Effect of Chemical and Mechanical Weed Control on Cassava Yield, Soil Quality and Erosion under Cassava Cropping System

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***Abstract*—Three years field experiments were conducted to study the effect of chemical and mechanical weed control on soil quality and erosion under cassava cropping system. The experiment were conducted at the University of Brawijaya field experimental station, Jatikerto Village of Malang Regency, Indonesia. The experiments were carried out from 2011 – 2014. The treatments consist of two cropping system (cassava mono culture and cassava + maize intercropping), and two weed control method (chemical and mechanical methods). The experimental result showed that the yield of cassava first year and second year did not influenced by weed control method and cropping system. However, the third year yield of cassava was influence by weed control method and cropping system. The cassava yield planted in cassava + maize intercropping system with chemical weed control methods was only 24.25 t.ha^{-1}, which lower compared to other treatments, even with that of the same cropping system used mechanical weed control. The highest cassava yield in third year was obtained by cassava + peanuts cropping system with mechanical weed control method. After three years experiment, the soil of cassava monoculture system with chemical weed control method possessed the lowest soil organic matter, and soil aggregate stability. During three years of cropping soil erosion in chemical weed control method, especially on cassava monoculture, was higher compared to mechanical weed control method. The soil loss from chemical control method for the third year was 54.20 t.ha^{-1}, whereas from the mechanical weed control was only 38.40 t.ha^{-1}.**

***Index Terms*—herbicide, intercropping, soil organic matter, aggregate stability**

I. Introduction

Weeds are among the major pests in cassava cropping system which determine the success of farming [1]. The occurrence of weeds causes competition for light, water and plant nutrient. In addition weeds could be a host for insects and diseases for cassava. The loss of cassava yield has been reported varied from about 40% in Nigeria [2] to 94% in Columbia [3]. Therefore, clearing weeds is important work in cassava cropping system. Dixon [4] has shown that weeding can double national cassava yield in Nigeria from 12–13 t/ha^{-1} to 20-39 t/ha^{-1}.

Most of cassava farmers practice weeding by mechanical methods which done by slashing, or hand or hoe weeding. Some farmers do weeding, especially weeding at 30 and 60 days after planting, together with ridging. It needs a lot of labor and cost. Therefore, most farmers let their cassava crops invested by weeds. It seems that herbicide to become increasingly importance for weeds clearing in cassava farming system, especially when labor is limited or expensive. The used of herbicide in cassava farming systems actually is not a practice. Kassian [5] has reported the selectivity of some herbicides for cassava crops.

Indeed, the use of herbicide for weed control will make farming more efficient because it reduce the cost and get a high yield [4] and [6]. It also has been reported the use of herbicide could improve soil quality and reduced soil erosion [7] and [8]. However, herbicide can also create many detrimental effects. The environmental pollution resulted from the use of pesticides had been reported by many workers [9] and [10]. The effect of herbicide application on cassava crops on soil quality should also be assessed carefully. Most workers agree that the use of herbicides will decrease soil erosion. However, the study of herbicides application are mostly combined with conservation farming [7] and [11], such as reduced tillage zero tillage. This is mostly not the case in cassava crops. In order to favor tuber development, cassava needs a friable soil, and therefore soil tillage is necessary.

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The experiment reported here was aimed to study the effect of weeding methods on cassava yield. The experiment was also investigated the effect of herbicides application on soil quality and erosion.

II. Materials and Method

A. Location

The field experiments were conducted on the Field experimental station of Brawijaya University at Jatikerto Village of Malang Regency, Indonesia (08 °03' S, 112 °30' E; 228 m above sea level). The experiments were carried out during 3 year planting season. The first year experiment was planted in December 201, the second year experiment was started in November 2012, and the third year experiment was started in December 2013. Cassava was harvested at 11 months old.

The soil of the experimental site belongs to Inceptisols with an effective depth of less than 30cm. The soil is relatively neutral with soil pH of 6.6, soil organic` carbon of 1.03%, total nitrogen of 0.09%, available P of 2.1 ppm, exchangeable K of1.60 cmol/kg and Cation Exchange Capacity of 12.8 cmol/kg. Based on the number of wet and dry months, the climate at the experimental station can be classified as D climate type [12] with distinct wet and dry seasons. The rainy season is usually started from October and ended in March of the following year with the average annual rainfall about 1,800 mm.

B. Experimental Treatments

The treatments consist of two cropping systems (cassava mono culture and cassava + maize intercropping), and two weed control method (chemical and mechanical methods). These treatments were arranged in a Randomized Block Design with 3 replications.

The cassava cultivar of 'Faroka', a high yielding bitter cassava, was planted on 10 x 4.0m plot with 12% slope at a plant distance of 1.0 x 1.0m. Prior to tillage, the chemical weeding treatment was prayed with herbicides (round-up). The weeds control for the mechanical technique was done by hoe at 15, 30 and 45 days after planting. Soil tillage was done by hoe. The All plots were given N, P and K fertilizers in the form of Urea (400kg ha^{-1}), Super Phosphate 36 (100kg ha^{-1}), and KCl (100kg ha^{-1}). All P and K fertilizers were given at planting date, and N fertilizer was applied in three splits: one-third at planting, one-third at 15 days after planting, and the rest at 45 days after planting. The resulted weeding and maize biomass were put back to the plot as mulch.

The data collected were: cassava yield, soil carbon, soil nitrogen, soil aggregation, and soil loss. To collect soil loss, a soil collector was build up at the lower part of the plot. The soil was sampled before the experiment, and after the harvesting of the third cassava. Soil samples were taken to a depth of about 20cm, and sampling was done following a zigzag system (4 sub-samples from each plot), mixed, and then a 0.5kg composite sample of each was processed for laboratory analysis.

Soil characteristics were determined in accordance with the method developed by Soil Research Institute, Bogor [13]. Soil Organic-C was determined with the Walkley and Black Method; soil N with the Kejdahl Method. To analyzed soil aggregation, soil aggregate of 2.0 -4.0mm diameter were put on a series of sieves (2.0; 1.5; 1.0 and 0.5mm diameter) and then the aggregate stability measurement was done with the wet sieving method as described Utomo and Dexter [14], and the result was expressed as the Mean Weight Diameter (MWD) of the aggregate retained on the sieves [15].

C. Statistical Analysis

Analysis of Variance (ANOVA) was employed to analyzed the data, and if there was a significant differences, LSD ($P<0.05$) was used to compare between treatments.

III. Results and Discussion

A. Cassava Yield

The result presented in Table I show that the method of weed control did not significantly influenced cassava yield. However, the yield of cassava in the third year, cassava yield was significantly influenced by weed control techniques. Looking the data given in Table II, it could be suggested that the low yield of the cassava in chemical weed control method was due to the low soil organic matter, and of course soil nitrogen content.

TABLE I. Means Cassava Yield as Influenced by Cropping Systems and Weed Control Techniques

Treatments		Fresh tuber yield (t/ha)*		
Cropping system	Weed control technique	2011/12	2012/13	2013/14
Cassava monoculture	Mechanical	38.45 b	35.25 c	33.40 cd
	Chemical	39.22 b	34.20 c	32.20 c
Cassava + Maize	Mechanical	32.45 ab	28.36 ab	28.30 b
	Chemical	31.56 a	26.44 a	24.25 a

*Means followed by the same letters, in the same column are not significantly different ($P > 0.05$)

TABLE II. Soil Organic Matter and Nitrogen Content as Influenced by Cropping System and Weed Control Techniques

Treatments		Soil carbon and nitrogen content *		
Cropping system	Weed control technique	C (%)	N (%)	C/N ratio
Cassava monoculture	Mechanical	1.15 b	0.11 a	10.45
	Chemical	0.94 ab	0.09 a	10.44
Cassava + Maize	Mechanical	1.38 c	0.11 a	13.80
	Chemical	1.02 a	0.09 a	11.33
Before planting		1.19	0.10	11.90

*Means followed by the same letters, in the same column are not significantly different ($P > 0.05$)

The results presented in Table I also show that cassava yield decreased in the second and third year. This could be attributed to the decrease of soil fertility status of the soil. The decrease in cassava yield when it is planted on

the same field continuously is not the new phenomena [16] and [17].

Similar to cassava yield, the yield of maize intercrop decreased as the land was continuously planted with cassava (Table III). However, the phenomenon of lower cassava yield in chemical weed control treatment did not occur for maize intercrops.

TABLE III. MEANS YIELD OF MAIZE INTERCROP FOR DIFFERENT WEED CONTROL TECHNIQUES

Treatments		Maize grain (t/ha)		
Cropping system	Weed control technique	2011/12	2012/13	2013/14
Cassava + maize	Mechanical	4.22± 0.55	3.52± 0.55	3.04 ± 0.52
	Chemical	4.30 ± 0.60	4.00 ± 0.60	3.22 ± 0.48

B. Soil Qualities

Experimental result presented in Table III show that soil organic matter content of chemical weed control was lower compared to that of the mechanical weed control. After harvesting the 3rd year cassava, soil organic-C content in chemical weed control treatment vary from 0.92% (cassava + maize intercropping) 0.94% (cassava monoculture), whereas that of in mechanical weed control varies from 1.15% to 1.38%. Planting of maize as the intercrop increased soil organic matter of the mechanical weed control treatment.

Although there was a tendency that soil nitrogen content in the chemical weed control lower than that of the mechanical weed control, the differences was not significant at the probability level of 5%.

The higher content of soil organic matter content in mechanical weed control is reasonable; because the soil organic matter was originated from the plants grew on the soil. It was observed that on chemical weed control treatments the land surface was relative clean form any plant. This was not the case with the mechanical weed control treatment (Fig. 1). Within just 15 days after planting, weeds already fully cover land surface in the mechanical weed control treatment plot.

Figure 1. Weeds condition at 15 days after planting. Chemical weed control method (left), and mechanical weed control (right)

After harvesting the first year cassava the treatment imposed in this experiment did not significantly influence soil aggregate stability (Table IV). However, after 2 and 3 years planting, soil aggregate stability was significantly influenced by both cropping system and the method of weed control. Intercropping tend to have a higher soil aggregate stability compared to the mono culture. Soil aggregate water stability of mechanical weed control tends to be higher compared to that of the chemical weed control.

TABLE IV. SOIL AGGREGATE STABILITY AS INFLUENCED BY CROPPING SYSTEM AND WEED CONTROL TECHNIQUES

Treatments		Mean Weight Diameter (mm)*		
Cropping system	Weed control technique	2011/12	2012/13	2013/14
Cassava monoculture	Mechanical	1.20 a	1.19 a	1.28 ab
	Chemical	1.08 a	1.20 a	1.04 a
Cassava + Maize	Mechanical	1.12 a	1.40 b	1.38 b
	Chemical	1.15 a	1.08 a	1.12 ab
Before planting	1.30			

*Means followed by the same letters, in the same column are not significantly different (P > 0.05)

The result presented in Table IV show that the soil aggregate in the cassava + maize intercrop with mechanical weed control technique had the highest Mean Weight Diameter (MWD), thus the highest soil aggregate stability. Looking the result in Table II, it could be explained that the highest soil aggregate stability of this treatment was due to the high soil organic matter content. The importance of soil organic matter for soil aggregate formation and stabilization has been discussed elsewhere [18]. The high content of soil organic matter of this treatment was originated from weeds and maize biomass which put back on the plot.

The effect of cropping system and weed control techniques on surface run off is presented in Table V, and their effect on soil erosion on Table VI. In general, surface run off from cassava + maize intercrop was lower compared to that from cassava monoculture (Table V). Furthermore, the experimental result given in Table V also shows that chemical weed control tend to have a higher surface run off than the mechanical weed control.

TABLE V. SURFACE RUN OFF AS INFLUENCED BY CROPPING SYSTEM AND WEED CONTROL TECHNIQUES

Treatments		Surface run off (% rain)*		
Cropping system	Weed control technique	2011/12	2012/13	2013/14
Cassava monoculture	Mechanical	25.46 b	26.20ab	24.28 ab
	Chemical	24.35ab	28.22 b	27.64 b
Cassava + Maize	Mechanical	19.35 a	20.45 a	21.85 a
	Chemical	20.15 a	24.55ab	25.15 ab

*Means followed by the same letters, in the same column are not significantly different (P > 0.05)

The effect of cropping system and weed control techniques to soil erosion was similar to their effect on surface run off. Intercropped maize into cassava tends to decrease soil loss. Soil loss from chemical weed control was higher compared to that from the mechanical weed control treatment. The highest soil loss (54.t/ha^{-1}) was

obtained by cassava monoculture with chemical weed control method, and the lowest soil loss (32.45 t/ha^{-1}) was obtained by cassava + maize intercropping with mechanical weed control method.

TABLE VI. SOIL LOSS AS INFLUENCED BY CROPPING SYSTEM AND WEED CONTROL TECHNIQUES

Treatments		Soil loss (t/ha)*		
Cropping system	Weed control technique	2011/12	2012/13	2013/14
Cassava monoculture	Mechanical	36.55 ab	42.34bc	38.40 ab
	Chemical	40.25 b	44.80 c	54.20 c
Cassava + Maize	Mechanical	34.62 a	38.22 a	32.45 a
	Chemical	36.27 ab	40.28 ab	40.28 b

*Means followed by the same letters, in the same column are not significantly different (P > 0.05)

The lower of surface run off and soil erosion from intercropping system with mechanical weed control method could be as a result of more surface coverage (Fig. 1), more soil organic matter (Table II), and a better soil aggregate stability (Table IV).

The experimental results discussed in Table V and Table VI are in contradiction with the previous study [7] and [11]. However, it should be carefully considered that the study of Kettler *et al*. [7] and Fykse *et al*. [11] was dealt with the reduced and no tillage system where there was no soil disturbance. As discussed before, in order to favor tuber development, planting cassava needs friable soil, and therefore require a proper soil tillage in the area where the tuber will develop. As shown in Fig. 1, chemical weed control almost totally kills the weeds. In the early growth of cassava, with wide plant spacing, soil surface coverage is poor, therefore it will be susceptible to rain drop detachment and lead to higher soil loss.

IV. CONCLUSION

The experimental results discussed above show that the method of weed control in cassava cropping system significantly influenced soil quality, soil erosion and hence cassava yield. Since cassava need a proper tillage system, the use of herbicide for weed control could speed up soil degradation due to worst soil aggregation and increasing soil erosion. The highest cassava yield in third year was obtained by cassava + peanuts cropping system with mechanical weed control method. After three years experiment, the soil of cassava monoculture system with chemical weed control method possessed the lowest soil organic matter, and soil aggregate stability. During three years of cropping soil erosion in chemical weed control method, especially on cassava monoculture, was higher compared to mechanical weed control method. The soil loss from chemical control method for the third year was 54.20 t/ha^{-1}, whereas from the mechanical weed control was only 38.40 t/ha^{-1}.

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