table 15). Seven neutral compounds among 15 ones tested inhibited germination of radish and other plants at 1-0.1%

concentration. Ethyl valerate showed the greatest growth acceleration effect in a 0.1% solution.

Table 15. Effect of acids on germination of Chinese cabbage.

Chemical compound	Concentration (%)	Germination (%)		Growth rate (%)	
		After 1 day	After 4 day	Radicle growth	Hypoctyl growth
Acetic acid	1	0	0	-	-
	0.1	0	0	-	-
	0.01	85	90	63.2	73.1
Propionica	1	0	0	-	-
	0.1	0	0	-	-
	0.01	87.9	95.0	17.3	54.9
Methyethyl ketone	1	90	98.3	58.7	100.5
	0.1	94.1	100.2	95.5	99.4
	0.01	98	101.5	98.2	103.6
Ethyl n-valerate	1	0	126.4	155.3	120.5
	0.1	119.3	135.7	1,484.7	407.6
	0.01	84.1	94.7	126.8	128.8

Yatagai (1989b) found that the germination and inhibition effects of alcohol were small or almost nil and the growth of radicle as well as hypocotyl was accelerated by addition of wood vinegar. He also found that phenolic compounds had an inhibition on germination and growth of Chinese cabbage (Table 16).

Table 16. Effect of neutrals on germination of Chinese cabbage seeds.

Chemical compound	Concentration (%)	Germination (%)		Growth rate (%)	
		After 1 day	After 4 day	Radicle growth	Hypoctyl growth
Methanol	1	142.9	100	98	80
	0.1	119	95	112	101
	0.01	104.7	95	105	98
Tatrahybro-furfuryl-alcohol	1	0	86.5	14	82.9
	0.1	94.4	94.7	53.2	93.8
	0.01	90	95	106	86.3
Cylotene	1	0	0	-	-
	0.1	30.3	95	3.1	42
	0.01	100	92.1	72.3	101
Maltol	1	0	126.4	155.3	120.5
	0.1	119.3	135.7	1484.7	407
	0.01	84.1	94.7	126.8	128.8
Control		100	100	100	100

Effect of wood vinegar spraying on surface of crops

Wood vinegar diluted 1/1000 with water are practically sprayed on surface of crops, for acceleration of plant growth. Those effect was examined by Hayashi (1990) on tea (Table 17). Almost non-damage for tea growth and accelerating effect were observed at spraying of wood vinegar diluted 1/200-300 with water.

Table 17. Influence of spraying of wood vinegar on tea leaf surface.

Dilution	Damage	Growth
100	A little	Good
200	None	Good
300	None	Good
1,000	None	Not changed

Yoshimoto's unpublished data showed that the effect of diluted wood vinegar in growth of crops might be caused by change of physical character of water, in addition to that a homonal effect of minor constituents of wood vinegar (Table 18). Then line width (half width, Hz) of ^{17}O-NMR was observed on original and diluted wood vinegar and the result showed that the value of diluted wood vinegar indicated different physical character from city water. Diluted wood vinegar (300 times) might be bio-active for crop on the base of one hypothesis on active water.

Table 18. The line width (half width. Hz) of O-NMR (36.63MHz) is recently assumed that water having low value of line wide is biologically active. (K. Matusita. Pharmacia. 28:20. 1992).

Wood vinegar	Well water	Line width	Pure water	City water	Line width	Charged water	Well water	Line width
1	0	57.6	1	0	56.1	1	0	51.0
1	100	50.5	1	100	127.7	1	100	84.7
1	500	51.4	1	500	128.7	1	500	82.2
1	1,000	81.9	1	1,000	118.8	1	1,000	80.5
0	1	91.2	0	1	131.6	0	1	91.2

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