**CRITICAL PERIOD FOR WEED CONTROL IN SOYBEAN ON AGROFORESTRY SYSTEM WITH KAYU PUTIH**

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**ABSTRACT**

The critical period for weed control is the period in the crop growth cycle in which weeds must be controlled to prevent yield losses. This study aims to determine the critical period for weed control in soybean on agroforestry system with kayu putih. The experiment was conducted in Menggoran Forest Resort, Playen Forest Section, Gunung Kidul Regency, Special Region of Yogyakarta from February 28 until May 9, 2015. The experiment was arranged in randomized complete block design (RCBD) with single factor of treatment with three blocks as replications. The treatments were weedy periods on 0, 2, 4, 6, and 8 weeks after planting (wap) and weed-free period on 0, 2, 4, 6, and 8 wap. ANOVA was employed to analyzed the observed data with α = 5%. Whenever the significant differences among treatments were found, the post-hoc analysis was carried out by applying the Duncan Multiple Range Test (DMRT) with α = 5%. The of soil moisture content, root surface area, root length, chlorophyll content, root dry weight, shoot dry weight, dry weight of soybean seeds and weed dry weight soybean were significantly decreased by weed competition in both weedy and weed-free treatments. The effective periods of weedy time for soybean in agroforestry systems with kayu putih began at 4 wap – 6 wap.

**Keywords**: agroforestry, kayu putih, soybean, weed, weedy periods.

**INTRODUCTION**

Over the last five years, soybean production is continuously declining (BPS, 2014) due to the shortage of suitable land for crop production. One solution to tackle the aforementioned problem is the utilization of available space among forest plants, which is called agroforestry. Moreover, agroforestry becomes one of the land management systems to enhance land productivity.

The vacant space between kayu putih in a forest has a potency for growing annual crops, such as soybean and corn. Therefore, by employing alley cropping, the land productivity will be improved. The benefit of the combination between kayu putih and annual crop is the resources sharing, such as light, nutrition, and water since soybean can make use of those resources (Scholes and Walker, 1993). The establishment of agroforestry systems are able to increase land value by implementing appropriate cultivation techniques. Intercropping system becomes a valuable system in order to improve land productivity and farmer’s income per unit area in time unit. Besides, intercropping systems can provide optimum yield since it composes of several commodities that build a sustainable system (Ong and Huxley, 1996).

Nevertheless, there is a drawback of combining kayu putih and soybean, which is weed. Weed can decrease the production, which then lead to lower income of farmers. Thus, weed control is considered as a key factor for successful soybean production, and various weed management systems have been developed for that purpose (Zimdahl, 1980).

Both soybean and weed are competing for solar radiation, water and nutrients. As pointed by Moenandir (1990), the exact timing on weeding might reduce the number of weeds and lessen the competition. In plant life cycle, not at all the growth stages of a crop susceptible to weed competition. For instance, approximately around 25–33% of the life cycle of annual plant is the most critical competition period to weeds. However, there is a misinterpretation that weeding in any time during plant growth will overcome the problems of competition with weeds (Zimdahl, 1980). The critical period of weed control indicates the optimum time for applying the weed control measure (Cardoso *et al*., 2011). Hence, information on these periods can be used to improve the efficiency of weed management practices (Hall *et al*, 1992, Amador-Ramírez, 2002 and Bukun, 2004).

To gain better yield and quality, controlling weeds during the critical period of crop growth is crucial. Identification of critical period of weed control in major crops is the first step in designing a successful integrated weed management programme ([Swanton and Weise, 1991](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib31) and [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23)). Moreover, the critical period threshold model will assist the decision for the exact weeding time ([Zimdahl, 1988](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib43) and [Zimdahl, 1993](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib44)). The critical period for weed control is the length of time that the crop must be kept weed-free to prevent yield losses at a certain level ([Weaver and Tan, 1983](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib39) and [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23)). The critical period for weed control is determined by measuring the time interval between two separately measured crop-weed competition components: (i) the critical period of weed interference and (ii) the critical weed-free period ([Weaver and Tan, 1983](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib39) and [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23)). The critical period of weed interference is defined as the maximum length of time of the initial emerging weeds that can interfere crop without causing a significant yield loss ([Weaver and Tan, 1983](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib39); [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23)). The critical weed-free period, which usually less concerned, is defined as the minimum length of time required for crop to be maintained weed-free before yield loss, which is caused by late emerging weeds ([Weaver and Tan, 1983](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib39) and [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23)). From the practical point of view, crop yield losses from weed interference before or after the critical period for weed control is trivial ([Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23)).

Many studies have been conducted worldwide to determine the critical period for weed control in various crops under diverse environmental conditions ([Evans *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib11), [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23), [Van Acker *et al*., 1993](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib38), [Arslan *et al*., 2006](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib4), [Uremis *et al*., 2009](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib37), [Knezevic *et al*., 2013](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib25), [Tursun *et al*., 2015](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib34) and [Tursun *et al*., 2016](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib35)). Studies conducted in different crops under diversified environmental conditions might not be applicable to all kind of systems due to different conditions of each location, including soil and climatic conditions, as well as weed populations ([Van Acker *et al*., 1993](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib38), [Evans *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib11), [Knezevic *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib23), [Bukun, 2004](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib7), [Tursun *et al*., 2015](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib34) and [Tursun *et al*., 2016](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib35)). Hendrival *et al.,* (2014) mentioned that the critical period of soybean that grown in the post-rice cultivation field occurred on day 26after planting. For that reason, the objectives of this study were to determine the critical period for weed control in soybean on agroforestry system with kayu putih

**MATERIALS AND METHODS**

This study was carried out in Menggoran Forest Resort, Playen Forest Section, Gunung Kidul Regency, Special Province of Yogyakarta from February 28 until May 9, 2015. The experiment was arranged in Randomized Complete Block Design (RCBD) with single factor treatment and three blocks as replications. The treatments were the weedy periods in soybean, which consisted of ten levels as shown in Table 1.

Table 1.Weedy and weed-free periodsof treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Treatment | | | Remarks |
| 1 | W | - | 0 wap | Weedy until harvest |
| 2 | W | - | 2 wap | Weedy after 2 wap |
| 3 | W | - | 4 wap | Weedy after 4 wap |
| 4 | W | - | 6 wap | Weedy after 6 wap |
| 5 | W | - | 8 wap | Weedy after 8 wap |
| 6 | WF | - | 2 wap | Weed-free after 2 wap |
| 7 | WF | - | 4 wap | Weed-free after 4 wap |
| 8 | WF | - | 6 wap | Weed-free after 6 wap |
| 9 | WF | - | 8 wap | Weed-free after 8 wap |
| 10 | WF | - | 0 wap | Weed-free until harvest |

The observed variables were soil moisture content, leaf area, root surface area, root length, chlorophyll content, dry weight of soybean root, shoot, and seeds, and dry weight of weeds. All observed variables were analyzed using ANOVA and proceeded to Duncan's Multiple Range Test (DMRT) as the post-hoc analyses, with α = 5%. The simple linear regression analysis was performed to determine the relationship between weed dry weight and grain yield of soybean. The statistical analyses were done with SAS 9.0 for windows (SAS Institute, 1994).

**RESULTS AND DISCUSSION**

Based on the field observation and laboratory test, the soil in the research location was dominated by clay fraction for 75,17 %, which concluded that the soil has a clay texture. The bulk density was 1,14 g/cm3 with a slow permeability, i.e. 0 cm/hour, due to the high clay content that resulted in very low porosity. The nutrient content in the study location ranged from the very low to very high level with neutral pH.

Soil moisture affects the availability of nutrient in the soil and therefore influences the process of nutrient absorption and translocation by plants (Kramer, 1969). Table 2 shows a significant difference in the soil moisture content on the 2 wap to 10 wap. The weed-free treatment showed the highest value compared to other treatments from the beginning of the study until the harvest time.

It is assumed that the soil moisture content was relatively high since there was no weed (only soybean). In a weedy until harvest, the soil moisture content was relatively lower than other weedy treatments because soybean and weeds absorbed the water. The degree of yield decrease due to weeds interference depended on various factors, including type of weeds, weeds density and distribution, time of emergence of weeds species relative to crop as well as soil characteristics, such as,soil type, soil moisture status, pH and fertility level ([Papamichail *et al*., 2002](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib29) and [Bukun, 2004](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib9)).

Table 2. Soil moisture content on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | | | Soil Moisture Content (%) | | | | |
| 2 wap | 4 wap | 6 wap | 8 wap | 10 wap |
| WF | - | 0 wap | 46,90 a | 48,89 a | 50,79 a | 47,15 a | 40,89 a |
| WF | - | 2 wap | 44,16 ab | 46,20 b | 47,21 b | 44,55 b | 38,64 ab |
| WF | - | 4 wap | 40,88 cd | 43,43 c | 45,20 c | 41,56 d | 35,46 cd |
| WF | - | 6 wap | 40,80 cd | 43,04 c | 44,80 c | 41,21 d | 35,36 cd |
| WF | - | 8 wap | 40,81 cd | 43,25 c | 44,90 c | 41,27 d | 35,37 cd |
| W | - | 0 wap | 40,85 cd | 43,43 c | 44,85 c | 41,56 d | 35,35 cd |
| W | - | 2 wap | 41,67 bcd | 44,07 bc | 45,82 bc | 42,14 cd | 36,27 bcd |
| W | - | 4 wap | 40,17 d | 42,57 c | 44,27 c | 40,67 d | 34,77 d |
| W | - | 6 wap | 41,01 cd | 44,04 bc | 45,59 bc | 42,09 cd | 35,62 cd |
| W | - | 8 wap | 43,18 bc | 45,97 b | 47,16 b | 44,09 bc | 37,68 bc |
| Average | | | 42,01 | 44,48 | 46,06 | 42,61 | 36,54 |
| CV | | | 3,64 | 2,72 | 2,06 | 3,04 | 4,00 |

Remarks :

* Number followed by same letter in same column indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap; WF: weed-free after *n* wap.

Leaf is a part of a plant that plays a significant role and as a photosynthetic organ, it highly determines the growth and development of the plant. In addition, leaf is not only able to produce photosynthate, but also other compounds such as growth hormone. One of the parameters that is very important related to the function is leaf area (Gardner *et al*., 1991).

Table 3 shows that the weedy treatment period has a significant effect on soybean leaf area at 2 wap, where the weed-free treatment after 0 wap had the highest leaf area compared to the weed-free treatments after 2 wap, 4 wap, 6 wap and 8 wap. It was also significantly different from the weed treatments after 0 wap, 2 wap, 4 wap, 6 wap and 8 wap. However, at the age of 4, 6, 8, and 10 wap, each treatment had no significant effect on the leaves area of the soybean. There is no critical period for leaf area because not significant different between weedy and weed-free.

Table 3. Leaf area on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | | | Leaf Area (cm2) | | | | |
| 2 wap | 4 wap | 6 wap | 8 wap | 10 wap |
| WF | - | 0 wap | 168,73 a | 610,0 a | 854,0 a | 1164,5 a | 996,3 a |
| WF | - | 2 wap | 143,69 ab | 556,7 a | 804,1 a | 1096,5 a | 950,3 a |
| WF | - | 4 wap | 80,55 b | 533,0 a | 769,8 a | 1049,8 a | 898,2 a |
| WF | - | 6 wap | 91,85 b | 688,8 a | 964,4 a | 1315,1 a | 11251 a |
| WF | - | 8 wap | 129,12 b | 494,1 a | 691,7 a | 943,2 a | 807,0 a |
| W | - | 0 wap | 90,11 b | 433,6 a | 650,3 a | 867,1 a | 780,4 a |
| W | - | 2 wap | 104,81 b | 521,8 a | 782,6 a | 1043,5 a | 939,2 a |
| W | - | 4 wap | 78,92 b | 459,6 a | 689,4 a | 919,2 a | 827,2 a |
| W | - | 6 wap | 79,37 b | 536,2 a | 804,4 a | 1072,5 a | 959,8 a |
| W | - | 8 wap | 81,74 b | 429,3 a | 633,4 a | 863,8 a | 748,6 a |
| Average | | | 101,89 | 526,30 | 764,41 | 1033,51 | 903,21 |
| CV | | | 39,55 | 30,98 | 30,46 | 30,65 | 30,32 |

Remarks :

* Number followed by same letter in same coloumn indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.

Roots are the main vegetative organ which supplies water, minerals and materials that are essential for the growth and development of the plants. Strong roots are necessary for the strength and growth of shoots. However, the roots may be damaged due to biological, physical or mechanical disruption, which result in yield decrease (Gardner *et al*., 1991).

Table 4 presents the results of ANOVA for root surface area. It is shown that the weedy period treatment had a significant effect on the root surface area when the soybean at the age of 2 to 10 wap. The weed-free treatment until the harvest time had the highest roots surface area compared to 9 weedy period treatments at all observation periods. Meanwhile, the weedy treatment until the harvest time had the lowest roots surface area at all observation periods. The critical period of roots surface area is from 4 until 6 wap.

This circumstance was due to the soybean grown on a weedy land and led to competition in nutrients, water and grow space. Therefore, this competition disrupted the plant growth, which was indicated by root that was unable to absorb nutrients and water optimally. However, when the soybean was grown on a weed-free land until the harvest, the plants was able to optimally absorb the nutrients without any competitors so that the growth was better than the other nine treatments.

Table 4. Root surface area on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | | | Root Surface Area (cm2) | | | | |
| 2 wap | 4 wap | 6 wap | 8 wap | 10 wap |
| WF | - | 0 wap | 138,95 a | 334,22 a | 555,78 a | 583,57 a | 601,08 a |
| WF | - | 2 wap | 108,09 b | 278,89 b | 493,64 ab | 515,16 ab | 525,62 ab |
| WF | - | 4 wap | 78,27 cd | 222,14 cd | 355,58 cd | 366,81 cd | 371,69 cd |
| WF | - | 6 wap | 68,28 d | 203,01 d | 313,17 de | 321,69 de | 324,94 de |
| WF | - | 8 wap | 78,20 cd | 261,93 bc | 312,80 de | 325,32 de | 333,45 cde |
| W | - | 0 wap | 38,58 e | 142,43 e | 231,51 e | 234,98 e | 237,33 e |
| W | - | 2 wap | 80,35 cd | 187,17 d | 362,93 cd | 374,41 cd | 379,47 cd |
| W | - | 4 wap | 81,76 cd | 228,81 cd | 369,42 cd | 381,31 cd | 386,59 cd |
| W | - | 6 wap | 90,78 bc | 246,15 bc | 412,69 bc | 428,18 bc | 435,57 bc |
| W | - | 8 wap | 96,76 bc | 257,60 bc | 483,80 ab | 495,90 ab | 505,81 ab |
| Average | | | 86,00 | 236,23 | 389,13 | 402,73 | 410,15 |
| CV | | | 13,21 | 9,57 | 12,91 | 13,31 | 13,54 |

Remarks :

* Number followed by same letter in same coloumn indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.

The weedy period treatment had a significant effect on the roots length of soybean as presented in Table 5. Weedy period had an effect when the soybeans were at the ages of 2, 4, 6, 8, and 10 wap. On the other hand, the weed-free treatment until the harvest had the longest roots at the age of 2 to 10 wap in comparison to the other nine treatments. In addition, the weedy treatment until the harvest had the shortest roots at all ages. It was presumably that weedy soybean could not develop its roots optimally and affected the length of roots due to the competition of growing space. The critical period of roots length area is after 8 wap.

Table 5. Root length on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | | | Root Length (m) | | | | |
| 2 wap | 4 wap | 6 wap | 8 wap | 10 wap |
| WF | - | 0 wap | 3,75 a | 6,81 a | 11,78 a | 14,85 a | 15,46 a |
| WF | - | 2 wap | 3,38 ab | 6,28 ab | 10,61 ab | 14,07 a | 14,36 a |
| WF | - | 4 wap | 2,72 cd | 5,56 bc | 9,15 bc | 12,01 ab | 12,27 ab |
| WF | - | 6 wap | 2,38 d | 5,00 cd | 7,89 c | 11,79 ab | 12,12 ab |
| WF | - | 8 wap | 2,78 cd | 6,32 ab | 8,05 c | 10,66 b | 10,79 b |
| W | - | 0 wap | 1,00 e | 1,94 e | 3,97 d | 5,28 c | 5,47 c |
| W | - | 2 wap | 2,81 bcd | 4,47 d | 9,58 bc | 12,83 ab | 13,02 ab |
| W | - | 4 wap | 2,98 cb | 5,87 b | 9,96 bc | 12,95 ab | 13,02 ab |
| W | - | 6 wap | 3,09 bc | 6,11 ab | 10,44 ab | 13,86 ab | 14,10 a |
| W | - | 8 wap | 3,13 bc | 6,13 ab | 10,34 ab | 13,58 ab | 13,76 ab |
| Average | | | 2,80 | 5,45 | 9,18 | 12,19 | 12,44 |
| CV | | | 10,85 | 7,95 | 12,35 | 14,33 | 13,72 |

Remarks :

* Number followed by same letter in same coloumn indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.

Chlorophyll is a vital element on the photosynthesis that is mostly found in leaves. The content of chlorophyll of the leaves is closely related to the greenness of the leaves. The higher chlorophyll content, the higher photosynthesis ability. According to Taiz and Zeiger (2002), chlorophyll is a complex molecule that plays a role in capturing solar energy and transferring energy and electron, which influence the process of photosynthesis and its products.

Table 6. Chlorophyll content on various weedy periods of soybean in agroforestry system with kayuputih

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment | | | Chlorophyll Content | | |
| a chlorophyll | b chlorophyll | Total chlorophyll |
| WF | - | 0 wap | 0,54 a | 0,49 a | 1,03 a |
| WF | - | 2 wap | 0,52 ab | 0,48 ab | 0,97 ab |
| WF | - | 4 wap | 0,49 bc | 0,43 b | 0,92 bc |
| WF | - | 6 wap | 0,47 c | 0,42 bc | 0,89 c |
| WF | - | 8 wap | 0,46 cd | 0,44 b | 0,91 bc |
| W | - | 0 wap | 0,43 d | 0,30 e | 0,73 e |
| W | - | 2 wap | 0,49 bc | 0,33 d | 0,82 d |
| W | - | 4 wap | 0,49 bc | 0,33 d | 0,83 d |
| W | - | 6 wap | 0,50 abc | 0,40 c | 0,90 bc |
| W | - | 8 wap | 0,52 ab | 0,42 bc | 0,94 bc |
| Average | | | 0,49 | 0,40 | 0,90 |
| CV | | | 4,41 | 4,36 | 4,26 |

Remarks:

* Number followed by same letter in same coloumn indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.

Table 6 shows that the weedy period treatment had a significant effect on the contents of chlorophyll a, chlorophyll b and the total chlorophyll of the soybean. The critical period of chlorophyll a, chlorophyll b and the total chlorophyll are consecutive 4-10 wap, 2-10 wap and 4-10 wap.

The contents of chlorophyll a, chlorophyll b and the total chlorophyll in weed-free treatment until the harvest were higher than the other weedy treatments due to the competition for nutrients, which was nitrogen that influenced the chlorophyll content. The availability of essential nutrients was one of the many site-specific factors, which directly influenced the results of crop-weed interference of a particular site ([DiTomaso, 1995](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib12), [Evans *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib13) and [Leskovsek *et al*., 2012](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib25)). Nitrogen (N) is the major nutrient that applied to increase crop yield. Nonetheless, weed demographic processes and crop-weed competitive interactions were affected by changing soil N levels ([Camara *et al*., 2003](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib11) and [Blackshaw *et al*., 2004](http://www.sciencedirect.com/science/article/pii/S0261219415300090#bib4)).

Table 7. Root dry weight content on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | | | Root Dry Weight (grams) | | | | |
| 2 wap | 4 wap | 6 wap | 8 wap | 10 wap |
| WF | - | 0 wap | 0,61 a | 0,94 a | 2,13 a | 2,72 a | 2,90 a |
| WF | - | 2 wap | 0,51 abc | 0,82 b | 1,86 ab | 2,44 ab | 2,61 ab |
| WF | - | 4 wap | 0,58 ab | 0,67 cd | 1,51 bc | 1,97 bc | 2,19 bc |
| WF | - | 6 wap | 0,28 c | 0,64 cd | 1,38 cd | 1,78 cd | 2,00 c |
| WF | - | 8 wap | 0,30 bc | 0,64 cd | 1,36 cd | 1,74 cd | 1,94 cd |
| W | - | 0 wap | 0,30 bc | 0,58 d | 1,09 d | 1,36 d | 1,51 d |
| W | - | 2 wap | 0,39 abc | 0,68 cd | 1,54 bc | 2,01 bc | 2,23 bc |
| W | - | 4 wap | 0,38 abc | 0,67 cd | 1,56 bc | 2,04 bc | 2,25 bc |
| W | - | 6 wap | 0,37 abc | 0,73 bc | 1,66 bc | 2,19 bc | 2,39 bc |
| W | - | 8 wap | 0,35 abc | 0,81 b | 1,85 ab | 2,41 ab | 2,60 ab |
| Average | | | 0,41 | 0,72 | 1,59 | 2,06 | 2,26 |
| CV | | | 36,62 | 9,24 | 12,04 | 12,35 | 11,51 |

Remarks :

* Number followed by same letter in same column indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.

Table 7 shows that the weedy period treatment had a significant effect on the dry weight of the roots of soybean at 4 until 6 wap. The weed-free treatment until the harvest produced the highest dry weight of the roots compared to the other weedy treatments. When the soybean grew normally in which without any weeds grew around, it affected the growth soybean roots. The roots of soybean were able to grow well and so were able to absorb nutrients and water optimally, when there was no competitor, i.e. weeds. Hence, the dry weight of the roots of the weed-free treatment was also higher than the soybean with weedy treatment. It was confirmed that the soybean in the weedy treatment until the harvest had the smallest roots dry weight at the age of 4 to 10 wap. The rationale for this advent was because when the plants were in a vegetative phase, the weeds caused disturbance on the photosynthesis of soybean. This disturbance led to carbohydrate production decline that mostly used for cell division, cell elongation, and the growth of roots, stems and leaves. The critical period of shoots dry weight is 4 until 6 wap.

Table 8. Shoots dry weight content on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | | | Shoots Dry Weight (grams) | | | | |
| 2 wap | 4 wap | 6 wap | 8 wap | 10 wap |
| WF | - | 0 wap | 1,01 a | 6,42 a | 9,83 a | 9,97 a | 25,65 a |
| WF | - | 2 wap | 1,00 a | 4,86 b | 7,04 b | 6,94 b | 19,00 b |
| WF | - | 4 wap | 0,96 ab | 3,57 bc | 4,74 bc | 4,83 bc | 12,74 bcd |
| WF | - | 6 wap | 0,65 a-d | 3,23 c | 4,13 c | 4,31 c | 10,90 cd |
| WF | - | 8 wap | 0,60 bcd | 3,21 c | 4,11 c | 4,29 c | 10,74 cd |
| W | - | 0 wap | 0,89 abc | 2,66 c | 3,16 c | 3,47 c | 7,61 d |
| W | - | 2 wap | 0,43 d | 3,63 bc | 4,85 bc | 4,92 bc | 13,10 bcd |
| W | - | 4 wap | 0,53 cd | 3,68 bc | 4,94 bc | 5,00 bc | 13,37 bcd |
| W | - | 6 wap | 0,54 cd | 4,03 bc | 5,54 bc | 5,53 bc | 15,09 bc |
| W | - | 8 wap | 0,80 a-d | 4,83 b | 6,98 b | 6,91 b | 18,80 b |
| Average | | | 0,74 | 4,01 | 5,53 | 5,62 | 14,70 |
| CV | | | 26,54 | 18,07 | 23,37 | 23,32 | 22,99 |

Remarks :

* Number followed by same letter in same coloumn indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.

Table 8 shows that the weedy period treatment had a significant effect on the dry weight of the shoots of soybean at all observed ages. The weed-free treatment until the harvest produced the highest dry weight of the roots compared to the other weedy treatments. Increasing periods of weed interference significantly reduced yields in three corn types in both years (Tursun *et al*., 2016). The observed that weed competition throughout the crop growing season could cause about 51–72% yield losses in field corn, 50–79% in popcorn, and 47–54% in sweet corn (Tursun *et al*., 2016). These results are similar to [Dogan et al. (2004)](http://www.sciencedirect.com/science/article/pii/S0261219416302198#bib9), who also reported lower corn yields with increasing weed interference.

Table 9. Delta of seeds dry weight per hectare decrease on various weedy periods of soybean in agroforestry system with kayu putih

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | | Weeds Dry Weight per Hectar  (ton/ha) | | Seeds Dry Weight per Hectar  (ton/ha) | | Δ Decrease of Yield a result by Weeds  (%) |
| WF | 0 wap | 0,00 | e | 2,00 | a | 0,00 |
| WF | 2 wap | 0,60 | de | 1,53 | ab | 23,50 |
| WF | 4 wap | 2,00 | cd | 1,03 | bcd | 48,50\* |
| WF | 6 wap | 3,50 | bc | 0,86 | cd | 57,00\* |
| WF | 8 wap | 5,13 | ab | 0,84 | cd | 58,00\* |
| W | 0 wap | 6,86 | a | 0,56 | d | 72,00\* |
| W | 2 wap | 1,84 | cd | 1,08 | bcd | 46,00\* |
| W | 4 wap | 1,42 | cde | 1,10 | bc | 45,00\* |
| W | 6 wap | 1,01 | de | 1,25 | bc | 37,50\* |
| W | 8 wap | 0,18 | e | 1,53 | ab | 23,50 |

Remarks :

* Number followed by same letter in same coloumn indicates not significantly different based on DMRT α 5% test.
* W: weedy after *n* wap ; WF: weed-free after *n* wap.
* (\*): Significan different with control (WF after 0 wap).

Figure 1. Regression analysis between weeds dry weight with soybean dry weight

This study showed that the longer weedy period resulted in higher diversity of species of weeds than the shorter weedy period. Figure 1 showed relationship between weed dry weight with soybean dry weight. Increaseing of weed dry weight will be decrease of soybean dry weight. The weeds that had grown before the harvest time led to lower diversity of species of weeds. The longer the weeds grew with soybean, the greater the competition that resulted in higher obstruction in the growth of the plants and lowered the product components. The competition of the weeds and soybean in the early growth period reduced the quantity of the products.

On the other hand, the competition near the harvest affected the quality of the products. Moreover, this study revealed the critical period of soybean begins at 40–70% of the soybeans age. Our results were different from the studies which were conducted by Hendrival *et al*., (2014), Zimdal (2004) and Mercado (1979). Hendrival *et al*., (2014) stated that the critical period of soybean plants against the competition with weeds occured in 2–6 wap, whereas Zimdahl (2004) stated that the critical period of a plant occurs in the 25%–33% of the first life cycle of the plant and Mercado (1979) states that the critical period of a plant ranges from 33%–50% of the age of the plant.

**CONCLUSION**

1. The of soil moisture content, root surface area, root length, chlorophyll content, root dry weight, shoot dry weight, dry weight of soybean seeds and weed dry weight soybean were significantly decreased by weed competition in both weedy and weed-free treatments.
2. The appropriate period of weeding time for soybean in agroforestry systems with kayuputih began at age 4 – 6 wap.

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