Soil-Turning Tillage Combined with Soil-Amendment in the Fields Continuously Cropped to Vegetables

By MOTOSHIGE HIGUCHI, KEN-ICHI KOMATSU, KAZUYOSHI YAMADA, REI-ICHI AKANUMA*, HIROKAZU HAYASHI**, TOSHISADA MATSUSHITA* and BANZOU NAKAMURA***

Department of Upland Crops Cultivation,
Nagano Prefectural Chushin Agriculture Experiment Station
(Shiojiri, Nagano, 399-64 Japan)

Introduction

Seba district of Shiojiri City located in the cool area of the central part of Japan is a representative production area of field vegetables such as lettuce etc. and is known in the whole country as a great supply source of summer vegetables[4]. This area has a history of about 20 years of vegetable production since leaf vegetables like lettuce and Chinese cabbage were first introduced. At present, soil sickness caused by continuously repeated cropping of vegetables is recognized in about 10% of the total cropped area. It becomes a serious problem disturbing the supply stability of the vegetables[8].

In general, the crop injury caused by continuously repeated planting of the same kind of crops (hereafter referred to crop injury by continuous cropping) occurs due to the continuous cropping system aiming at increased efficiency alone. The continuous cropping induces various soil-borne diseases and crop injury by nematodes. On the other hand, the fields specialized to vegetable production are subjected to the typical intensive cultivation. In such fields, the use of large machines induces soil hardpan formation, and heavy application of fertilizers causes mineral salt accumulation and increased pH values of the soil, resulting in the deterioration of soil environment[7]. These changes are accelerated by the so-called industrialization of agriculture, causing further soil distortion[5]. The deteriorated soil environment together with the continuous cropping of vegetables seems to lower the yield and quality.

The present authors conducted an experiment to prevent the occurrence of crop injury by continuous cropping of leaf vegetables, mainly lettuce, on Andosol distributed in Seba district, by adopting a new method of soil treatment, i.e., soil-turning tillage combined with soil amendment such as soil sterilization, application of organic matter, etc. This experiment was carried out for four years[2]. In the present paper, the effectiveness of this new method is described based on the data of the first year (1983) and the fourth year (1986).

Present address:
* Department of Environment, Nagano Vegetable and Ornamental Crops Experiment station (Matsushiro, Nagano, 381-12 Japan)
** Department of Environment, Nanshin Agriculture Experiment Station (Takamori, Nagano, 399-31 Japan)
*** Department of Planning and Coordination, Nagano Agricultural Research Center (Suzaka, Nagano, 382 Japan)

Method of the soil treatment

1) Method of tillage to replace surface soil with subsoil

As a method of improving Andosol fields, the soil-layer mixing tillage has so far been known. For Andosol in Hokkaido, soil turning tillage is also practiced to bring up fertile buried soil contained in the subsoil and to utilize it as topsoil[9].

Our experiment on the Andosol fields under intensive cultivation of vegetables showed that the best method with the lowest cost and highest effectiveness was soil-turning tillage down to 60 cm from the soil surface, followed by that of 1 m-depth.

(1) Soil-turning tillage of 60 cm-depth

By using the back hoe, two steps operation was made so as to replace 30 cm of subsoil with 30 cm of topsoil, and 30 cm of topsoil with 30 cm of subsoil (Fig. 1). When the topsoil has not been in good condition due to base accumulation, contamination, etc., care must be taken to avoid the mixing of that topsoil into the subsoil (virgin soil) which becomes new topsoil. After the soil-turning, rotary tillage is made crosswise to pulverize soil clods.

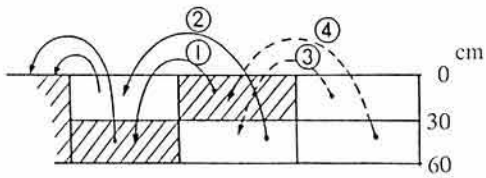

Fig. 1. Operational process of soil-turning tillage to the depth of 60 cm

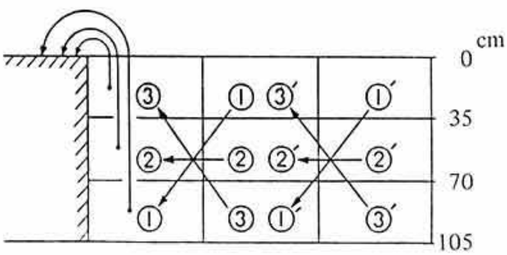

Fig. 2. Operational process of soil turning tillage to the depth of 1 m

(2) Soil-turning tillage of 1 m-depth

By using the back hoe, three-steps operation was made to replace the lower soil layer (70–105 cm in depth) with the surface layer (0–35 cm), and the surface layer (0–35 cm) with the lower layer (70–105 cm), as shown in Fig. 2. After the soil turning, rotary tillage pulverized soil clods in the soil surface.

(3) Untreated control

Tillage to the depth of 20 cm was made with the usual rotary tiller.

2) Additional treatments to improve soil

As shown later, the soil-turning treatment exerts plus effect as well as minus effect on the soil. The topsoil (derived from subsoil) is markedly deficient in total carbon, total nitrogen, available phosphorus, and cation exchange capacity (CEC). Therefore, after the soil-turning, phosphatic fertilizer was applied to make the content of available phosphorus at ca. 30 mg/100 g of dry soil, and also compost was applied at the rate of 2–4 t/10 a. To get 6.5 of soil pH, calcium fertilizer was applied. To prevent the contamination by pathogenic fungi and nematodes, soil disinfectant, like chloropicrin, was poured into soil, before the soil-turning tillage, at the rate of 27 *l*/10 a. The soil disinfection was made in the control plot, too.

The order of the treatments was as follows: Soil disinfection—(more than two weeks)—Soil-turning tillage—Application of calcium fertilizer, phosphatic fertilizer and compost—Tillage with a usual rotary tiller to mix the fertilizers and compost into soil. Thus, three experimental plots were prepared; the treatment of 60 cm-depth, that of 1 m-depth, and untreated control (abbreviated as 60 cm-treatment, 1 m-treatment, and control).

To the three experimental plots, lettuce was planted in 1983 and 1986. The variety used was Calmer for spring and Olympia for autumn of 1983, and Shinanogreen for spring and Exceed for autumn in 1986. Chemical fertilizers were broadcast by taking the nitrogen at the rate of 0.65–1.2 kg/a as the standard. In the plots of soil-turning treatment, additional supply of available phosphatic fertilizer and compost was made in response to the crop grown every year.

Effect of soil-turning tillage combined with soil amendment

1) Soil environment

The soil profile, chemical and physical properties, and biological property are shown in Fig. 3, Table 1, and Table 2, respectively. The soil surface layer (0–20 cm) of each plot shows plus and minus effects of the treatment (Table 1). Increased soil porosity, properly adjusted soil pH, remarkable decrease of accumulated salts, disappearance of soil nematodes, etc. are plus effects. On the other hand, decrease of total carbon, total nitrogen, and available phosphorus are minus effects. CEC was also considerably decreased by the treatment.

In a field, the soil-turning and amending treatment was carried out and then vegetables were grown. After eight crops were harvested within 4 years, the surface soil layer (0–20 cm) was examined[2]. The result showed that (1) the soil pH was in the appropriate range, (2) although total carbon and total nitrogen were apparently less than those of the control, the amount of available phosphorus was almost appropriate, due to its accumulation with time, and (3) exchangeable cations, like calcium, showed an increasing trend. This result indicates that the negative effect of soil-turning was offset with the soil-amending treatment.

The fate of bases and living organisms in the topsoil which was buried deeply in the ground was scarcely traced. An example obtained in Kanagawa[3] indicates that pathogenic organisms like Fusarium were observed in fairly plenty, when soil-turning tillage was practiced without soil disinfection. According to Matsuda and Shimonagane[6], soil microflora and fungistasis are distributed even to the deep soil, though they become poor in deep soil, and pathogenic fungi capable of sustaining their activities in deep soil may not be suppressed by the deep tillage alone. The result of the present experiment showed that the small number of soil microorganisms and nematodes was counted in the lower soil layers after the soil-turning, but it tended to decrease with time. Anyway, there still remain many problems to be clarified in relation to the methods of the soil-turning and amending treatment.

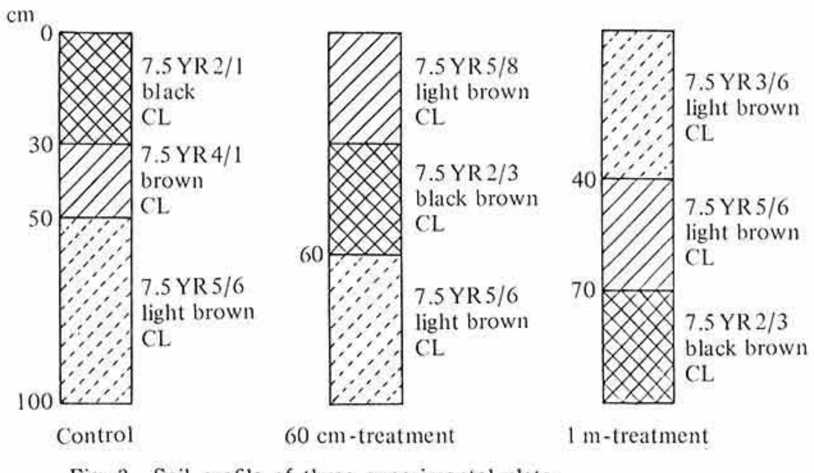

Fig. 3. Soil profile of three experimental plots
Humus content: 2– 5%: Hatching with broken lines
5–10%: Hatching with solid lines
10%<: Crosshatching

Table 1. Physical and chemical properties of soil* determined just after the treatment

Plot	pH (H_2O)	Porosity (%)	T—C (%)	T—N (%)	Available phosphorus (mg/100 g dry soil)	CEC (me)	Exchangeable cation (mg/100 g dry soil)		
							CaO	MgO	K_2O
Control	7.04	64	6.88	0.524	48.0	38	761	95	166
60 cm-treatment	6.81	69	2.08	0.011	0.4	16	243	40	60
1 m-treatment	6.82	71	2.21	0.009	0.4	15	231	42	64

* Soil (0 to 20 cm in depth) was sampled.

Table 2. Population of microorganisms and nematodes in soil* determined just after the treatment

Plot	Number of microorganisms (/g dry soil)			Number of nematodes (/20 g dry soil)
	Bacteria ($\times 10^6$)	Actinomycete ($\times 10^5$)	Fungi ($\times 10^5$)	
Control	36.3	12.4	87.4	1754
60 cm-treatment	3.0	1.0	11.0	0
1 m-treatment	7.2	1.2	20.5	0

* Soil (0 to 20 cm in depth) was sampled.

2) Crop injury caused by continuous cropping

This injury found in major vegetable-producing areas is that caused by continuous cropping of vegetables having common properties to the same field[1]. According to this definition, the soil-borne diseases and physiological disorder observed in the main producing area of leaf vegetables such as lettuce, Chinese cabbage, cabbage, etc. are regarded as crop injury by continuous cropping.

In Seba district, soil-borne diseases such as *Sclerotium* and softrot, injury by soil nematoda, wilting by unknown cause, and vascular diseases (roots become brown) of unknown cause are usually observed on lettuce. On Chinese cabbage and cabbage clubroot is recognized.

Table 3 shows the markedly reduced occurrence of wilting and vascular diseases of lettuce in the treated plots. The soil-borne diseases mentioned above are also less than those in the control plots[2].

The fact that the crop injury by continuous cropping of leaf vegetables like lettuce was overcome to a great extent by the soil-turning and amending treatment, i.e., an integrated technology, is attributable to the favorable effect of the treatment to the soil environment, as described above.

3) Vegetable yields

In general, the treatment tends to delay the crop growth, but it greatly increased the yield particularly in the first year after the treatment (Table 4). Yields obtained in the following three years were higher than the yields of the control plot by about 10% except cabbage in the spring of 1984. Thus, it was made clear that this treatment is very effective in recovering the productivity of vegetable fields, where continuous cropping has been practiced. This effectiveness seems to last for about four years. As the hardpan formation was recognized in the fourth year after the treatment[2], the effectiveness of the treatment may be reduced gradually from year to year.

Table 3. Rate* of occurrence of wilting and vascular disease of lettuce

Year	Plot	Wilting (%)			Vascular disease (%)		
		Cropping season			Cropping season		
		Spring	Autumn	Mean	Spring	Autumn	Mean
1983	Control	6.7	21.6	14.2	46.8	90.8	68.8
	60 cm-treatment	0	2.5	1.3	29.9	25.0	27.5
	1 m-treatment	0	12.0	6.0	34.6	3.8	19.2
1986	Control	16.7	70.0	43.4	40.4	72.5	56.3
	60 cm-treatment	6.7	5.0	5.9	10.0	17.5	13.8
	1 m-treatment	6.7	2.5	4.6	20.0	37.5	28.8

$* \frac{\text{Number of diseased lettus}}{\text{Total number of lettuce examined}} \times 100$

Table 4. Lettuce yield in experimental plots

Year	Plot	Corpping season			
		Spring		Autumn	
		Yield (kg/a)	Index	Yield (kg/a)	Index
1983	Control	332	100	128	100
	60 cm-treatment	441	133	279	218
	1 m-treatment	403	121	252	197
1986	Control	402	100	400	100
	60 cm-treatment	444	110	427	107
	1 m-treatment	441	110	482	121

Cautions to be taken in recommending this treatment

(1) This treatment is applicable to the vegetable fields where physical, chemical, and biological properties of the subsoil are not so inferior, ground water level is low, and intensive land use is practiced.

(2) To adopt this treatment to vegetable fields on sloped land, the catch drain has to be constructed, aiming at preventing the inflow of contaminated soil and rain water.

(3) It is desirable to adopt this treatment to area as large as possible, in order to reduce unit cost. A trial made on small area of about 30 a indicated that the unit cost per 10 a required for soil-turning, using the back-hoe, was calculated at ¥180,000 for the soil-turning of 60 cm-depth, and ¥370,000 for that of 1 m-depth.

(4) It is necessary to apply fertilizer and organic matter every year to the fields where this treatment was made. In addition, the hardpan formation should be avoided by using the subsoiler once in about three years in order to sustain the effectiveness of the soil-turning and amending treatment.

Acknowledgement

The authors wish to express sincere thanks to the staff of the organizations listed below for their kind cooperation extended to the present study.

Resources Section, Planning Department, Kanto Regional Agricultural Administration Office; Land Improvement Section, Agricultural Administration Department, Nagano Prefectural Government; Shochiku Agricultural Extension Office; Chushin Disease and

Insect Control Station; Shiojiri City Office; Seba Agricultural Cooperatives.

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* Resources Section, Planning Department, Kanto Regional Agricultural Administration Office

(Received for publication, December 3, 1987)