Application of reduce tillage with a strip tiller and its effect on soil erosion reduction in highland agriculture

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Abstract
A tiller consisting of a 4 rows strip tillage device and fertilizer applicator was developed for reduced tillage and its effect on soil and fertilizer loss in field application was tested. The field was tilled at 10 cm width and at 10 cm depth by the equipment which was 16.7% of full-width tillage. The working performance and fuel consumption of the equipment were 3.8 hours/ha and 24.4 liter/ha respectively, which were 59% and 74% less than those of the conventional tillage. Fertilizer efficiency of the equipment in cultivation of 7 crops including Chinese cabbage was 1.5~1.8, 1.4~2.1 and 1.2~1.6 times higher in nitrate, phosphorous and potassium respectively, than conventional tillage. When the equipment was used after covering of rye residue, the quantity of runoff was 49~67% lower than the conventional tillage. The quantity of soil loss were 1.3 and 0.2 ton/ha right after and 30 days after planting of Chinese cabbage respectively, and 11.5 and 4.1 MT/ha in conventional tillage. In conclusion, the strip tillage equipment developed in this study can be applicable to slope land, so that soil loss can be decreased by 90%.

Key Words
Reduced tillage, strip tiller, soil loss, fertilizer loss, highland agriculture.

Introduction
Since highland agriculture in Korea has been developed in mountainous area with high slope, the agricultural lands are mostly with high slope. The conventional tillers used by farmers are apt to disturb surface soil heavily, and causes severe soil erosion. The fertilizer application using the conventional method spreading on surface before rotary cultivation also is subject to loss at rainfall events. Reduced tillage minimizing soil disturbance might reduce soil erosion (Luna 2003; Peterson 2004), and so site application of fertilizer might be decreased. This study is to develop a tiller for reduced tillage, and to test field applicability for sloped land in highland conditions.

Material and methods
Strip tiller development
A four row strip tiller with 12 tilling blades modified from Park *et al.* (2002) is shown in Figure 1. The distance of tilling blades was 60 cm (Figure 1b), and plain blades were attached at both side ends to protect soil and fertilizer from spreading outside. The tiller was attached to a 65HP tractor. The working performance and fuel consumption was analyzed as Park (2002). There were 3.8 hours/ha and 24.4 liter/ha respectively, which were 59% and 74% less than those of the conventional tillage operated with plow (data not shown).

Figure 1. A four row tiller designed for reduce tillage.

Field test for reduced tillage in sloped land of highland agriculture

A field experiment was conducted on a farm of which soil was silty clay loam with the 10 percent slope located on 750 m elevation in Hoenggye-Ri, Daegwallyeong-Myun, Pyeongchang-Gun, Gangwon-Do. The size of the field was 70 X 25 m^2. The 7 crops including Chinese cabbage, radish, cabbage, lettuce, soybean and corn were planted to evaluate effectiveness of reduced tillage and conventional tillage. The basal fertilizer application for Chinese cabbage was 83N-30P_2O_5-39K_2O kg/ha. The row distance was fixed at 60 cm, and the planting distance was 35 cm for Chinese cabbage, 25 cm radish and soybean, 45 cm for cabbage, and 30 cm for lettuce and corn, respectively, as RDA recommendation (RDA 2003). The harvesting date was 45 days after planting for lettuce, 60 days for Chinese cabbage, 75 days for cabbage, and radish, and 90 days for soybean and corn. During the cropping period, soil and fertilizer loss by water erosion at every rainfall events was monitored by simple lysimeter catchment installed in the field. The soil and plant samples were taken after harvest, and N, P and K nutrient contents were analyzed according to soil and plant analysis methods (NIAST 2000).

Figure 2. Lysimeter catchment to collect runoff and soil loss for conventional tillage (left), reduced tillage (center) and reduced tillage with rye mulching of Chinese cabbage.

Results

Strip tiller development

The tiller was attached to a 65HP tractor. The working performance and fuel consumption analyzed as Park (2002) were 3.8 hours/ha and 24.4 liter/ha respectively, which were 59% and 74% less than those of the conventional tillage operated with plow (data not shown).

Runoff and soil loss from reduced tillage

Figure 2 shows soil surface condition after intensive rainfall event at early stage of Chinese cabbage. As surface coverage was low due to young plant stands, severity of soil erosion from the ridge clearly shows in order of the conventional tillage, reduced tillage, and reduced tillage with rye mulching. Soil loss from the conventional tillage plots after 280 mm rainfall event from July 23 to 26 were 4.1 to 11.5 MT/ha, while that from the reduced tillage plots was 2.2 to 2.4 MT/ha (Table 1).

Table 1. Runoff, turbidity and soil loss from conventional tillage and reduced tillage with of without rye mulching.

	Planting date	Runoff (m^3/ha)	Turbidity (NTU)	Soil loss (MT/ha)
Conventional	July 21[1)]	857	10,906	11.5
	June 25[2)]	1,167	961	4.1
Reduce tillage	July 21	429	1,162	2.4
	June 25	920	649	2.2
Reduced tillage with rye mulching	July 21	286	357	1.3
	June 25	596	81	0.2

* Rainfall event : 280 mm from July 23 to 26

1) Lysimeter with 10% slope

2) Lysimeter with 17 % slope

The soil loss from the reduced tillage with rye mulching was 0.2 to 1.3 MT/ha, which was 1/2 to 1/9 of soil loss from the conventional tillage. The runoff from conventional tillage amounts 857 to 1,167 M^3, which was 30.6 to 41.7 percents of the total rainfall amount during this rainfall event. It reduced to 15.3 to 32.9 percent for the reduced tillage, and to 10.2 to 21.3 percent for the reduced tillage with rye mulching. The turbidity of the runoff ranged 961 to 10, 906 NTU from conventional tillage, and 649 to 1,162 NTU from reduced tillage and 81 to 357 NTU from the reduced tillage with rye mulching, respectively. These results clearly indicate that reduced tillage cut down soil loss and runoff, and thus improved runoff water quality.

Effect of plant growth and nutrient uptake

Table 2 shows plant growth and nutrient uptake at 40 days after planting. Reduced tillage increased plant growth for all tested crops by 34 to 61 percent on a dry matter basis. The nutrient uptake of the crops was also increased by reduced tillage in comparison with conventional tillage by 50 to 75 percents for nitrogen, 47 to 105 percent for phosphorus, and 28 to 61 percent for potassium. This result revealed that fertilizing methods could drastically affect the effectiveness of applied fertilizers. Conventionally, all fertilizers were wide spread on the surface of soil before planting and were incorporated by mixing soil with a rotary cultivation. In reduced tillage, fertilizers were applied in a band where the crop grew. Little physiological defect was found due to over fertilizing on site. More detailed examination on site specific fertilizing effect should be performed for different soils and plants.

Table 2. Plant growth and nutrient uptake at 40 days after planting.

Cropping		Fresh Crop (kg/ha)	Dried yield (kg/ha)	Nutrient uptake (kg/ha)		
Crop	Tillage			T-N	P_2O_5	K_2O
Chinese Cabbage	Conventional	24,805	1,609	58	25.1	54
	Reduce tillage	41,885	2,163	96(166)	39.0(157)	79(148)
Radish	Conventional	5,164	371	11	2.2	6
	Reduce tillage	8,209	532	27(171)	7.6(188)	18(148)
Soybean	Conventional	2,880	442	24	3.6	10
	Reduce tillage	4,041	602	36(150)	5.3(147)	12(124)
Lettuce	Conventional	8,255	446	19	3.2	18
	Reduce tillage	13,411	658	33(170)	5.7(179)	29(161)
Red cabbage	Conventional	5,623	521	24	4.3	13
	Reduce tillage	8,849	743	41(167)	8.8(205)	19(146)
Cabbage	Conventional	9,575	796	38	6.8	21
	Reduce tillage	12,361	1,051	59(157)	12.1(176)	26(128)
Corn	Conventional	11,696	1,035	39	8.5	37
	Reduce tillage	17,860	1,668	69(175)	14.5(170)	52(141)

Additionally, according to evaluation of workability and costs of operation, the fuel requirement for conventional tillage was 92.8 L which included plowing-harrowing-ridging, while 24.4 L for reduced tillage. The reduced tillage saving fuel consumption in the field by 74 percent, and might help farm economy.

Conclusion

The experimental results clearly showed that reduced tillage reduced soil erosion and runoff, and thus decreased turbidity of the runoff water. Especially, reduced tillage with rye mulching on soil surface doubled the effect of reducing soil erosion. Increasing surface coverage by rye mulching reduces raindrop impacts, and reduces water flow through rills. Decreasing runoff caused increasing infiltration, which might increase soil water reserve efficiency, and improve filtering effect of water. The reduced tillage also saved fuel consumption (Park 2002). Therefore, use of strip tiller for reduced tillage could be strongly recommended to reduce soil erosion and to improve farm economy. This might also improve water quality downstream of the highland agriculture.

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