GROWTH, CHLOROPHYLL CONTENT AND FRUIT YIELD OF CAYENNE PEPPER AS AFFECTED BY SEEDLING AGE AND WEED INTERFERENCE PERIOD

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ABSTRACT

Field trials were conducted at the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria (70^0, 20′ N, 30^0, 23′ E) in the early and late wet seasons of 2012, to evaluate response of growth, chlorophyll content and fruit yield of cayenne pepper (*Capsicum annuum* L.) to seedling age and weed interference period. Split-plot arrangement in a randomized complete block design with three replicates was adopted in the trials. The main plot treatments were age of pepper seedlings at transplant, (four and six weeks after sowing (WAS)) while the sub-plot treatments consisted of ten periods of weed interference. Data were collected on stem girth, chlorophyll content, pepper fruit count, fruit yield and weed dry matter production. Data collected were subjected to analysis of variance and treatment means were separated using least significant difference at $p \leq 0.05$. The results showed that six-week old pepper seedling had higher chlorophyll content and pepper fruit yield. Chlorophyll content and fruit yield of pepper increased with weed free period and decreased with weed infestation period. Uncontrolled weed infestation for whole season caused 98.6% and 91.6% reduction in pepper fruit yield in the early wet and late wet season respectively. In this study, six-week old pepper seedling kept weed free for at least 12 weeks after transplanting (WAT) resulted in significantly higher pepper fruit yield than four-week old pepper seedling irrespective of period of weed interference. Hence, six-week old pepper seedling should be planted and kept weed-free for the first 12 WAT for maximum fruit at harvest.

Keywords: *Capsicum annuum*, chlorophyll content, fruit count, fruit yield, seedling age, weed free

Introduction

Pepper (*Capsicum* spp. L.) is grown in the majority of the world's countries, occupying 1.93 million hectares of cropland. Over the last 26 years, global pepper production has risen from more than 12 million tons in 1993 to more than 38 million tons in 2019. (Food and Agriculture Organization of the United Nations 2019). China is the largest producer of peppers (19 million tons), followed by Mexico (3.2 million) and Turkey (2.6 million) (FAO, 2019). Pepper is high in vitamin C, vitamin A, vitamin E, and the majority of B vitamins, particularly vitamin B5. (Howard *et al*., 2000; Ganguly *et al*., 2017). It is also very high in potassium, magnesium, iron and rich in calcium and phosphorus (Pawar *et al*., 2011). Pepper comes in a variety of species, as well as hundreds of varieties and types. They are eaten fresh as unripe fruits, ripened red or other colours, and dried. The nutritional and anti-oxidant content of various species, varieties, and consumption forms varies. (Howard *et al*., 2000). Transplanting, also known as indirect seedling, is the act of growing seedlings in a greenhouse or other controlled environment before transplanting them to their final location. The plants are grown in a controlled environment until they reach maturity or until the weather conditions are ideal. (Cavero, *et al*. 2001). Weston (1988) attributed low production in pepper to inappropriate use of cultural practices. Cultural factors such as pepper seedling age at transplantand geographical location production. Previously, Essilfie *et al*. 2017 advised farmers to transplant chilli pepper seedlings 44 days after sowing, because 44-day seedlings generated taller plants, higher vegetative biomass, and more fruits per plant. Safina-Naz *et al*. (2006) reported 100 % survival in pepper seedlings transplanted at 24 days and above after 50% nursery germination, compared to those transplanted earlier. He also stated that the well-established root system in older seedlings was capable of inducing better water absorption and translocation as well as nutrients from the rhizosphere, resulting in increased survival.

Weeds emerge fast and grow rapidly competing with the crop for growth resources viz., nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of chilli. The wide space provided in between chilli plants allows fast growth of different weed species, causing considerable reduction in yield (Peachey *et al*., 2004; Osunleti *et al*., 2021; Adeyemi *et al*., 2022). The presence of weeds reduces the photosynthetic efficiency, dry matter production and its distribution to economical parts, thereby reducing the sink capacity of the crop and resulting in poor fruit yield. The extent of reduction in fruit yield of chilli has been reported in the range of 60 to 70 per cent depending on the intensity and persistence of weed density in standing crop (Patel *et al*., 2004). Fu and Ashley (2006) observed that *Amaranthus retroflexus* L. and *Galinsoga quadriradiata* Cav. reduce pepper yield by 88 and 99 percent, respectively. *Cyperus rotundus* L., was found to reduce pepper yield by as much as 70 percent (Morales-Payan *et al*., 2003). Uncontrolled weed infestation for throughout crop life cycle had been reported to cause 91 to 98% reduction in pepper fruit yield (Osunleti *et al*., 2021a).

The effect of age of pepper seedling (Ibrahim *et al*., 2013) and period of weed interference (Adigun *et al*., 1992) on fruit yield of pepper had been exploited over the years in Sub-Sahara Africa (SSA) but there is scarcity of information on chlorophyll content. Also, the effect of age of seedling at transplanting on *Capsicum annum* L. cv. Rodo (Ibrahim *et al*., 2013), *Capsicum annum* L., Green Pepper (Akinrotimi & Aniekwe, 2018) had been exploited over the years in Sub-Sahara Africa, but there is scarcity of information on effect of age of seedling at transplanting and period of weed interference on Cayenne Pepper (*Capsicum annum* L.). The present study hypothesized that varying pepper seedling age and weed interference period will have different effect on growth, yield and chlorophyll content of cayenne pepper. Hence, the objectives of this study were to determine the effects of age of transplanting and weed interference period on growth, chlorophyll content of the leaves and cayenne pepper fruit yield in Sub-Sahara Africa.

Experimental

Description of experimental site

The experiments were conducted during the early wet season (April to October) and late wet season (June to December) of 2012 at the Teaching and Research Farm Directorate of the Federal University of Agriculture, Abeokuta, Ogun State (70^0, 20′ N, 30^0, 23′ E) in the forest savannah transition zone of South-Western Nigeria. The study site is characterized by a bimodal pattern of rainfall with 978.4 mm in the early wet season and 833.9 mm in the late wet season (Table 1). The mean monthly temperature ranged from a minimum of 25.5 ^{0}C in both seasons to maximum of 28.5 ^{0}C and 28.8 ^{0}C in the early and late wet seasons, respectively (Table 1).

TABLE 1

Mean monthly temperature, rainfall and relative humidity at the experimental site.

Month	Rainfall (mm)	Temperature (^{o}C)	Humidity (%)
January	0.00	27.0	75.2
February	67.2	28.8	70.5
March	67.7	29.1	79.3
April	80.1	28.5	79.5
May	115.3	27.7	77.3
June	225.1	26.9	78.7
July	155.4	26.0	78.7
August	36.4	25.5	80.9
September	181.4	26.2	82.6
October	184.7	27.2	76.0
November	49.6	28.2	77.5
December	1.3	28.8	81.9

Source: Federal University of Agriculture, Abeokuta Meteorological Station.

Treatments and experimental design

The experiments in both seasons comprised of two main plot treatments of age of pepper seedlings (four and six weeks). Weed interference period, consisting of two sets were assigned to the subplots. In the first set, the sub plots were kept weed free initially for 3, 6, 9 and 12 weeks after transplanting (WAT), and subsequently left weed infested until final harvest. In the second set, the subplots were left weed infested initially for 3, 6, 9 and 12 WAT, and subsequently kept weed free. Two treatments in which the subplots were left weed infested and kept weed free for whole season were included as the respective controls. All the treatments in both seasons were arranged in a split-plot design with three replications.

Nursery establishment

The nursery was located at the organic skill demonstration farm of the Federal University of Agriculture, Abeokuta in the forest savannah transition agro ecological zone (70^0, 20′ N, 30^0, 23′ E). A bed of 10 m by 2 m was made with hand hoe after the land area of the nursery had been cleared manually to remove the existing vegetation. The bed was divided into two sections, pepper seeds (cayenne peppers, which are a group of tapering, 10 –25 cm long, generally skinny, mostly red-coloured peppers, often with a curved tip) were drilled in rows in one of the sections immediately after adequate watering while the other was planted two weeks later. The nursery was hand weeded two and four weeks after establishment.

Cultural practices

In each season, the experimental site was ploughed and harrowed at two-week interval to destroy existing vegetation, destroy weed seedlings and produced a well levelled and weed-free fields. After the removal of weed debris, the land was marked out into replicates, plots and subplots. Transplanting of 6-week (average of 6 leaves at transplant) and 4-week (average of 4 leaves at transplant) old pepper seedlings into appropriate plots, according to the treatments was done at inter-row and intra-row spacings of 60 and 50 cm, respectively at one seedling per stand giving a plant population of 33,333 plants/ha. The gross and the net subplot sizes were 12 m^2 and 5.4 m^2, respectively. Hoe weeding was carried out according to the treatment requirement using West African hand hoe. Split application of fertilizer was carried out at 2 and 7 WAT. In the first and second application, compound fertilizer NPK 15-15-15 at the respective rates of 37.5 and 65 kg/ha each of N, P_2O_5 and K_2O was applied as ring around the pepper plant.

Data Collection and Analysis

Data collected on stem girth, chlorophyll content (taken in situ with Soil Plant Analyzer Development (SPAD) – 502 plus), pepper fruit count, pepper fruit yield, and weed dry matter production were subjected to analysis of variance (ANOVA) using GENSTAT procedures. Least significant difference (LSD) was used to separate significant means at a 5% level of probability.

Results

Chlorophyll Content

At 9 and 12 WAT in both seasons, the leaves of six week old pepper seedlings had higher chlorophyll content (52.0, 51.9; 49.8, 48.1 SPAD 502) than the leaves of four week old seedling (45.9, 49.8; 45.2, 46.9 SPAD 502). (Table 2). At 6 WAT in both seasons, weed free situation for various periods had higher chlorophyll content than weed infestation periods for 6 WAT and beyond. Weed infestation for 9 WAT and more resulted in the lowest chlorophyll content (31.3 to 33.5 SPAD 502) and (45.0 to 46.3 SPAD 502) in the early and late wet season, respectively. Also at 9 WAT, keeping plots weed free throughout resulted in the highest chlorophyll content (63.5 and 57.9 SPAD 502) in early and late wet season, respectively. At 12 WAT in both seasons, plots kept weed free for 9 WAT and more resulted in higher chlorophyll content than weed infestation for 6 WAT and beyond (Table 2). There was significant interaction between age of seedling at transplant and weed interference period on chlorophyll content at 6 and 9 WAT in the late wet season. At both periods, the leaves of six-week old pepper seedlings kept weed free for 6 WAT and more had higher chlorophyll content than leaves of plants kept weed infested for various periods irrespective of age of pepper seedling at transplant (Figures 1 and 2).

TABLE 2

Effects of age of seedling at transplant and weed interference period on chlorophyll content of leaves

	Chlorophyll Content of Leaves (SPAD 502)					
	6 WAT		9 WAT		12 WAT	
Treatments	Early Wet Season	Late Wet Season	Early Wet Season	Late Wet Season	Early Wet Season	Late Wet Season
Age of seedling at transplant (A)						
6 WAS	45.9	53.0	52.0	51.9	49.8	48.1
4 WAS	43.1	50.7	45.9	49.8	45.2	46.9
LSD	5.449	2.691	2.34	2.387	4.461	0.903
p value	0.159	0.067	0.008	0.06	0.047	0.035
Weed Interference Period (P)						
Weed infested for 3 WAT	51.3	50.1	56.7	50.1	55.3	49.5
Weed infested for 6 WAT	33.5	47.4	41.5	48.5	44.3	47.9
Weed infested for 9 WAT	32.6	46.6	33.5	46.3	41.9	43.5
Weed infested for 12 WAT	32.3	46.2	31.3	45.1	32.6	40.1
Weed Infested THROUGHOUT	33.3	46.3	32.6	45.0	31.6	40.3
Weed free for 3 WAT	47.0	51.5	47.4	48.3	43.6	46.1
Weed free for 6 WAT	52.3	55.2	59.9	54.5	48.5	51.0
Weed free for 9 WAT	55.2	57.1	61.2	55.9	57.0	52.1
Weed free for 12 WAT	52.9	58.4	61.9	56.9	63.3	52.3
Weed Free THROUGHOUT	54.6	59.7	63.5	57.9	56.3	52.4
LSD	3.38	2.737	6.028	1.767	7.608	1.267
p value	<.001	<.001	<.001	<.001	<.001	<.001
Interaction (AxP)	ns	3.886	ns	2.649	ns	ns

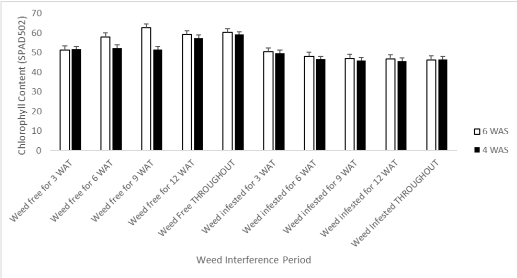

Fig. 1: Interaction between age of seedling at transplant and weed interference period on pepper chlorophyll content at 6 WAT in the late wet season.

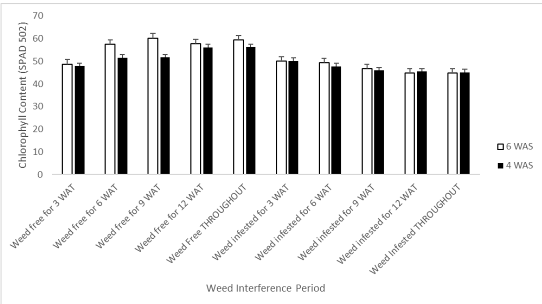

Fig. 2: Interaction between age of seedling at transplant and weed interference period on pepper chlorophyll content at 9 WAT in the late wet season.

Stem girth at harvest

In both seasons, six week old pepper seedling (10.1 mm, 11.1mm) had bigger stem than the four week old (7.7 mm, 10.6mm) (Table 3). Weed free situation for 9 WAT and beyond in both seasons resulted in bigger stems than weed infestation period for 6 WAT and beyond. In both seasons, weed infestation throughout resulted in the smallest stem (2.8 mm, 6.3 mm) while the biggest stem was recorded on plots kept weed free throughout (13.0 mm, 12.8 mm) (Table 3).

Number of fruits

In both seasons, six week old pepper seedling (675300, 802300 fruits/ha) had higher fruits count than the four week old (566200, 736600 fruits/ha) (Table 3). In both seasons, plots kept weed free for 12 WAT and beyond, and weed infestation for 3 WAT only in the late wet season resulted in the highest number of pepper fruits. In the early wet season, weed infestation for 9 WAT and beyond resulted in the lowest pepper fruit count (76700 to 151100 fruits/ha), while the lowest fruit count in the late wet season was recorded on plots left weed infested throughout (119300 fruits/ha) (Table 3). Also in the late wet season, there was significant decrease in pepper fruit count with increase in period of weed infestation.

Fruit yield

In the late wet season, six week old pepper seedling (7702 kg/ha) had higher fruit yield than the four week old (6981 kg/ha) (Table 3). Plots kept weed free for 12 WAT and more in the early wet season (12559 kg/ha to 12942 kg/ha), and weed free throughout in the late wet season (12368 kg/ha) resulted in the highest fruit yield (Table 3). In the early wet season, weed infestation for 9 WAT and beyond resulted in the lowest pepper fruit yield (177 to 623 kg/ha), while the lowest fruit yield in the late wet season was recorded on plots left weed infested throughout (1043 kg/ha) (Table 3). Also in the late wet season, there was significant decrease in pepper fruit yield with increase in period of weed infestation (11549 kg/ha to 1043 kg/ha). Conversely, there was increase in pepper fruit yield with increase in weed free period in the late wet season (5043 kg/ha to 12368 kg/ha) (Table 3). Uncontrolled weed infestation for whole season caused 98.6% and 91.6% reduction in pepper fruit yield in the early wet and late wet season respectively. There was significant interaction between age of seedling at transplant and weed interference period on pepper fruit yield in the early wet season. Six week old pepper seedling kept weed free for 12 WAT and more resulted in higher pepper fruit yield than various weed infestation periods irrespective of the seedling age (Figure 3).

TABLE 3

Effects of age of seedling at transplant and weed interference period on stem girth, number of fruit and fruit yield

	Stem Girth at Harvest (mm)		Number of Fruit (x000/ha)		Fruit yield (kg/ha)	
Treatments	Early Wet Season	Late Wet Season	Early Wet Season	Late Wet Season	Early Wet Season	Late Wet Season
Age of seedling at transplant (A)						
6 WAS	10.1	11.1	675.3	802.3	6470	7702
4 WAS	7.72	10.6	566.2	736.6	5326	6981
LSD	1.962	0.323	74.287	3.212		378.765
p value	0.035	0.021	0.024	<.001	0.09	0.015
Weed Interference Period (P)						
Weed infested for 3 WAT	11.8	12.5	850.0	1145.1	8720	11549
Weed infested for 6 WAT	6.7	10.9	388.9	835.3	3408	7791
Weed infested for 9 WAT	3.6	9.4	151.1	577.0	623	5233
Weed infested for 12 WAT	3.1	8.4	113.3	221.0	445	1819
Weed Infested THROUGHOUT	2.8	6.3	76.7	119.3	177	1043
Weed free for 3 WAT	10.7	11.1	565.6	564.6	4510	5043
Weed free for 6 WAT	12.1	12.1	802.2	860.5	7138	7835
Weed free for 9 WAT	12.4	12.6	924.4	1067.9	8462	9653
Weed free for 12 WAT	12.9	12.8	1148.9	1145.0	12942	11082
Weed Free THROUGHOUT	13.0	12.8	1186.7	1159.5	12559	12368
LSD	0.786	0.33	99.525	60.924	888.786	669.115
p value	<.001	<.001	<.001	<.001	<.001	<.001
Interaction (AxP)	ns	ns	ns	ns	1456.39	ns

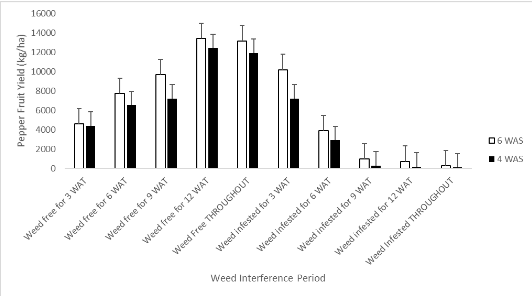

Fig. 3: Interaction between age of seedling at transplant and weed interference period on pepper fruit yield at in the early wet season.

Grasses

In both seasons, weed infestation for 12 WAT and more had higher grass weed weight than various weed free periods and those weed infested for 3, 6 and 9 WAT (Table 4). While the plots kept weed free throughout crop life cycle had the lowest grass weight (106 kg/ha, 90 kg/ha) in both seasons, the highest grass weight was recorded on plots left weed infested for 12 WAT in the early wet season (7688 kg/ha) and till throughout in the late wet season (6085 kg/ha) (Table 4).

Broadleaves

In both seasons, the weight of broadleaves reduces with increase in weed free period (3386 kg/ha to 103 kg/ha) in the early wet season and (4163 kg/ha to 154 kg/ha) in the late wet season. Conversely, the weight of broadleaves increased with increase in weed infestation period (1059kg/ha to 2880 kg/ha) in the early wet season and (1108 kg/ha to 4229 kg/ha) in the late wet season (Table 4).

Sedges

Weed infestation for 12 WAT and more resulted in higher sedge weight than various weed free period (Table 4).

TABLE 4

Effects of age of seedling at transplant and weed interference period on weed dry matter production.

Treatments	Grass weight (kg/ha)		Broadleaf weight (kg/ha)		Sedge weight (kg/ha)	
	Early Wet Season	Late Wet Season	Early Wet Season	Late Wet Season	Early Wet Season	Late Wet Season
Age of seedling at transplant (A)						
6 WAS	3835	3015	2043	2692	44	46
4 WAS	3947	3088	2003	2551	115	38
LSD	177.506	655.891	182.469	128.134	343.286	92.535
p value	0.112	0.679	0.444	0.042	0.465	0.734
Weed Interference Period (P)						
Weed infested for 3 WAT	893	747	1059	1108	2	15
Weed infested for 6 WAT	2425	1912	1766	2152	16	65
Weed infested for 9 WAT	5731	3590	2374	2891	0	41
Weed infested for 12 WAT	7688	5620	2880	4322	353	110
Weed Infested THROUGHOUT	7587	6085	2882	4229	325	116
Weed free for 3 WAT	6585	5810	3386	4163	38	20
Weed free for 6 WAT	4095	3451	3137	3843	14	18
Weed free for 9 WAT	2211	2011	2205	2671	42	15
Weed free for 12 WAT	1594	1201	444	686	6	10
Weed Free THROUGHOUT	106	90	103	154	1	9
LSD	422.662	565.914	228.126	362.134	267.942	64.294
p value	<.001	<.001	<.001	<.001	0.048	0.004
Interaction (AxP)	ns	ns	ns	ns	ns	ns

Discussion

Chlorophyll Content

Pepper plants transplanted at 6 weeks had higher chlorophyll contents than 4 weeks old seedling. The higher value with 6 week old seedling could be attributed to more leaves and broader leaves on the six week old seedling at transplant than the four week seedlings. Pepper plants kept weed-free for 9 WAT in both seasons had leaves with higher chlorophyll content compared to those left weed infested for 6 WAT and more, and those kept weed free for only 3 WAT. The high chlorophyll content on weed-free plots might be ascribed to the absence of weeds on the plots as a consequence of frequent weeding, which gives the crop an advantage over the weeds and so makes the soil nutrient accessible for the crop alone. In contrast, low chlorophyll content on weed-infested plots may be attributed to severe weed infestation on the plots, and in most cases, the weeds are taller than the crop, producing shadow and limiting the crop's access to sunlight. This results corroborate the findings of Korav *et al*., 2020 who reported that chlorophyll content measured using SPAD chlorophyll meter reading was found to decrease with increasing duration of weed interference period in groundnut. Completely weed free plots accumulated higher SPAD value than the other weed free periods and weedy plots. Hakim *et al*. (2013) reported that the chlorophyll content was found to decrease with increasing duration of weed interference period. Qiu *et al*. 2007 noted that chlorophyll content in plants is strongly influenced by environmental factors.

Pepper fruit yield

The experiment revealed that, for optimal pepper fruit yield, pepper should be kept weed free for the first twelve weeks, as this ensures a favourable environment for the crop and permits appropriate and proper exploitation of the available environmental resources. Furthermore, a weed-free environment for the first twelve weeks promotes faster canopy development, which slows growth of weed and reduces weed competition, resulting in increased fruit output. Adigun *et al*. (1992) observed in sweet pepper at Samaru that the crop required a weed-free time of 12 weeks to obtain optimal output. Initial weed infestation for 3 WAT only in the late wet season in this study resulted in similar yield to those kept weed free for 12 WAT. The reason for this result could be that the initial weed infestation for the first three weeks in the late season is not severe to have caused serious damage to the crop. Also, the ploughing and harrowing carried out in the late wet season before the establishment of the late season crop must have destroyed various flushes of weeds and consequently reduced weed competition with the crop at the early stage of development. Similarly, other reports in the Nigeria, conducted in the Northern Guinea and Sudan Savanna by several workers have revealed that weed infestation for the first 3WAT did not cause any significant depression in crop growth and yield of pepper (Lagoke et at 1988, Adigun *et al*; 1992). In both seasons, the highest fruit yield loss (5312 and 3758kg/ha) occurred on plots with a further 3 weeks infestation beyond the first three weeks (3 to 6 WAT), indicating that this is the key period when pepper is most vulnerable to weed interference. Similar studies done in the rainy season at Samaru and under irrigation in the dry season at Kadawa (Adigun *et al*. (1992) showed that the time between 3 and 6 WAT was most critical when sweet pepper initially weed infested had the greatest fruit loss. In this study, uncontrolled weed infestation for whole season caused 98.6% and 91.6% reduction in pepper fruit yield in the early wet and late wet season respectively. Motis *et al*. (2003) had earlier reported 70% pepper yield loss due to high weed infestation of nut sedge, also Osunleti *et al*. 2021a reported 98.4% yield loss in pepper as a result of uninterrupted weed growth.

Weed dry matter production

Higher grass weight, broadleaf weight and sedge weight on plots left weed infested for 12 WAT and more was as result of undisturbed weed growth on the plots during the crop life cycle. Conversely, lower grass weight, broadleaf weight and sedge weight on plots kept weed free for 12 and more was because of constant weed removal on the plots during crop life cycle with did not allow accumulation of weeds on the plots and thereby resulting in higher pepper yield. The results corroborates that of Adigun *et al* (2018) who reported higher weed cover, weeds biomass accumulation and density with increasing length of weed interference period. The maximum weed build-up (2816 and 3530kg/ha) occurred between 6 and 9 WAT in both seasons, showing that this period is particularly essential and pepper should be weeded to avoid significant yield loss. Adigun *et al*. (1992) observed that the time between 6 and 9 WAT was the most crucial, with the maximum fruit loss owing to initial weed infestation in irrigated pepper.

Conclusion

Planting 6-week-old pepper seedlings gave higher chlorophyll content, stem girth, fruit count, and yield than planting four-week-old pepper seedlings. Thus, for increased pepper fruit yield, 6-week-old pepper seedlings should be planted. Similarly, weed free situation for 12 WAT and more resulted in higher chlorophyll content, number of fruits and pepper yield than various weed infestation periods and those kept weed free for up to 9 WAT. Uncontrolled weed infestation for the whole season reduced chlorophyll content by 50.1 percent and 23.1 percent in the early and late wet seasons, respectively. Furthermore, weed infestation for the entire season reduced pepper fruit output by 98.6 percent in the early wet season and 91.6 percent in the late wet season, respectively. In this study, chlorophyll content and yield of pepper fruits rose as the weed-free situation extended. As a result, pepper should be kept weed-free for the first 12 WAT for maximum fruit at harvest.

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