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An Analysis of Soil Erosion, Value of Crop Management and Conservation Practice Factor of Red Pepper Crop under Different Ridge Types

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Abstract

Land use and management influence the magnitude of soil erosion. In general, erosion is the main factor that causes soil degradation. To keep soil degradation does not occur and the land can be used sustainably, then the target of the erosion value should be equal to or smaller than the tolerable erosion. Among the different soil erosion risk factors, the crop management factor and conservation practice factor (CP factor) is the one that policy makers and farmers can most readily influence in order to help reduce soil erosion rates. The objective of research is to analyze value of erosion and CP factor, that is combination of crop management factor (C) for red pepper and conservation practice factor (P) especially the ridges. The Research of determination the value of CP factor, on planting of red pepper with various soil conservation techniques have not been widely applied. This is important because the value of CP factor which is obtained will help in planning the management of land resources and in predicting the amount of erosion that will occur based on USLE if these plants will be cultivated. The research was conducted with field measurement approach method by model of erosion plots with 2 x 20 meters size that is made at the 40 % slope. Experimental design is using factorial randomized block design that are consist of two factors. The first factor is cropping pattern which are monocultural red pepper (T_1) and intercropping red pepper with cabbage (T_2). The second factor is soil conservation technique which are the ridges in the direction of the slope as the control (K_1), the ridges in the direction of the slope + the ridges cut off the slopes in every 6.6 meters (K_2), the ridges across the slope (K_3), and the ridges across the slope with 20° tilted (K_4). The research result shows that the ridges across the slope that combined with red pepper + cabbage (T_2K_3 treatment) is capable to decrease the erosion less than tolerable erosion limit (26,96 ton.ha^{-1}.yr^{-1}) and CP factor value is 0,04.

Keywords : CP factor, erosion, red pepper, soil conservation

1. Introduction

Soil plays an important role in the ability of ecosystems to provide diverse services necessary for human wellbeing. However, as a response to mismanagement by human being, there has been a continuous deterioration of soil and depletion of land resources (Panagos et al., 2015). The land resources are very susceptible to degradation due to erosion. Erosion is the event of soil loss or erosion of soil or parts of soil from the someplace and raised elsewhere, either by the movement of water, wind and/or ice. The process of erosion caused by water in general through three stages, the first stage of solving the soil aggregates into particles of soil (detachment) by raindrops, the second stage of the transportation by runoff and third stages of the deposition of soil particles (sedimentation) when the flow energy no longer be able to carry soil particles (Hogarth et al., 2004; Shukle and Lal, 2005; Asdak, 2007; Arsyad, 2010).

Erosion is one of causes of declining land productivity of the highlands, particularly those used for seasonal crops such as food crops and horticulture (Kurnia et al., 2005; Dariah, 2007). The research results showed the seasonal food crop cultivation in the highlands without soil conservation practices causing erosion with a range of between 87 and 652 $ton.ha^{-1}.yr^{-1}$ (Arsanti and Boehme, 2006; Firmansyah, 2007; Zhou, 2008; Sutrisna et al., 2010; Panagos et al., 2015). Erosion is not only transports soil material, but also nutrients and organic matter, both contained in the soil or in the form of agricultural inputs (Sutono, 2008; Chen et al., 2013). Erosion also damage the physical properties of soil which is reflected in decrease of infiltration capacity and ability to hold water, increasing soil density and reduced stability of soil structure. (Shukle and Lal, 2005; Kinnell, 2010). Therefore, the application of conservation techniques is one of prerequisites for sustainability of farming in the highlands. Targets to be achieved is to minimize erosion below the limit of tolerance, with a range of between 4 and 25 $ton.ha^{-1}.th^{-1}$, depending on the nature of soil and its substrate (Arsyad, 2010).

Soil and water conservation strategies leads to protection of soil from force of rain water with soil surface cover, reducing runoff by increasing infiltration capacity, increase soil aggregate stability, and reduction of flow rate by increasing surface roughness of the soil (Kinnel, 2010). To minimize erosion within the threshold of tolerable erosion limit, some kind of conservation techniques can be applied with due regard to the technical requirements (Asmaranto and Juwono, 2007; Lahmar, 2010). Broadly speaking, soil and water conservation methods are grouped into three main groups, namely agronomically (biology), mechanical (physics), and chemistry. Agronomical or biological method is to utilize vegetation to help reduce erosion of land. Mechanical or physical method is conservation that concentrating on land preparation to be covered with dense crops or vegetation, and the way to manipulate the micro topography to control the water flow. Whereas chemical methods aimed to improving soil structure making it more resistant to soil erosion. So in short it can be said as agronomic methods to protect the soil, mechanical methods to control the runoff energy that erosive and chemical methods to improve the durability of the ground. (Suripin, 2002; Arsyad, 2010).

In practice, the application of mechanical conservation techniques often combined with vegetative technique, because it is effective in controlling erosion (Dariah et al., 2004; Santoso et al., 2004) and more rapidly adopted by farmers. Setting the cropping pattern by laboring the land surface is always covered by vegetation and /or plant residues or litter, also plays an important role in soil conservation. Besides that the setting of lines planting or ridges in the direction of the contour also contribute in preventing erosion. Results of research conducted by Zhang et al., 2004; Sumarni et al., 2006; Asmaranto and Juwono, 2007; Zhou et al., 2008; and El Kateb et al., 2013 showed that the application of mechanical conservation techniques combined with vegetative conservation techniques can reduce erosion up to <10 $ton.ha^{-1}$.

Land use policies in a conservative manner, can be determined from the results of erosion rate prediction and determination of tolerable erosion. Broadly speaking, the factors that affect the magnitude of the rate of erosion is climate, soil, topography, vegetation and human action factors. All of these factors can be controlled, except climatic factor. In predicting the rate of soil erosion, the equation commonly used is Universal Soil Loss Equation (USLE): A = R.K.L.S.C.P, where A is the rate of erosion, R = rainfall index factor, K = soil erodibility factor, L = slope length factor, S = slope factor, C = cover crop and crop management factor, P = land management/conservation practice factor. (Asdak 2007; Arsyad, 2010). In an effort to conserve soil and water as well as land in general, management of the cultivation of red peppers in particular, it needs to be assessed the amount of value of crop management factor (C) and land management/conservation practices factor (P). According to Asdak (2007) CP factors shows overall the effect of vegetation, litter, soil surface conditions, crop management and soil management (soil conservation) to the amount of erosion. CP factor in USLE is the ratio between amount of erosion of soil planted with certain management and conservation to amount of erosion on land that is not cultivated and without conservation measures. CP factor measures joint effect of the type of crop management and conservation measures. Its values range between 0 (very high crop cover and conservation practice protecting the topsoil against soil erosion) and 1 (no effect of the crop cover and conservation practice and high soil loss that is comparable to that of bare soil) (Renard et al., 1991).

The Research of determination the value of CP factor, on planting of red pepper with various soil conservation techniques have not been widely applied. This is important because the value of CP factor which is obtained will help in planning the management of land resources and in predicting the amount of erosion that will occur based on USLE if these plants will be cultivated. As argued by Kinnell (2010) that the USLE allows planners suspect an average rate of a particular soil erosion on a slope steepness with a particular rainfall pattern for every kind of crop and soil conservation measures that may be done or are being used. When the CP factor values that obtained can provide the actual erosion value equal to or below the value of tolerable erosion, then the fears of soil degradation by erosion as a result of the intensification of the red pepper crop with conservation techniques applied can be reduced.

The purpose of this study was to analyze erosion and the value of CP factor, which is a combination factor of crop management that is red pepper and land management factors (soil conservation measures) in the form of ridges. Long-term effects of soil erosion are considered to have strong ecological impacts and socio economic consequences (Meng et al., 2001). Information on the quality and quantity of soil erosion is required in order to control soil erosion through well adapted management and conservation practices.

2. Method

2.1. Study Site

The experiment was conducted in the District of Cikajang, Garut Regency, West Java Province, Indonesia. The total area of the District Cikajang around 12,139.35 ha. District Cikajang situated at an altitude 1,200 to 1,300 meters above sea level with an average rainfall of 2,527 $mm.th^{-1}$, and are included in the climate type C (slightly wet), where every year there are 8 wet months and 4 dry months. Map location of the study are presented in Figure 1. Analysis of soil samples carried out in the Soil Laboratory, Faculty of Agriculture, Bogor Agricultural University. Research is done on January 2013 until December 2013.

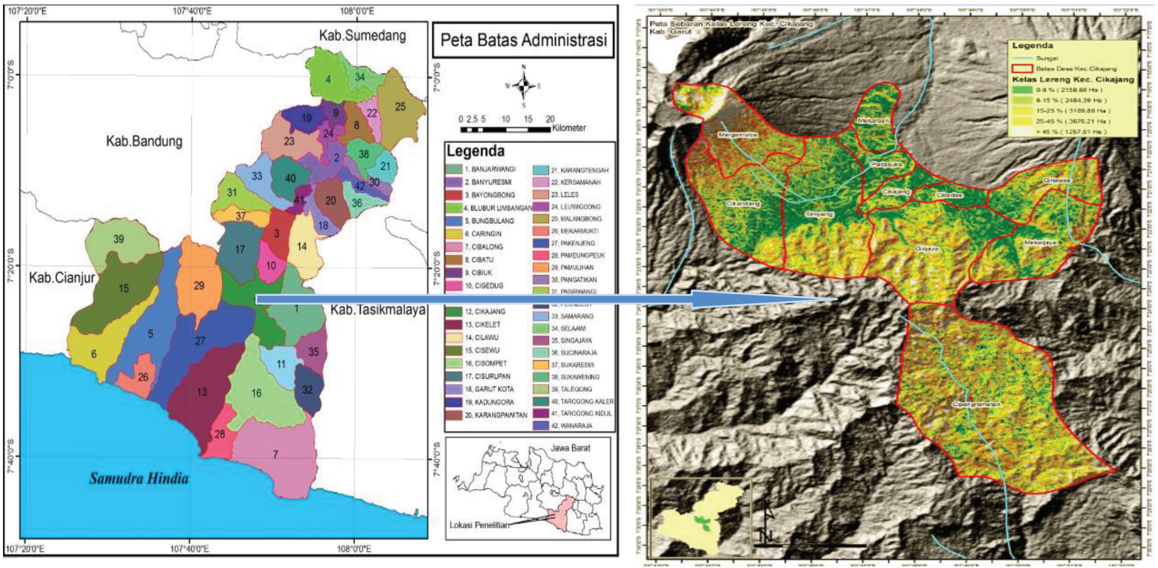


Figure 1. Studi Area

2.2. Materials and Tools

Materials used are: red peppers and cabbage seedlings, fertilizer (manure, urea, TSP and KCl), pesticides, stake, ropes, drums, tarpaulins, buckets, paralon pipe, and materials for the analysis of soil chemical properties in the laboratory. Equipment used are: roll meter, ombrometer, digital cameras, hoes and knives, equipment used in the laboratory, a set of personal computers (PCs) and software used for data analysis was MS. Excel and Minitab.

2.3. Experimental Design

To determine the effect of conservation technology towards erosion and the value of CP, conducted plots erosion experiments in the field. This study was designed using a factorial randomized block design that are consist of two factors. The first factor is cropping pattern which are monocultural red pepper (T_1) and intercropping red pepper with cabbage (T_2). The second factor is soil conservation technique which are the ridges in the direction of the slope as the control (K_1), the ridges in the direction of the slope + the ridges cut off the slopes in every 6.6 meters (K_2), the ridges across the slope (K_3), and ridges across the slope with 20° tilted (K_4). Thus the total number of experimental plots is 2 x 4 = 8 plot, each experiments are repeated 3 times to obtain 24 experimental plots, and to calculate the value of CP factor is made comparator plots separately with 3 replication, so that total erosion plots created were 27 plots.

Experiments erosion plots measuring 2 x 20 meters (the length of plot in the direction of the slope), made on slope 40% . Measurement of surface runoff and erosion with Multi-slot method Diviser. Limiting plot experiment using a plastic tarp embedded ± 30 cm into the ground and ± 40 cm above the ground. The tank of runoff and erosion measuring 2 x 0.5 x 0.5 m with a hole (ϕ 5 cm) to 5 cm from its edge and one hole amid connected with paralon pipe (ϕ 5 cm) to drain overflow into a small tub of size 0.5 x 0.5 x 0.5 m.

Once the soil cultivated is perfectly, embankment is made with 80 cm width, 40 cm height, 20 m length , and the distance between embankment is 40 cm. Planting red chili using a spacing of 60 x 50 cm (60 cm between rows and 50 cm within rows). Red chilli seeds used are varieties of Hot Beauty. In the treatment of intercropping, cabbage planted in between the two of red pepper plants in a row, and the planting hole of cabbage is not aligned with the planting hole of red pepper, but a little bit out, with the aim of growing cabbage is not disturbed/unobstructed by red pepper plants higher. Seed varieties of cabbage used is the Grand Master.

Basic fertilizer that is used consists of manure (40 $ton.ha^{-1}$) and NPK 15:15:15 (500 $kg.ha^{-1}$). Basic fertilizer applications performed 1 week before planting. Supplementary fertilizer for plants red peppers used fertilizer NPK 15:15:15 (500 $kg.ha^{-1}$). Supplementary fertilizer applications done by melted and poured (cast) around the red pepper plants from the age of 14 days after transplanting with intervals of 10 days. In the intercropping treatment of red peppers + cabbage, use of NPK plus 120 $kg.ha^{-1}$ for a supplementary fertilizer of cabbage with applications casted around cabbage plant from age 14 days after transplanting and intervals of 10 days.

2.4. Data Collection and Analysis

The data collected, namely: (a) The rainfall was observed continuously by rain events experienced during the study period lasts, with ombrometer installed at the study site, (b) Growth of crops observed included: age, height and canopy wide made in the weekly period per plot , (c) Volume of water/plot/rain events, and (d) The amount of soil erosion/plot/rain events, for each type of plot.

Measurements of soil erosion samples initiated from measurement of samples volume of runoff (cm^3/plot/ rain events) by measuring the water level in the tank. The amount of soil erosion/plot/rain events, determined through analysis of water samples of runoff that deposited in the drum and sediment samples in the tank. Samples of runoff that accommodated in the drum, after being mixed and stirred evenly, taken as a sample of 500 cc. Samples were analyzed in a laboratory to determine levels of soil (dry soil).

The amount of suspended sediment in surface flow is calculated by the formula:

$$E = \frac{V}{500} x\ B \quad (1)$$

where: E = total suspended sediment in runoff ($g.plot^{-1}$), V = volume of runoff ($cm^3\ plot^{-1}$), B = dry weight of suspended sediment in runoff ($g.plot^{-1}$).

Samples of sediment in the tank that has been removed from the tank dried and then weighed to determine the wet weight. To determine the dry weight of sediment, retrieved a sample of 250 grams is then dried.

The amount of sediment in the tank sediment is calculated using the formula:

$$E' = \frac{total\ weight\ of\ wet\ sediment\ (g)}{250\ (g)} x\ \ dry\ weight\ of\ the\ samplel\ (g) \quad (2)$$

where: E '= the amount of sediment in the sediment tank ($g.plot^{-1}$).

Total of soil erosion calculated using the formula:

$$A = E + E' \quad (3)$$

where A = total soil erosion ($g.plot^{-1}$), E = total suspended sediment in runoff ($g.plot^{-1}$), E' = the amount of sediment in the sediment tank ($g.plot^{-1}$).

CP factor value calculated by comparing the amount of soil erosion in treatment plots with the comparator plots, or by the formula

$$CP\ Factor\ Value = \frac{soil\ erosion\ in\ treatment\ plots}{soil\ erosion\ on\ soil\ identical\ without\ any\ treatment} \quad (4)$$

Tolerable erosion is calculated based on the equation Wood and Dent (1983) *in* Arsyad (2010) by the equation:

$$T = \frac{D_E - D_{min}}{MPT} + LPT \quad (5)$$

Where T = tolerable Erosion ($mm.th^{-1}$), DE = equivalent depth (soil effective depth x soil depth factor) (mm), d_{min} = minimum depth of soil, MPT = resources life, 250 year for continuos use and intensively, LPT = rate of soil formation by 1.0 $mm.yr^{-1}$.

Data analysis experimental design using analysis of variance (ANOVA) at 5%. From the analysis of variance, if significantly different F test, followed by a test of Least Significant Difference (LSD) to see a significant difference between the degree of treatment.

3. Results and Discussion

3.1. Tolerable Erosion

Based on guideline of determination the value of tolerable erosion by Wood and Dent (1983) in Arsyad (2010), the tolerable erosion is calculated on the soil with an effective depth of 1,081 mm and a depth factor for sub order Udult of 0.8. Thus the depth of the soil equivalent of 864.4 mm. The minimum depth of soil for agricultural crops is 300 mm. If the average soil formation rate of 1.0 mm.yr^{-1}, soil bulk density of 0.83 gr.cm^{-3}, and age of the land for 250 years, then tolerable erosion in the study site at 26.96 ton.ha^{-1}.yr^{-1}.

3.2. *Effect of combination of The Ridges and Red pepper Plants to Runoff and Erosion*

Analysis of variance results showed that the treatment of soil and water conservation measures significantly affect runoff and soil erosion. The average of runoff and soil erosion with LSD test results ($P < 0.05$) is presented in Table 1.

Table 1. Effect of soil and water conservation measures on runoff and erosion.

Treatment	Runoff (m^3.ha^{-1}.yr^{-1})	The percentage of runoff to rainfall (%)	Erosion (ton.ha^{-1}.yr^{-1})
T_1K_1	253.35a	87.58	109.08a
T_1K_2	195.89b	67.72	28.74b
T_1K_3	92.74d	32.06	10.66d
T_1K_4	130.76c	45.21	18.43c
T_2K_1	203.57a	70.38	89.26a
T_2K_2	143.56b	49.63	19.29b
T_2K_3	60.21d	20.82	5.22d
T_2K_4	95.11c	32.88	11.46c

* *Figures followed by the same letters in the same column are not significantly different at 5% according to LSD*
* *Rainfall = 289,26 mm.month^{-1}*

Based on the results of LSD test, T_2K_3 treatment most effective to decrease runoff and erosion below the tolerable erosion, followed T_1K_3 treatment, T_2K_4, T_1K_4, and T_2K_2. This is consistent with research result of Wezel et al. (2002) that the horizontal ridge system, as the rules of the terrace, very effective in reducing the rate of erosion and effectiveness of the ridges will increase if the ridges closer distance. The ridges cut off the slope is very effective in slowing down runoff, to hold and collect them so that more water will seep into the ground through a process of infiltration so that runoff and erosion becomes small (Zhang et al., 2004; Shukle and Lal, 2005; Asmaranto and Juwono, 2007; Mawardi, 2013).

Intercropping system is also excellent for soil conservation because crop canopy closure more extensive than monocultures. Table 1 shows that the percentage of rainfall as runoff on the treatment of red pepper intercropping smaller than of red pepper monoculture treatment. The smallest percentage of rainfall as runoff, found in T_2K_3 treatment. The more extensive and tightly of canopy cover, then the amount of water that passes penetrate plant canopy and up to the surface gets smaller so that erosion is also getting smaller. The role of canopy cover in reducing percentage of rain as runoff, asides of reduction of the kinetic energy of the rain as well as more rainfall is intercepted by plant canopy (Auerswald et al., 2006; Sumarni, 2006; Zhou et al., 2008; Panagos et al., 2015)

3.3. The Value Factor Crop Management and Soil Conservation (CP)

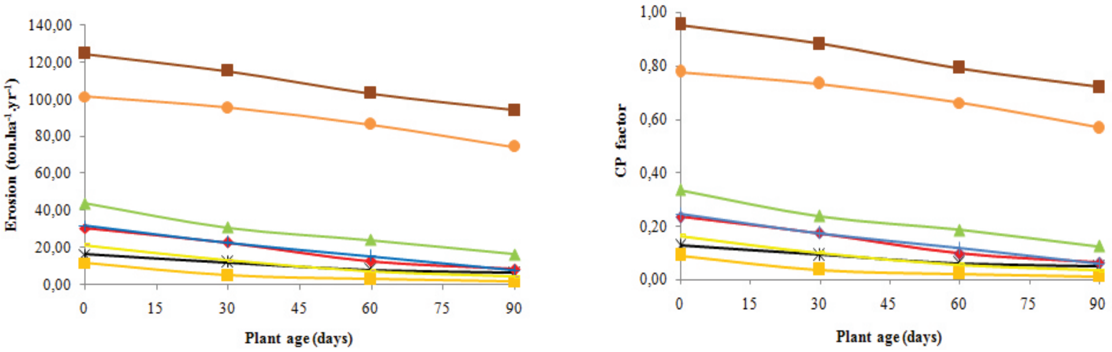
Analysis of variance results showed that treatment of soil and water conservation measures significantly affect the value of CP factor. The average of value CP factor with LSD test results ($P < 0.05$) is presented in Table 2.

Table 2. Effect of soil and water conservation measures on the value of CP factor

Treatment	CP Factor	Treatment	CP Factor
T_1K_1	0,84a	T_2K_1	0,68a
T_1K_2	0,22b	T_2K_2	0,15b
T_1K_3	0,08c	T_2K_3	0,04c
T_1K_4	0,14d	T_2K_4	0,09d

* *Figures followed by the same letters in the same column are not significantly different at 5% according to LSD*
* *Erosion on the comparator plot = 130,47 ton.ha^{-1}.yr^{-1}*

Based on LSD test results, T_2K_3 treatment provide value of CP factor significantly smaller followed by T_1K_3 treatment, T_2K_4, T_1K_4, T_2K_2, T_1K_2, T_2K_1 and T_1K_1. The Low value of CP factor found in T_2K_3 treatment due to erosion is also lower in the treatment compared to other treatments. The monthly average value of erosion and CP factor can be seen in Figure 2.



	Erosion 0	Erosion 30	Erosion 60	Erosion 90		CP 0	CP 30	CP 60	CP 90
	124,36	115,04	102,99	93,92	T1K1	0,95	0,88	0,79	0,72
	43,70	30,83	24,09	16,35	T1K2	0,33	0,24	0,18	0,13
	16,44	11,96	8,04	6,21	T1K3	0,13	0,09	0,06	0,05
	30,45	22,55	12,54	8,19	T1K4	0,23	0,17	0,10	0,06
	101,38	95,31	86,32	74,03	T2K1	0,78	0,73	0,66	0,57
	31,87	22,53	15,24	7,53	T2K2	0,24	0,17	0,12	0,06
	11,73	4,80	2,87	1,48	T2K3	0,09	0,04	0,02	0,01
	21,37	12,94	7,14	4,39	T2K4	0,16	0,10	0,05	0,03

Figure 2. The monthly average value of erosion and CP factor

Figure 2 shows that age of plant 0, 30, 60 and 90 days consecutive the value of CP factor has decreased, which means a role in erosion control increase or amount of soil eroded more smaller. The value of CP factor consecutive slight declined, with a look at the stages in erosion process, that treatment of cropping patterns and the ridges running the conservation function both at the stage of transporting when the rain lasts or at the stage of release of the aggregate when runoff occurs. Besides, the role of vegetation through root growth and plant canopy work increased sharply in controlling erosion and runoff.

Based on observations towards extensive of crop canopy closure in Figure 3, it appears that in first month (crop age 0-30 days) red pepper crop both monoculture and intercropping still in the early phase of growth. CP factor values are relatively higher at the start of planting, in which the closure of the crop canopy is still so low cause erosion is high. In 2 and 3 months (crop age 60 and 90 days) the value of CP factor then decreases with the increase in the crop canopy closure, so that erosion also be decrease. Crops give good influence through the soil surface protection function,scattering raindrop energy and reducing velocity of water movement over the soil surface (Gyssels et al., 2005; Nyakatawa et al., 2007; Smets et al., 2008). This means that the role of synergy between the ridges and red pepper plant in controlling of soil erosion, its value is partly determined by the role of vegetation/crop.

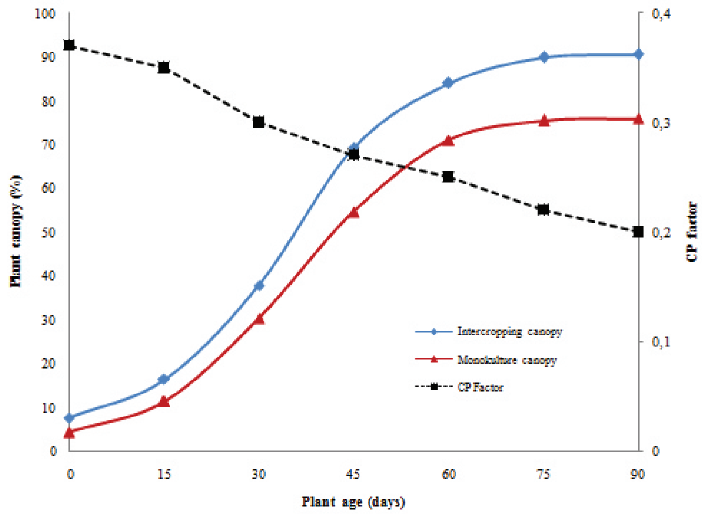


Figure 3. Relationship Between Crop Canopy Closure and Value of CP Factor

4. Conclusion

T_2K_3 treatment significantly most effective lowers the runoff amounted to 60.21 $m^3.ha^{-1}.yr^{-1}$ and erosion of 5.22 $ton.ha^{-1}.yr^{-1}$ below the value of tolerable erosion (26.96 ton.ha-1. th-1). T2K3 treatment also provide the value of CP significantly smaller in the amount of 0.04 followed by T_1K_3 treatment, T_2K_4, T_1K_4, T_2K_2, T_1K_2, T_2K_1 and T_1K_1 with successive values of 0.08, 0.09, 0.14, 0.15, 0.22, 0.68, and 0.84.

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