Effect of Straw Mulch and Deep Tillage in Tea Fields

By MITOSHI MAEHARA

Makurazaki Branch, National Research Institute of Tea

Straw mulching and deep tillage in autumn are regarded as important soil management practices in tea fields of Japan. However, effect of deep tillage is not fully known, and needs to be re-examined in view of the recent labor shortage situation. There is no question about the benefit of straw mulch, but the mechanism of its effectiveness in increasing soil fertility is not fully known yet. Recently, straw mulching is becoming difficult to be practiced due to difficulties of obtaining straw and the use of farm machines, and therefore it is needed to clarify in detail the effects of mulching organic materials in order to find out the substitute for straw.

From the above viewpoint, the author carried out a field experiment as shown in Table 1. Results confirmed the outstanding benefit of straw mulch, whereas deep tillage customarily practiced yearly was found to cause root damage which was so far neglected but which upset the favorable soil management effects of deep tillage, making the practice as useless and rather dangerous.

Effect on growth and yield of tea plants

Yearly trends of yields as expressed by taking the yield of control plot as 100 are shown in Fig. 1. It is clear that effect of straw mulch is outstanding, giving the yield as much as more than two times that of the control plot at the young stage, and 30% more than the control plot at the adult stage. On the contrary no favorable effect of deep plowing was observed. Yield was rather reduced by deep tillage under the condition of

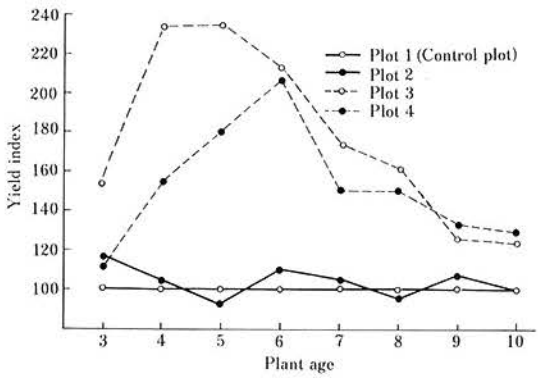

Fig. 1. Yearly trend of yield index (control plot=100)

Table 1. Design of field experiment

Experimental plot	Treatments
1. No mulch, no tillage	Bare field and no tillage (control plot)
2. No mulch, deep tillage	Autumn tillage at 30cm depth (at 15cm since 6 years of age of plants)
3. Straw mulch, no tillage	2000kg/10a of straw mulch applied in autumn
4. Straw mulch, deep tillage	Straw mulch and deep tillage applied

straw mulching. Therefore, after the stage of 6 years of age, the depth of tillage was reduced, but still no favorable effect was found, although its negative effect was gradually disappeared.

Effect on physical property of soil[1)]

As shown in Table 2 and Fig. 2, deep tillage caused a big change in physical property of soil by reducing solid phase, and increasing coarse pores, air percentage and water permeability. This change was fostered when the straw mulch was plowed into the soil. Fig. 3 shows changes of soil moisture under a moderate rainfall condition. Straw mulch was effective in reducing the fluctuation of gravity water in deep soil layer due to reduced percolation and evaporation of water, with a result of contributing reduced leaching loss of fertilizers and soil nutrients. On the other hand, deep tillage promoted drainage as a result of above-mentioned effect on physical property of soil, and consequently it caused an adverse effect on water and

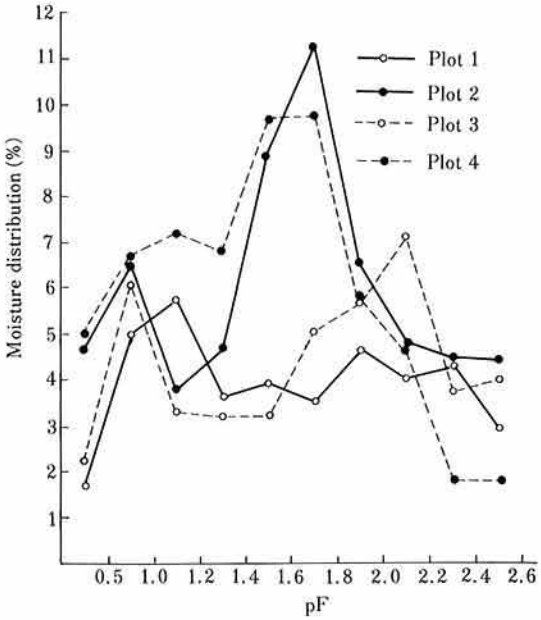

Fig. 2. PF-soil moisture distribution curve

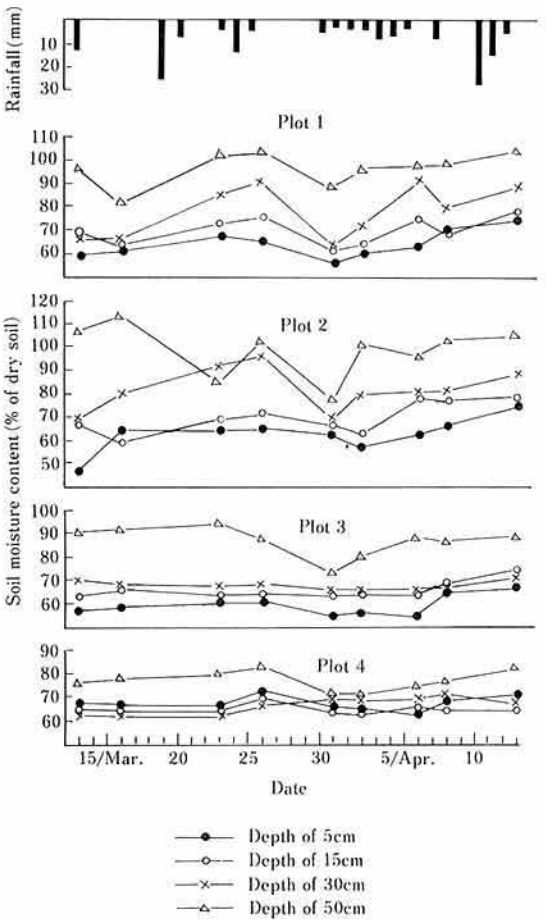

Fig. 3. Effect of straw mulch and deep tillage on soil moisture content

nutrient preservation. This is the fact not to be overlooked. A survey conducted separately at the time of drought indicated that soil moisture of the field under straw mulch was more than that of bare field by 30 ton/10a. In this case also, deep tillage caused a considerable decrease in water-holding capacity of soil.

Effect of both treatments on soil temperature is shown in Fig. 4. Straw mulch lowered soil surface temperature by 4–5°C in daytime in summer, and raised by 2–3°C in the night in winter. Thus, the diurnal range of soil surface temperature was reduced to less than several tenths that of the bare field in any season of the year. Deep tillage always lowered soil temperature by about 1°C.

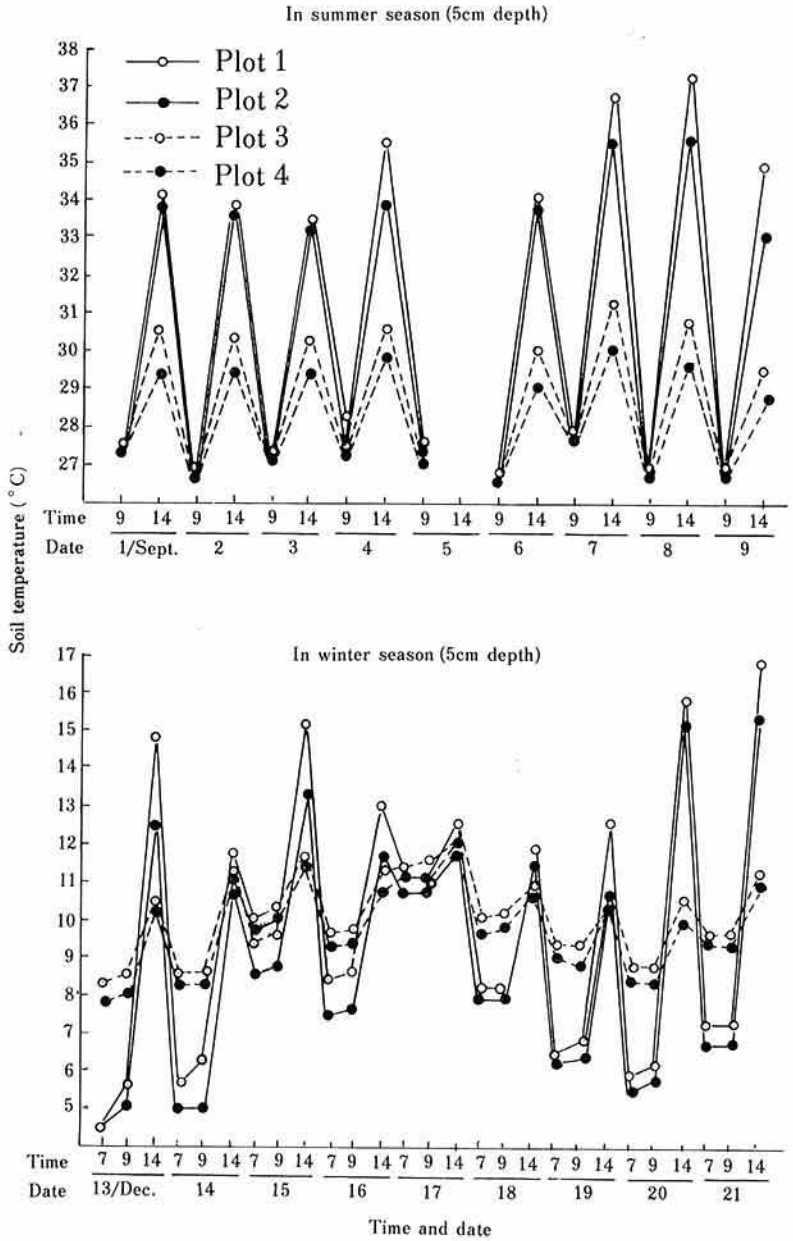

Fig. 4. Effect of straw mulch and deep tillage on soil temperature

These results indicate that straw mulch plays an important role in protecting and regulating the physical environment of rhizosphere, that is one of the basic factors for plant growth, but the effect of deep tillage is hardly judged whether positive or negative.

Effect on chemical property of soil

By tracing the movement of ammonium sulfate applied as the summer fertilizer, it was suggested that deep tillage accerelated

Table 2. Effect of straw mulch and deep tillage on physical properties of soil

Physical property		Treatments											
		Without straw mulch						With straw mulch					
		No tillage			Deep tillage			No tillage			Deep tillage		
		Soil depth (cm)			Soil depth (cm)			Soil depth (cm)			Soil depth (cm)		
		5	15	30	5	15	30	5	15	30	5	15	30
Three phase distribution (%)	Solid phase	29.4	21.0	17.0	25.0	24.5	21.4	26.4	22.9	26.5	25.3	17.0	19.0
	Liquid phase	38.6	42.0	52.0	36.0	37.5	37.6	40.8	39.1	43.5	37.0	37.0	46.0
	Gaseous phase	32.0	37.1	31.0	39.8	38.0	41.0	32.8	38.0	30.0	37.7	46.0	35.0
Air percentage (%)		49.0	46.8	38.3	52.0	50.5	51.9	44.6	49.6	44.6	50.5	55.4	43.2
Hardness (mm)		20	17	19	16	10	11	14	15	14	10	10	6
Water permeability(cm/sec × 10^2)		1.7		1.0	1.9		2.0	1.9		1.2	1.8		2.5

Table 3. Mineralization of soil nitrogen(mg%) of soils with or without straw mulching

Soil sample	Treatments of mineralization						
	Fresh soil	Air dried soil	Change of pH		Neutral salts application		
			pH8	pH9	Na_2HPO_4	NaF	NaCl
No straw mulch plot	0.8	0.8	3.2	6.2	8.0	5.6	0.9
Straw mulch plot	1.2	6.2	5.2	10.5	14.0	10.5	2.0

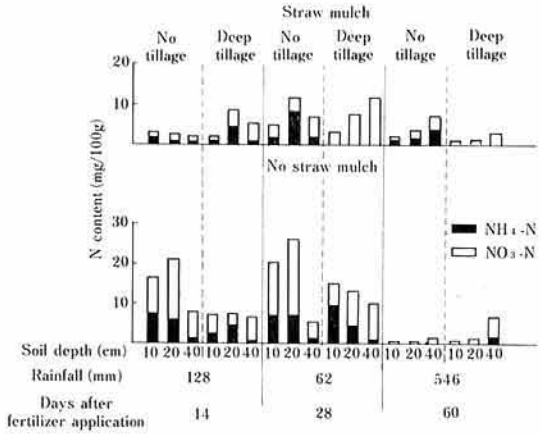

Fig. 5. Effect of straw mulch and deep tillage on behavior of nitrogen applied

the leaching of applied nitrogen, whereas straw mulch not only reduced nitrogen leaching by reduced percolation of rain water, but also contributed to the prevented leaching and sustained supply of nitrogen through the transformation to organic nitrogen and its mineralization[2] (Fig. 5).

To confirm this effect of straw mulch, a laboratory experiment was carried out. Soil samples supplied with ammonium sulfate alone or together with chopped straw were incubated for 35 days, and nitrogen in the soil samples was fractionated. In case of ammonium sulfate applied alone, no formation of organic nitrogen was observed. However, in case of ammonium sulfate applied together with straw, about 2/3 of applied nitrogen was transformed to organic nitrogen, comprised of an acid-soluble fraction and acid-insoluble fraction at about an equal amount. The acid-soluble fraction is regarded as amino nitrogen which is readily mineralized and utilized by plants[3]. The result seems to suggest that readily decomposable organic matter, rich in nitrogen, might be accumulated in the soil under the straw mulch. Hence, mineralization of soil nitrogen was determined by applying several treatments

which Harada[4] used as an indicator of nitrogenous soil fertility. The result given in Table 3 showed a very large amount of mineralization[5] with the soil of straw mulch plot.

On the other hand, Tyulin[6] defined soil colloid as organo-mineral colloidal complex, which was fractionated into G_1 colloidal group and G_2 colloidal group as he named, and proposed that G_1 colloidal group was closely related to fertility of Chernozem. Atkinson[7] reported that yields of barley and clover showed a close correlation to phosphorus content of G_1 colloidal group. The author[8] also found out by the Tyulin method that the content of G_1 colloidal group in the soil with straw mulch was as high as more than 20 times that of the bare field. He observed also that the content of nitrogen and phosphorus in the G_1 colloidal group was much higher than that of original soil. Such a localization of nutrients may explain the function of G_1 colloidal group that represents soil fertility. By a separate investigation, it was also observed that the content of exchangeable potassium in the soil of straw mulch plot was increased over that of bare field by 50 kg/10a.

Effect on root system development[9]

Following points were made clear from the study on root system as shown in Fig. 6.

1) Quantity of roots in the straw mulch plot was about two times that of the bare field plot. This ratio of root quantity coincided to the ratio of yield. The difference was larger between plots without deep tillage, and between roots of large diameter.

2) Effect of deep tillage was more remarkable in the field with straw mulch than in the bare field. Namely, in the former case, root quantity was decreased by deep tillage to about 70% of that of untilled field, and this ratio coincided to the yield ratio. The difference was greater between roots of large diameter. showing only 30% of that of untilled field. The fact that the deep tillage causes a more serious reduction of root quantity in the field with straw mulch, which favors root system development, indicates that the negative effect of the deep tillage is mainly root damage.

3) As to the vertical distribution of root system, it was observed that the distribution was more in the surface layer in the field under straw mulch whereas more roots developed in the deep soil layer in the bare field. Deep tillage caused the shallow root system, due to a direct effect of root damage and subsequent root regeneration in the upper soil layer.

These results are summarized as follows. In the field under straw mulch, root system develops quite well, but in the bare field it is very poor with the distribution of more roots in the deep layer. This may be due to the fact that the fertility of the surface soil layer is decreased after being kept under the bare condition for long time, and consequently root system has to move down to the deep

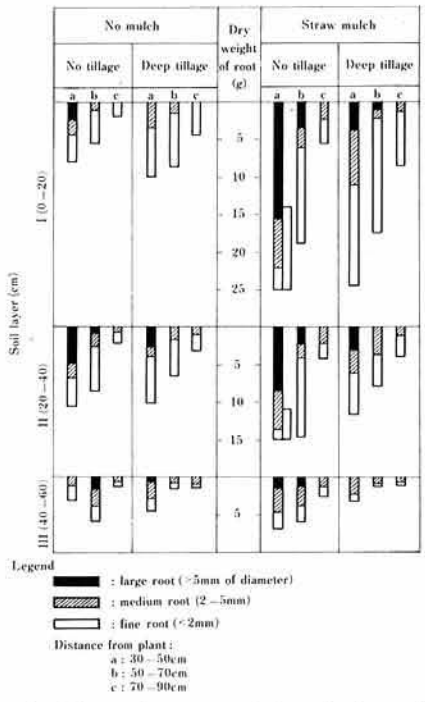

Fig. 6. Effect of straw mulch and deep tillage on root system development

layer which is originally inferior in its property. On the other hand, it can be said that the deep tillage causes a reduction of root quantity making roots small and root system shallow. This suggests that the root damage caused by deep tillage is more than upsetting the improvement of physical property of soil by deep tillage. The deep tillage is apparently noxious, although it has been emphasized that yearly practice of it is necessary. Incidentally, after a period of 6 years elapsed, the depth of trampled soil layer in the no deep tillage plot was less then 15 cm with a hardness below 20 mm. Therefore, the deep tillage should be done by taking into consideration a balance sheet of positive and negative effect when soil condition becomes really needing it.

References

1) Maehara, M. et al.: The effects of straw mulching, deep plowing and liming on tea soil, tea yield and tea qualities. II. The effects on some physical properties of soil. *Kyushu Agricultural Research* No. 28, 147–148 (1966) [In Japanese].
2) Maehara, M. et al.: The effects of straw mulching, deep plowing and liming on tea soil, tea yield and tea qualities. III. The effects on behavior of applied nitrogen in soil. *Kyushu Agricultural Research* No. 28, 149–150 (1966) [In Japanese].
3) Stewart, B. A. et al.: Immobilization of nitrogen in several organic fractions of soil. *Soil Sci. Am. Proc.*, 27, 302–304 (1963)
4) Harada, T.: The mineralization of native organic nitrogen in paddy soils and the mechanism of its mineralization. *Bull. Nat. Inst. Agr. Sci.* B, 9 (1959) [In Japanese with English summary].
5) Maehara, M. et al.: The effects of straw mulching, deep plowing and liming on tea soil, tea yield and tea qualities. IV. The effects on the readily decomposable organic matter in soil. *Kyushu Agricultural Research*, No. 29, 145–146 (1967) [In Japanese].
6) Tyulin, A. F. et al.: The composition and structure of soil organomineral gels and soil fertility. *Soil Sci.* 45, 343–358 (1938).
7) Atkinson, H. J. et al.: Soil colloids III. Relationship to soil fertility. *Soil Sci.* 57, 234–246.
8) Maehara, M. et al.: The effects of straw mulching, deep plowing and liming on tea soil, tea yield and tea qualities. V. The effects on the soil colloidal complexes. *Kyushu Agricultural Research* No. 29, 147–148 (1967) [In Japanese].
9) Maehara, M. et al.: The effects of straw mulching, deep plowing and liming on tea soil, tea yield and tea qualities. VI. The effects on the root systems. *Kyushu Agricultural Research*, No. 31, 115–116 (1968) [In Japanese].