Performance of sesame (*Sesamum indicum* L.) as influenced by weed interference period in Sudan Savanna zone of Nigeria

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Abstract
Weed is one of the biotic stress factors affecting sesame yield and its control has been very difficult. Field experiment was conducted during 2017 rainy season at Teaching and Research Farm of Bayero University Kano and Guringawa, Kano State to evaluate the effects of weed interference period on growth and yield of sesame in Sudan savanna zone of Nigeria. The experiment consisted of two sets of treatments. Sesame (variety Ex-Sudan) was kept weed-free at 3, 6, 9 and 12 weeks after sowing and afterward remained weedy till harvest and the other set of weed interference periods was kept weed infested for same corresponding periods and then remained weed-free till harvest. Weed free and weedy check till harvest were included as controls. The experiments was laid out in a randomized complete block design (RCBD) replicated three times. Data were collected on weed characters, sesame growth and yield characters. Data generated were subjected to analysis of variance. Results revealed that plots kept weed infested until harvest had higher weed dry weight while weed free until harvest had the lowest in both locations. The unrestricted weed growth reduced sesame grain yield by 50% in BUK and 63% in Guringawa. Weed infestation for 3WAS and beyond resulted in significant depression of various sesame growth and yield compared with the sesame kept weed free throughout the growing period. Sesame was most critically affected by weed competition between 3 and 6 weeks after sowing. Thus, it can be recommended that sesame (Ex-sudan) should be kept weed free at 3 to 6WAS in the study areas and similar environments.

Keywords: Critical period, sesame, yield, weed competition

Introduction
Sesame is cultivated in the derived, southern and northern the country included Nasarawa, Jigawa, Kogi, Adamawa, Katsina, Targuinea savanna ecological zones of Nigeria. Sudan and Sahel Savanna ecological regions of the country are also among the important sesame production areas (Alegbejo, 2003). The major producing states inaba and Benue (Busari and Ajewole, 1993; FAO, 2002). In Africa, Nigeria is the second largest producer after Sudan and ranks seventh in the world (FAO, 2008).Nigeria has a large market potential for the production of sesame seeds for domestic purposes and export. According to Umar, (2005) Nigeria export of sesame seed also rose from 60,000 metric tons in 2000 to 200,000 metric tons in 2014/2015.

The importance of sesame lies on its high oil contents which is about 50% of the seed weight (Babaji *et al*., 2006). It is used in the preparation of weaning foods and as ingredient in soap making (Lalude and Fashaki, 2006). The marketable sesame products are the whole seeds, oil and the meal. Sesame is multipurpose crop use as raw materials in the production of confectionery and bakery products; while the oil is use in the industry to produce soap, perfume, carbon paper, pharmaceuticals and edible vegetable oils (Yol *et al*., 2010). It has high medicinal and nutritional value (Jayaweera, 1982; Rajapaksha, 1998; Anastasi *et al*., 2017). Sesame has been recognized as a good source of high-grade oil (high proportion of unsaturated fatty acids, protein content and antioxidants) (Were *et al*., 2006; Elleuch *et al*., 2007; Bahrami*et al*., 2012 Hegde, 2012).

The seed is rich in protein and the protein has disable amino acid profile with good nutritional value similar to soybean (NAERLS, 2010). The chemical composition of sesame shows that the seed is an important source of oil (44-58%), protein (18-25 %), carbohydrate (13.5%) and ash (5 %) (Borchani *et al*., 2010). The quality index for edible oil (i.e. the ratio between unsaturated fatty acid to saturated fatty acid) varies from 83-87 % in sesame seeds (Wei *et al*., 2015). Eighty per cent of sesame oil is composed of unsaturated fatty acids (Hegde, 2012). Analysis of oil composition shows sesame has 30 to 53 % oleic acid and 33 to 52 % linoleic acid as major unsaturated fatty acids (Wei *et al.*, 2015). In addition, sesame seeds are rich in minerals (calcium, iron, phosphorus) and vitamins (vitamin A, thiamine, and riboflavin) (Weiss, 2000). It provides food for human beings, cakes for livestock and poultry feeds as well as use for organic fertilizer (Ogbonna& Umar-Shaaba, 2011). The whole seed is used and may be roasted and eaten. Sesame seed is important for pregnant and lactating women because of its high protein content. Sesamum and sesamolin contents make it useful as synergist for insecticide (Reamaeker, 2001).

Despite huge potentials associated with sesame its yield has been very low due to weed interference. Its seedling growth is slow during the first four weeks making it a poor competitor at earlier stages of its growth (Bennett *et al.*, 2003).Singh *et al.* (1992) reported that weed induced reductions of sesame yield up to 85% and a need for a critical weed free period up to 50 days after sowing. Poor weed control at the early stage of the life of the crop can result in higher yield loss (Langham, 2007).Unrestricted weed growth reduces yield of sesame by 50-100 % (Hamada, 2000). Grichar *et al.* (2011) reported that, unrestricted weed growth could lead to high losses in saseme ranging from 65 to 95. Zubair*et al.* (2011) on the other hand showed that, insufficient weed control during early growth period of sesame causes yield reduction between 35.0% - 70.0%. Under weedy conditions, Eagleton *et al*. (1987) recorded a weed biomass six times that of sesame at 48 days after sowing. Longer weed interference period will have greater potential to cause yield losses than those with short interference periods (O'Donovan *et al*., 1997).

The early growth period of sesame is the most critical stage at which stress of any kind can affect the economic yields. Sesame seedlings are sensitive to weed competition during the early growth stages, therefore it must be weeded at least two times at 10-15 and 30-45 days after emergence to obtain high yield (Terefe *et al*., 2012). Researches on sesame production in Nigeria are mostly on plant population, fertilizer rate, sowing dates, row spacing and planting patterns (Ndarabu, 1997; Olowe & Busari, 2000; Malik *et al*., 2003). Research on critical period on weed interference has been very scanty. The information on how long weeds can compete with sesame after emergence without significant yield reduction is not only important but necessary. Thus, there is need to determine critical period of weed interference for sesame in Nigeria as it is a period during which weed must be controlled to avoid significant lost. With the aid of critical period for weed control (CPWC), it is possible to make decisions on the need for and timing of weed control (Abdelmarouf, 2004 and Mukhtar & Hamada, 2011). The objective of this study is to determine the critical period of weed competition in sesame.

Materials and methods

The experiment was conducted in 2017 rainy season at Teaching and Research Farm of Faculty of Agriculture, Bayero University Kano (Lat 11^o 58$'$N and Long 8^o 33$'$E), and Guringawa located in Kumbotso Local Government Area (Lat 11^{o}55$'$N and Long. 8^{o}31$'$E) all in the Sudan savanna zone of Nigeria. Sesame (variety Ex-Sudan) was kept weed-free at 3, 6, 9 and 12 weeks after sowing and afterward remained weedy till harvest and the other set of weed interference periods was kept weed infested for same corresponding periods and then remained weed-free till harvest. Weed free and weedy treatments till harvest were included as controls for comparison thus making a total number of treatments to ten (10). These were arranged in Randomized Complete Block Design (RCBD) and replicated three times. Gross plot consisted of four ridges (0.75 m in between) measuring of 3m long (3m*3m = 9m^2). The net plot consisted of two ridges of 3m long (4.5m^2). Dibbling method of sowing was adopted at 75 cm between rows and 25cm between stand giving a total stand population of 53,333 ha^{-1}. Fertilizer was applied at the rate of 200 kg of NPK (15-15-15) ha^{-1} at 2 WAS and 50kg of Urea ha^{-1} at 5 WAS.

Weeds within 1m^2 quadrant were harvested and oven dried at 65^{o}C to a constant weight at physiological maturity. The dried weeds were weight using scale (Model-CLS 500) and extrapolated to kg ha^{-1}. Weed control efficiency was calculated on dry weight basis by adopting the formula given by Das (2011), Heights of the five randomly selected tagged plants within the sampling rows were taken at physiological maturity using a meter rule and the average height were recorded. Branches of 25 randomly selected plants were counted and average recorded at physiological maturity (12 weeks after sowing).

The numbers of capsules were counted manually from 10 representative plants in each plot and the averages were recorded. They were open and the number of seeds in each pod (counted and their means were recorded. 1000 seeds from each plot were counted using seed counter and weighed using digital sensitive balance. Capsules from each net plot were threshed and weighted to determine the yield/plot and extrapolated to kg ha^{-1}.

The data generated were subjected to analysis of variance (ANOVA) using GenStat, (2013), 16th edition, where F-test is significant, mean was separated using Student-Newman-keul-Test. Logistic equation was used to determine the beginning of the Critical period for Weed Competition (CPWC) and the Gompertz equation was used to determine the end of the CPWC for acceptable yield loss levels of 5 % and 10 % (Gompertz and Rawling, 1992)

Results and discussion

Results

Weed interference period significantly affected weed dry weight and weed control efficiency at both locations (Table 1). Plots kept weed infested throughout recorded the highest weed dry weight and the lowest weed control efficiency which were statistically different from other interference periods in both locations.

Keeping sesame weed free throughout until harvest recorded the tallest plants while weed infested throughout until harvest had the shortest plant height in both locations (Table 2). At Guringawa, plots kept weed free for 9WAS and beyond significantly produced taller plant than those in their corresponding weed interference periods. Weed interference period significantly affected sesame branches in both locations. Weed free until harvest resulted in significantly higher number of branches than all other interference periods in both locations. At BUK, plots kept weed free for 3WAS were statistically at par with weed infested period for 3WAS and beyond but produced higher number of branches than those weed infested for 12WAS and weedy check and beyond (Table 2).

Period of weed interference had significant effect on number of capsule plant^{-1} at both locations. Plots kept weed free until harvest produced highest number of capsule plant^{-1} compared with weed infested throughout which has the lowest (Table 3). Plots kept weed free for 12WAS and weed infested for 3 WAS were statistically similar but produced higher number of capsule plant^{-1} compared to other weed interference periods except weed free until harvest in both locations. At BUK, plots kept weed free for 6WAS and weed infested for 9WAS were statistically at par but had lower number of capsule plant^{-1} compared to the weed free periods.

At Guringawa, plots kept weed free for 3WAS and weed infested for 3WAS and beyond were statistically the same but lower in number of capsule plant^{-1} than all other interference periods. Keeping plots weed free until harvest in both locations significantly recorded higher number of seeds per capsule than the other weed interference periods in both locations (Table 3). Similarly, plots kept weed free for 3 and 6WAS in BUK and 3WAS in Guringawa were statistically at par but produced higher number of seed capsule^{-1} than all weed infested periods except 3WAS in both locations.

Table 4 showed the effect of weed interference period on sesame seed weight (g) and seed yield (kg ha^{-1}) at BUK and Guringawa. Weed interference period significantly affected sesame seed weight at both locations. Plots kept weed free until harvest significantly produced heavier seed weight compared to weed infested throughout which had the lowest. At both locations, plots kept weed free for 6, 9 and 12WAS were statistically at par but produced heavier seed weight compared to their corresponding weed infested periods. Sesame kept weed free throughout produced significantly higher seed yield than all other interference period in both locations. Plots kept weed free for 3 and 6 WAS except at Guringawa and weed infested for 3WAS and beyond were statistically at par but produced lowest seed yield compared to plots kept weed free for 9WAS and beyond in both locations.

Figures 1 and 2 of both BUK and

Guringawa revealed that the critical time of weed removal (CTWR), based on 5% acceptable yield loss (AYL) level started in base line between 2-3 WAS. On the other hand, the critical time of weed removal started at 3-6 WAS and the critical weed free period ended at 9 WAS. The duration of critical period for weed control (CPWC) is 3-9 and 3-9 WAS for 5 and 10 % AYL, respectively. The Maximum sesame yield loss due to weed competition was 50.0 % at BUK, while that of Guringawa the result indicated that the critical time of weed removal, based on 5% yield loss level ended at 20 DAS and the critical weed free period occurred at 29 DAS. At 10 % AYL on the other hand, the critical time of weed removal ended at 3 WAS and the critical weed free period occurred at 43 DAS. The duration of critical period for weed control is 20-63 and 28-42 days for 5 and 10% AYL respectively. The Maximum sesame yield loss due to weed competition was 63% (at Guringawa).

Discussion

Lower weed control efficiency and higher weed dry weigh recorded by weed infested plots until harvest could be attributed to increased weed population with prolonged interference period which might be due to the extra time available for weeds to germinate and continue to compete with the crop as reported by Zubair*et al.* (2011). On the other hand, higher weed control efficiency and lower weed dry weight observed on weed free plots implies that long duration of weed free periods reduced the number of germinated seeds and prevent others from germinating and growth as reported by Singh *et al.*(1992) and Sootrakar *et al.* (1995). Weed dry weight increases with the increase in the duration of weed interference period and decreased with the increase in duration of weed free condition. But this scenario is on the other way round on weed control efficiency. This could be attributed to the fact that as the duration of competition was increased the weed tend to have competitive advantage over sesame possibly because the weed are more competitive than sesame. These findings are in conformity with those of Tyagi *et al*. (2013) who reported an increase in weeds dry weight with increasing weedy period as a result of prolonged weed growing period.

Initial weed infestation for 6WAS and beyond resulted in significant decrease of sesame height and number of branches. These could be attributed to the increase in competition between sesame and weeds for growth resources. The slow growth rate of sesame favours luxuriant weed growth throughout the season resulting in reduction of growth characters. Increase in weed free period was associated with lower weed emergence and greater resources uptake by sesame crop that made it to be taller with many branches. These results were in agreement with Amare (2011), Tepe *et al.* (2011) and Abdul Hakim *et al.* (2013) in studies on sesame, chickpea and rice, respectively. Baskaran and Solaimalai (2002) reported that significantly shorter plant and few branches in unweeded sesame.

Sesame yield and yield characters increases with decrease in weed interference period in both location. This indicated that sesame compete poorly with weed. Weed free plots had higher number of capsule and seed plant^{-1} as well as heavier seed weight and higher seed yield compared to other interference period. This may be due to the fact that reduced interference period were associated with more branches and leaves that continued to produce enough assimilate that support more capsules plant^{-1} seed capsule^{-1} as reported by Zubair *et al.*(2011).

In a weed free conditions there is efficient utilization of environmental resources necessary for crop growth and higher yield. Venkatakrishnan and Gnanamurthy (1998) revealed that number of capsules per plant and seed yield of sesame were maximum in weed-free plot and were at par with weed-free period till 45, 60 and 75 DAS. Parvender *et al*. (2012) reported lower number of capsules plant^{-1} and seeds capsules^{-1} as well as lighter seed weight and lower seed yield in unweeded sesame. Seed weight of sesame increased with the increasing length of weed free conditions and decreased with the increasing length of weedy conditions (Anwar *et al.,* 2014).Unrestricted weed growth reduced sesame seed yield by 50 % in BUK and 63 % in Guringawa. This could be attributed to the competition between the crop and weed for environmental resource. And because the weeds have competitive advantage over the crop, the yield of crop therefore reduced at the expense of weed. This also shows that sesame is a poor competitor with weeds. This result is in line with many research findings like Bahrami *et al*. (2012) who reported 50- 75 % reduction in sesame seed yield.These findings were in accordance with those reported by several investigators.

Bennett (1993) who identified that critical period of weed competition in sesame lies between 15 to 45 days after sowing which resulted in maximum weed biomass. Mizan (2011) reported that the critical period of weed control in sesame is between 30 to 45 days after sowing. Zuhair *et al*. (2011) who also reported that the critical period of weed control in sesame is 2 – 3 weeks after crop emergence. Duary and Hazra (2013) reported a CPWC of 19-40 DAS in the first season and 20-42 DAS in the second season. Similarly, Tyagi *et al*.(2013) found a CPWC of 15-45 DAS for sesame. Those variations could be explained by differences in environmental conditions and weed species diversity among research locations. This could be expected because crop losses due to weed competition depend on the density of weed populations as well as with the time of emergence relative to the crop, soil fertility, crop cultivar, cultural practices and environmental conditions.

Conclusion and recommendation

The result obtained from this study showed that sesame was most critically affected by weed competition between 3 and 6 weeks after sowing (WAS) and that the critical period for weed control lies between 3 and 6 WAS. There is also need to further research on more varieties so as to ascertain the critical period of weed interference of sesame in the study areas and similar environments.

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Table 1: Effect of period weed of interference in sesame on weed control efficiency (%) and dry weight (kg ha $^{-1}$) at BUK and Guringawa, during 2017 rainy season
Week After Sowing

	BUK		GURINGAWA	
	Weed control efficiency (%)	Weed dry weight	Weed control efficiency (%)	Weed dry weight
Weed free for 3 weeks	27.3d	1.9d	26.1c	67.9b
Weed free for 6 weeks	34.6d	1.7d	45.5b	65.27b
Weed free for 9 weeks	49.26d	34.33c	46.7b	50.73b
Weed free for 12 weeks	58,6c	31.67e	58.9ab	41.37d
Weed free until harvest	99.2a	0.33d	99.3a	0.77d
Weed infested for 3 weeks	96.8a	1.9d	92.6a	3.13d
Weed infested for 6 weeks	97.2a	287c	46.7b	25.73c
Weed infested for 9 weeks	43.1d	32.67c	38.6c	32.00c
Weed infested for 12 weeks	35.2d	41.33b	12.6d	72.57b
Weed infested until harvest	0.00e	56.00a	0.00e	100.23a
Level of probability	0.001	0.005	0.034	0.007
SE$\pm$	3.78	1.972	3.21	4.123

Means within a column followed by the same letters (s) are not significantly different at 5% level of probability according to the Student-Newman (SNK).

Table 2: Effect of period weed of interference in sesame on plant height (cm) and number of branches plant^{-1} at BUK and Guringawa, during 2017 rainy season

Week After Sowing	BUK		GURINGAWA	
	Plant Height	Number of ssBranches Plant^{-1}	Plant Height	Number of Branches Plant^{-1}
Weed free for 3 weeks	100.1c	4.3cde	102.6cd	3.3dc
Weed free for 6 weeks	111.3c	5.0bc	107.bcd	4.0c
Weed free for 9 weeks	113.7c	5.6bc	112.3abc	5.0bc
Weed free for 12 weeks	123.4b	6.3b	117.0ab	6.3ab
Weed free until harvest	162.5a	9.0a	122.3a	7.6a
Weed infested for 3 weeks	92.5d	4.0cde	97.6d	3.0d
Weed infested for 6 weeks	83.5d	2.6def	78.3d	3.0d
Weed infested for 9 weeks	76.7e	3.0def	63.7e	2.2d
Weed infested for 12 weeks	75.7e	2.3ef	54.5fg	2.0d
Weed infested until harvest	70.2f	3.0f	45.9g	2.0d
Level of probability	0.024	0.001	0.005	0.001
SE$\pm$	15.70	1.18	5.00	1.43

Means within a column followed by the same letters (s) are not significantly different at 5% level of probability according to the Student-Newman-keul (SNK)

Table 4: Effect of period of weed interference on seed weight(gm) and seed yield (kg ha^{-1}) at BUK and Guringawa in 2018 rainy season

Week after sowing	BUK		GURINGAWA	
	1000 Seed weight	Seed yield	1000 Seed weight	Seed yield
Weed free for 3 weeks	2.50cd	251.0c	2.83c	238.0c
Weed free for 6 weeks	3.00b	301.7c	3.07b	264.1c
Weed free for 9 weeks	2.90b	345.1b	3.13b	330.0b
Weed free for 12 weeks	3.10ab	370.2b	3.20b	335.1b
Weed free until harvest	3.30a	462.7a	3.37a	451.3a
Weed infested for 3 weeks	2.86b	269.0c	3.29b	233.0bc
Weed infested for 6 weeks	2.50cde	263.4c	2.26d	212.7bc
Weed infested for 9 weeks	2.43cde	257.5c	2.50de	208.7bc
Weed infested for 12 weeks	2.50d	252.9c	2.50e	185.9c
Weed infested until harvest	2.20d	231.6c	2.43e	169.2c
Level of probability	0.020	0.004	0.001	0.002
SE$\pm$	0.059	33.64	0.104	41.48

Means within a column followed by the same letters (s) are not significantly different at 5% level of probability according to the Student-Newman-keul (SNK)

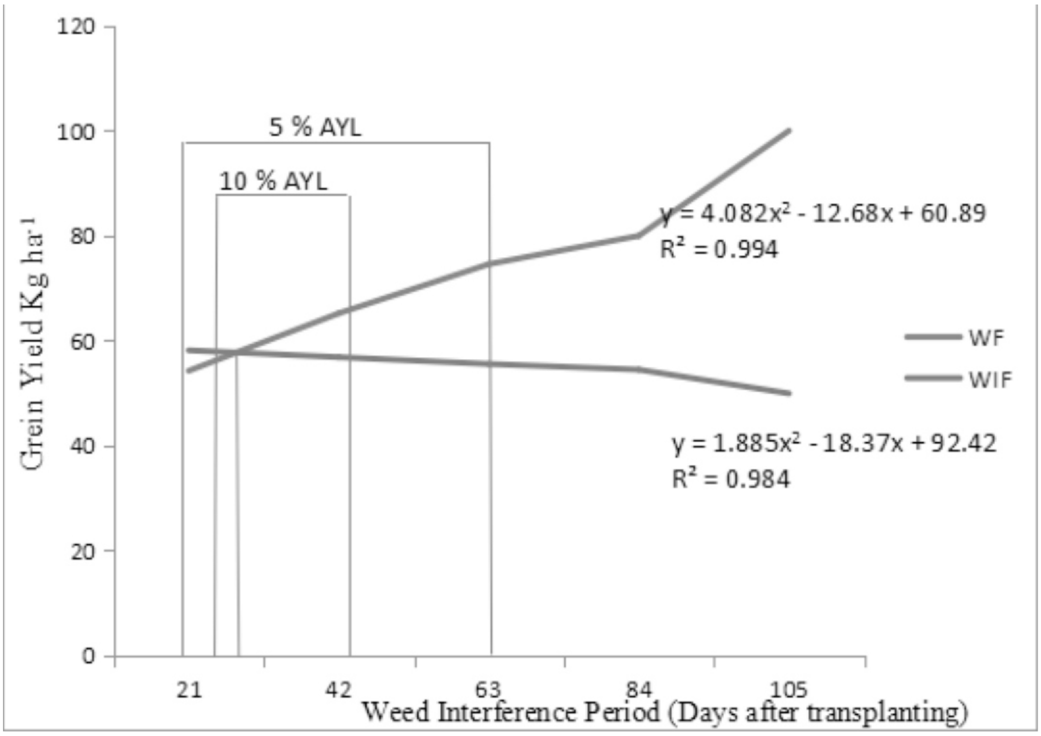

Fig 1. Critical period for weed competition at BUK.wf= weed free &wif= weed infested

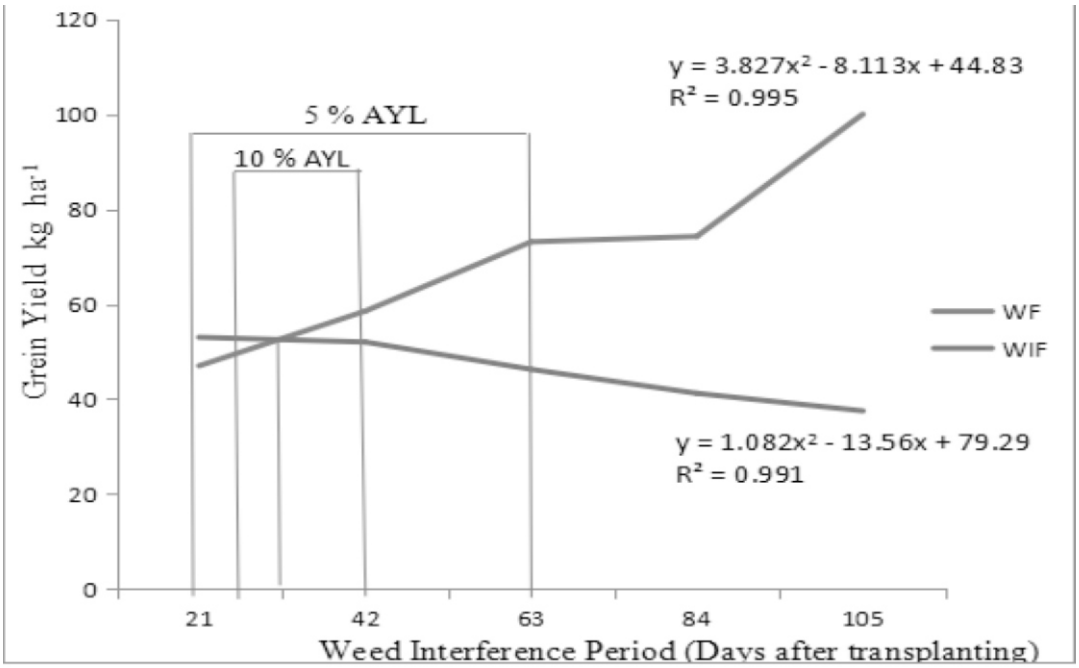

Fig 2: Critical period for weed competition in Guringawa. WF= weed free &WIF= weed infested