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Seedbank Composition and Periodicity of Seedling Emergence at Two Locations in Southeast Nigeria

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Abstract

In a bid to improve the timing and efficacy of weed management, the population and composition of weed seedbanks, above-ground weed flora, and pattern of weed seedling emergence were investigated in fields previously under four years fallow and fields continuously cultivated for four years, at two different locations in southeast Nigeria. The fields were in Amaoba-Ime town, Abia State and Ohaji-Mgbidichi town, Imo State. The results suggest that only four years of fallow reduced the weed seedbank populations by 96 % in Amaoba-Ime and 75 % in Ohaji-Mgbidichi compared to the continuously cultivated fields. Likewise, the above-ground weed populations in the fallowed fields were 84 % and 80 % less than in continuously cropped fields in Amaoba-Ime and Ohaji-Mgbidichi, respectively. Continuous cropping favoured the spread of annuals, while perennials dominated fallowed fields. The results suggest that weed seeds emerging from four years of fallow were dormant for the first 21 days after exposure to light. Highest weed seedling emergence was observed on the 2nd and 4th weeks in the continuously cropped and fallowed fields, respectively.

Keywords: Fallowed, continuous cropping, population, emergence, locations

Introduction

To optimize weed control and advance predictions of future weed problems farmers need a better understanding of the seedbank and pattern of weed emergence in their fields(Restuccia *et al.*, 2019). This is because the competitiveness of individual weed plants is influenced by their relative time of germination. Weeds that emerge in high populations at an early stage of crop growth may pose greater problems than weeds emerging later in the season (Ekeleme, 2011). The emergency time could also affect the weed seed recruitment(Clay *et al.*, 2014) and the efficacy of the herbicides(Ekeleme, 2011; Norsworthy *et al.*, 2018). Batlla and Benech-Arnold (2007)noted that the knowledge of weed emergence patterns and proper scheduling of interventions could improve the farmer's control of the weeds, especially for species-specific management in fields with a dominant weed species. However, the influence of fallow on seedbank characteristics also complicates weed seedling emergence (Bellinder *et al.*, 2004). Rodenburg *et al.* (2022) explained that cropping patterns that influence the weed seedbank could be referred to as preventive weed management practices and may include the use of cover crops, fallow, crop rotations, mulching, tillage, and other measures that impact the recruitment of weed seeds and seedlings. This implies that expanding knowledge of the impacts of various cropping patterns on the seedbank might encourage adopting eco-friendly preventive control practices that reduce the reliance on herbicides and their associated environmental disruptions. Among these strategies, abandoning the land to natural vegetation fallow is a popular method of improving soil productivity and controlling weeds in traditional farming systems in Southeast Nigeria (Akobundu & Ekeleme, 2002; Adekiya *et al.*, 2021). Fallowing impacts the weed community by altering the population and composition of the weed seedbank (Ekeleme *et al.*, 2019). Akobundu *et al.* (1999) indicated that such alterations become significant after only three years of fallow. In the past, farmers in Southeast Nigeria left their fields to fallow for up to 15 years, but due to current pressure on land, fallow periods often do not exceed three to four years (Irokwe *et al.*, 2020). This development necessitates a study into the extent of reductions to the weed seedbank after four years of fallow. The objective of this research was to improve understanding of the weed seedbank population and composition, above-ground flora, and weed emergence patterns under different cropping systems in two locations within southeast Nigeria.

Materials and Methods

The experimental sites were the Amaoba-Ime community (05^0 29'N; $07^0$33'E) of Ikwuano Local Government Area (L.G.A.) in Abia State and the Ohaji-Mgbidichi community (05^0 19'N; 06^0 56'E) of Ohaji L.G.A. in Imo State, both in SoutheastNigeria.Ten fields of about 0.25 ha each were chosen in each community. Five of these fields had undergone fallow for four years, while the others were continually cultivated for four years. The coastal plain sands are the parent material for the soils at both locations, which lie within Southeast Nigeria's rainforest zone. However, these sites were selected based on the different types of cropping patterns practised by the farmers in both areas. At both locations, fallow lands were dominated by shrubs, including leguminous species such as *Anthonotha macrophylla* P.Beauv., *Dalinum guineense*Willd., *Daniella oliveri*(Rolfe) Hutch. & Dalziel as well as *Centrosema pubescens*Benth.and *Calapogonium mucunoides* Desv., *Commelina diffusa*Burm.f. and *Chromolaena odorata*(L.) R.M.King & H.Rob.Land preparation in both locations involves slashing and burning (for fields coming from fallow) and mound making. Mounds are soil heaps on which the desired crops are planted. The major difference in the cropping systems at both locations was that farmers at Amaoba-Ime slash the field undergrowth and prune the shrubs completely before burning, while those at Ohaji-Mgbidichi only slash the undergrowth but do not prune the shrubs at all before burning. The leaves and young twigs not cut off at Ohaji-Mgbidichi are scorched by the heat generated during the burning of the slashed undergrowth. They consequently fall as litter in the fields. Farmers at both locations also practise intercropping, but Amaoba-Ime farmers intercrop Cassava (*Manihot esculentus* Crantz) with Egusi melon (*Citrillus vulgaris* L.), Maize (*Zea mays* L.) and African yam bean [*Sphenostylis stenocarpa* (Hochst. Ex A. Rich)]. While farmers in Ohaji-Mgbidichi intercrop Cassava (*Manihot esculentus* Crantz) with only Egusi melon (*Citrillus vulgaris* L.) and Maize (*Zea mays* L.), without the African yam bean component. At both locations, fields close to the farmers' homes are continuously cultivated yearly. These are mostly home gardens in which the farmers mainly raise vegetables such as Fluted pumpkin (*Telfairia occidentalis* Hook.f.), Pepper (*Capsicum frutescens* L.), Tomatoes (*Solanum lycoperscon* L.), Okra (*Hibiscus esculentus* K.) and sometimes Cassava and Maize. The farmers often apply organic manures to help manage soil fertility in the uninterruptedly cropped fields. These soil amendments include wood ash, animal wastes, dry leaves, etc. The application of these materials is not regular but is based on when and how much is available.

Soil sampling

At the beginning of the planting season, soil samples were collected from all the fields using a soil auger of 7.4cm diameter at a depth of 0-10cm from 10 points selected at random in each field. In fallowed fields, soil sampling was done after slashing but before the fields were burnt, while in the continuously cultivated fields, soil sampling was done before the fields were cultivated. All soil samples were air-dried for three days before processing. Processing involved passing the soil through a 2mm sieve to remove stones and root fragments. Seeds that could not pass through the sieve were returned to the sieved soil. Soil samples were collected from each sieved soil and bulked according to cropping system and location. Then, samples were taken to the Soil Science laboratory of the National Root Crop Research Institute, Umudike, where the soil chemical and physical properties of the fields in both locations were determined.

Weed assessment

Three subsets of 350ml each were also taken from the sieved soils from individual fields and placed in plastic pots of 121cm^{2}top surface area. These plastic pots were placed in the greenhouse of Michael Okpara University of Agriculture, Umudike. The pots were arranged in a Completely Randomised Block Design with three replications. The pots were checked and wetted regularly. Emerging seedlings were identified, counted, and pulled out every seven days. Unidentifiable seedlings were transplanted into wooden trays in the greenhouse after their emergence date was noted. They were allowed to grow until identification was possible. The soil was turned every 21 days to encourage the germination of more seeds, and the experiment was terminated after weed seedling emergence ceased (Akobundu & Ekeleme, 2002). The population and composition of above-ground weed flora were assessed in each location before the farmers commenced weed control in the fields. This assessment consisted of two random throws of a 1m x 1m quadrant per field and subsequent counting and identifying all weed seedlings within the quadrant.

Data analysis

Data was analysed using the student T-test in GenStatat 5% level of significance (Payne, 2015). The charts were prepared using MS Excel package.

Results

Soils at both locations had low nutrient levels and similar textural classes without and after four years of fallow (Table 1). However, the fallowed fields in Amaoba-Ime had slightly higher levels of some essential nutrients such as total nitrogen, organic carbon, magnesium, and cation exchange capacity compared to Ohaji-Mgbidichi, where higher levels of only phosphorus and sodium were observed. Fallowed fields had lower weed densities compared to continuously cultivated fields at both locations (Fig. 1). Mean above-ground weed densities of 11.8 and 17.6 weeds m^{-2} were observed in previously fallowed fields in Amaoba–Ime and Ohaji-Mgbidichi, respectively while the continuously cultivated fields had 75.2 and 90.1 weed plants m^{-2}, in that order. Continuously cultivated fields in Amaoba-Ime had a mean seed population of 19,725 m^{-2} while only 838 weed seeds m^{-2} were observed in fallowed fields of the same location. Also, a weed seed population of 4697 $m^{-2 \text{ was observed}}$ in fallowed fields of Ohaji-Mgbidichi, while continuous cropping in the same location resulted in seed populations of 18555 m^{-2}. About 80% of the above-ground weed flora in the fallowed fields at both locations were perennial weed species. Only 41% and 27% of the seedbank in the fallowed fields at Amaoba-Ime and Ohaji- Mgbidichi, respectively, were annuals. Annual weeds dominated continuously cropped fields at both locations comprising 66 – 75% of the above-ground flora and weed seedbank.

No weed seedlings emerged from the seedbanks of all the fallowed fields at both locations within the first 21 days of monitoring. Similarly, whenever the soils were stirred after three weeks of monitoring (to reposition lower buried seeds), very few or no weed seedlings were observed for another 21 days. Four peaks of weed seedling emergence were observed in the fallowed fields of Ohaji-Mgbidichi and Amaoba-Ime with the highest peak occurring on the fourth week. Weed seedlings continued to emerge from the seedbanks of Ohaji-Mgbidichi and Amaoba-Ime fallowed fields until the 24th and 26th weeks, respectively. In the continuously cultivated fields at both locations, weed seedling emergence commenced from the first week (Fig. 4). Peak seedling emergence was observed in week two at both locations, followed by a sharp decrease in the 5th week and another peak in week six. Weed seedling emergence from continuously cultivated fields ceased on the 22nd and 25th weeks in seedbanks of continuously cultivated fields at Amaoba-Ime and Ohaji-Mgbidichi, respectively.

Although there were some similarities in the emergence patterns of all six weeds, they appeared to differ according to their growth forms (Fig. 5). Emergence pattern for the broadleaf weeds was similar, while some resemblance was also observed in the emergence patterns of the narrow leaf weeds. *C. diffusa, C. benghalensis*, and *C. odorata* all had five peaks of seedling emergence at Amaoba-Ime, with the highest peak occurring in week four (Fig. 5a). Seedlings of both sedges, *C. esculentus* and *M. alternifolius* began to emerge at week 11 and peaked on the 21st week (Fig. 5b). *B. lata* seedlings began to appear by week four, but the highest weed seedling emergence occurred on week 11. Emergence of the seedlings of *B. lata, C. esculentus* and *M. alternifolius* from Amaoba-Ime continued until weeks 19, 22 and 26 respectively. In Ohaji-Mgbidichi there was also some similarity in the periodicity of seedling emergence for *C. odorata, C. diffusa* and *C. benghalensis* (Fig. 5c). All three weed species had three peak emergence periods each with the highest peak at week 15 for all three weed species. However, seedlings of *C. diffusa* and *C. odorata* started to emerge by week four, while *C.benghalensis* seedlings started emerging by week 15. *C. diffusa* and *C. benghalensis* seedlings stopped emerging by week 21, while *C. odorata* seedling emergence stopped on the 15th week. In agreement with the findings at Amaoba-Ime, *M. alternifolius, B. lata* and *C. esculentus* all had peak seedling emergence on week four in Ohaji-Mgbidichi (Fig. 5d). The seedlings of *C. esculentus* all emerged by week four, *B. lata* seedling ceased to emerge by week 12, but *M. alternifolius* seedlings continued to emerge until the 24th week.

Discussion

According to ratings described byAdesemuyi (2014), the results show that soils at both locations had low nutrient levels and similar textural classes without and after four years of fallow. Although Akobundu *et al.* (1999) reported benefits from fallow after only three years, the results of this study suggest that this might not be the case in terms of soil fertility management since four years of fallow did not leave considerable improvement in soil fertility in both locations. Even though most farmers used some soil amendments in their continuously cultivated fields, nutrient levels in these fields also did not vary considerably from the fallowed fields, and between locations.

Farmers in Amaoba-Ime and Ohaji-Mgbidichi may be advised to also apply some fertilizer to fields coming out of four years fallow or adopt some other fertility management strategies which will ensure improved soil nutrient levels, with better crops and enhanced weed suppression. The inclusion of legumes in the mixture of crops sown might contribute to raising the soil fertility as appeared to be the case in Amaoba-Ime where the farmers included the legume, African yam bean, in the mixture of crops they sowed after fallow. The farmers in Ohaji-Mgbidichi are encouraged to also include legumes in their crop mixtures. The farmers in both locations may also consider using soil fertility-enhancing plants like *Chromolaena odorata* (Imiolemen *et al.*, 2012) as planted fallows instead of the natural or bush fallow they currently favour. They may also try alley farming, mixed farming, and crop rotation. The nutrients which accumulate in the leaves and twigs of shrubs during fallow may contribute to replenishing soil nutrients when they are burnt after the fallow period. However, the leaves may get blown away while the twigs may take a longer time to mineralize if they are not pruned before the fields are burnt, as was being practised in Ohaji-Mgbidichi. Therefore, the farmers at Ohaji-Mgbidichi could be encouraged to emulate the farmers at Amaoba-Ime by clearing the bush undergrowth and pruning the shrubs before they set their fields on fire after fallow.

The observations of Akobundu *et al.* (1999) seemed more obvious about the weed community. In agreement with findings by Ekeleme *et al.* (2000), the results show that shortening fallow to only four years significantly reduced above-ground weed population and weed seedbank size compared to continuously cultivated fields. These results suggest that although soil fertility might not improve significantly, four years of fallow might still yield significant weed management benefits for farmers in Amaoba-Ime and Ohaji-Mgbidichi and perhaps southeast Nigeria. The results also agree that only a minute percentage of seeds in the seedbank may germinate at a given time. Hence, seed recruitment from weeds escaping unsuccessful control measures may worsen future weed problems. However, the results suggest that management practices might influence the kind of weeds that get recruited. Perennials might dominate the fallowed fields while annuals might be the biggest concerns under continuous cropping (Ekeleme *et al.*, 2005).

The results also suggest that the weed seeds may have acquired some dormancy during fallow. But, after fallow when the field is opened or the weed seeds are exposed to light, this dormancy may be broken within three weeks. The farmers might be advised to take advantage of this dormancy period by sowing their crops early enough to ensure the crops have a head start before the weeds begin to emerge. The farmers may be discouraged from waiting for the herbage to dry or insisting on communal burning before cultivation since both practices delay land cultivation for several weeks causing the weeds to emerge soon after or before the crops are planted. The farmers should try burning the herbage as quickly as possible. Where delays are inevitable, the herbage generated from slashing the fields after fallow should not be left to dry on the fields as this process will delay cultivation. The leaves and twigs should be gathered to dry at a small part of the field or elsewhere, where they could be burnt, and the ashes should be broadcast on the fields to improve soil fertility. Farmers at both locations are also encouraged to plant fast-growing crops immediately after opening fallow fields. Fast-growing crops such as Vegetable Cowpea (*Vigna unguiculata* L. Walp) could develop a good canopy cover in three weeks, thus enhancing weed competitiveness and suppression, and reducing weeding frequency with less cost of production.

In addition to similarities in parent materials, fertility status and impact of fallowing, the results also showed that both locations had similar patterns of weed seedling emergence. The results showed that most weed seeds in the seedbank of fields previously under fallow emerged in the 4th week. Following recommendations from Masin *et al.* (2012) who suggested improving control measures by targeting the peak emergence period, the farmers might target post-emergence herbicide application to the fourth or fifth week when most weeds have newly emerged. Such timing could ensure effective early control of weeds, encourage weed suppression where fertility is well managed, and prevent the attainment of economic thresholds for most crops.*C. diffusa* and *C. benghalensis* are likely to be the most troublesome weeds in the fallowed fields of Amaoba-Ime, while *M. alternifolius* and *B. lata* infestation may attract the most significant concerns after four years of fallow at Ohaji-Mgbidichi. This is because peak seedling emergence of these four weed species occurred within the first four weeks of monitoring. This suggests that these weeds are likely to heavily infest fields at these locations early in the cropping season when cultivated crops are still young with lesser competitive abilities. The study also revealed similarities in emergence patterns of the major broadleaf weeds and between the major sedges, suggesting that weeds with like growth habits may have similar emergence patterns under the same farm management practices.

Conclusion

A shortened fallow of only four years might reduce the weed seedbank size considerably, but soil fertility might not improve significantly. Pruning the leaves and twigs of shrubs before burning, and including legumes in crop mixtures might contribute to fertility and weed management. Annual weeds might be preponderant under continuous cropping, while perennials might dominate the fallowed fields. Weed seeds in fields previously under four years fallow might observe a dormancy period of about 21 days after the fields are cleared or the soil is exposed to sunlight. *C. diffusa* and *C. benghalensis* are likely to be the most troublesome weeds in the fallowed fields of Amaoba-Ime, while *M. alternifolius* and *B. lata* infestation may attract the most significant concerns after four years of fallow at Ohaji-Mgbidichi. Weeds with like growth habits may have similar emergence patterns under the same management practices.

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Table 1: Mean values of various soil properties observed at Amaoba-Ime and Ohaji-Mgbidichi

Soil Property	Amaoba-Ime		Ohaji-Mgbidichi	
	Fallowed	**Cont. cropping**	**Fallowed**	**Cont. cropping**
Texture	Loamy sand	Loamy sand	Loamy sand	Loamy sand
pH (in water)	4.30	4.21	4.28	4.22
P mg/kg	53.1	40.2	55.7	44.2
Total N	0.11	0.12	0.05	0.09
% Organic C	1.20	1.11	0.70	1.01
Ca Cmol kg^{-1}	2.76	2.44	2.76	2.51
Mg Cmol kg^{-1}	1.52	1.30	1.12	1.45
K Cmol kg^{-1}	0.08	0.09	0.08	0.10
Na Cmol kg^{-1}	0.28	0.33	0.42	0.38
Ex acidity C mol kg^{-1}	0.34	0.38	0.33	0.35
ECEC Cmol kg^{-1}	4.98	4.41	4.69	3.95

Cont. = Continuous; Ex = Exchangeable; ECEC = Effective Cation Exchange Capacity

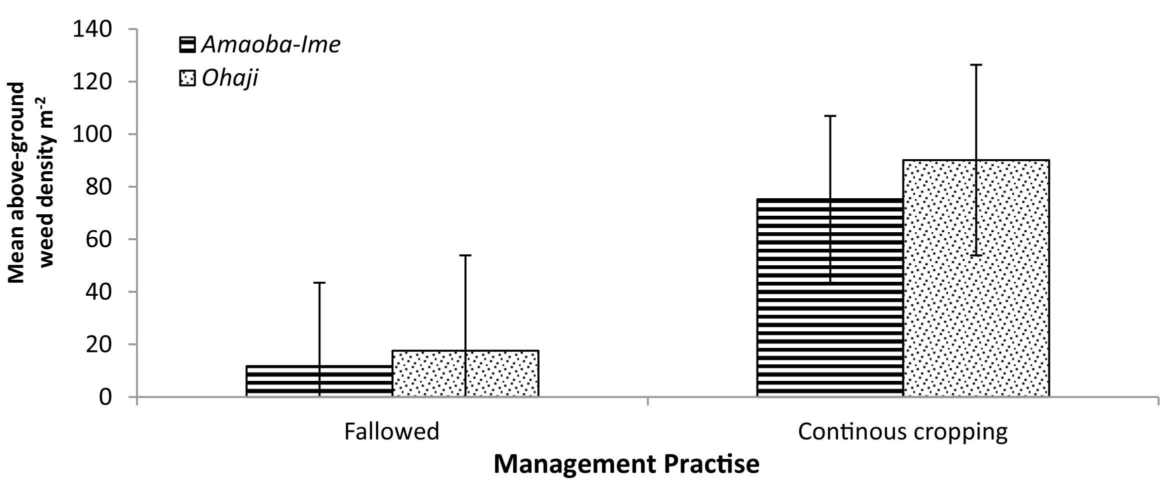

Figure 1: Mean above-ground weed densities at Amaoba-Ime and Ohaji-Mgbidichi

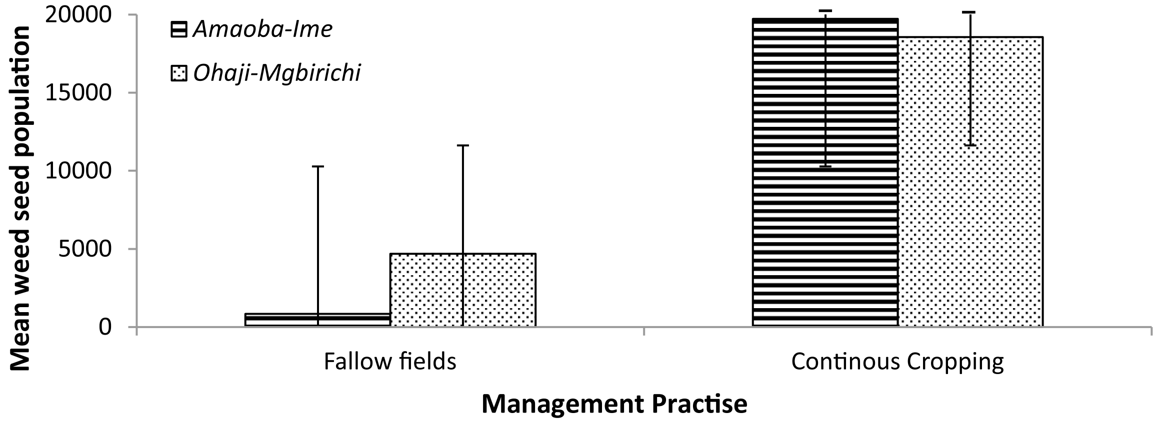

Figure 2: Mean weed seed population observed in seedbanks of fallowed and continuously cultivated fields at Amaoba-Ime and Ohaji-Mgbidichi

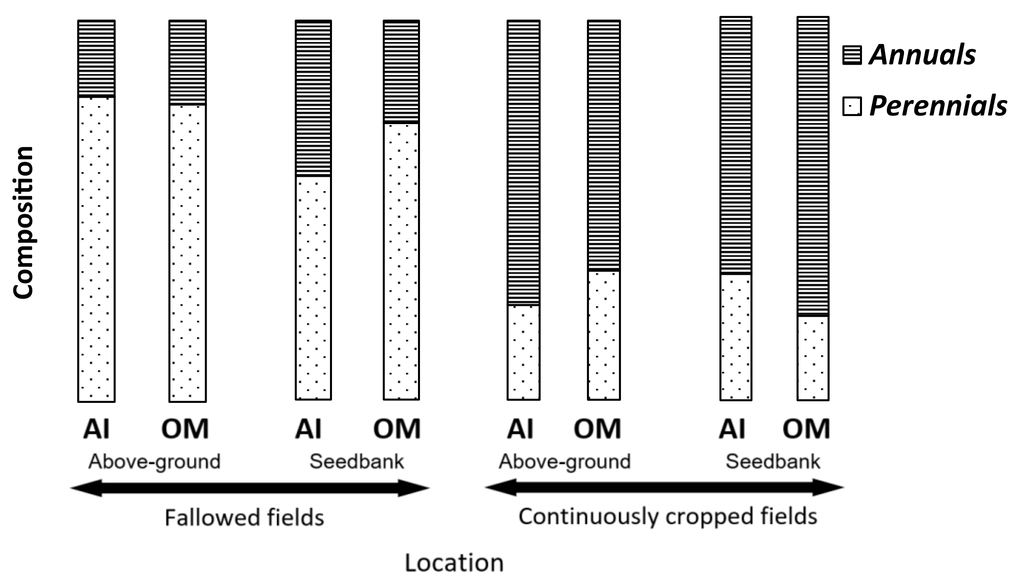

Figure 3: Percentages of annuals and perennials observed in above-ground and weed seedbanks of fields in Amaoba-Ime (**AI**) and Ohaji-Mgbidichi (**OM**)

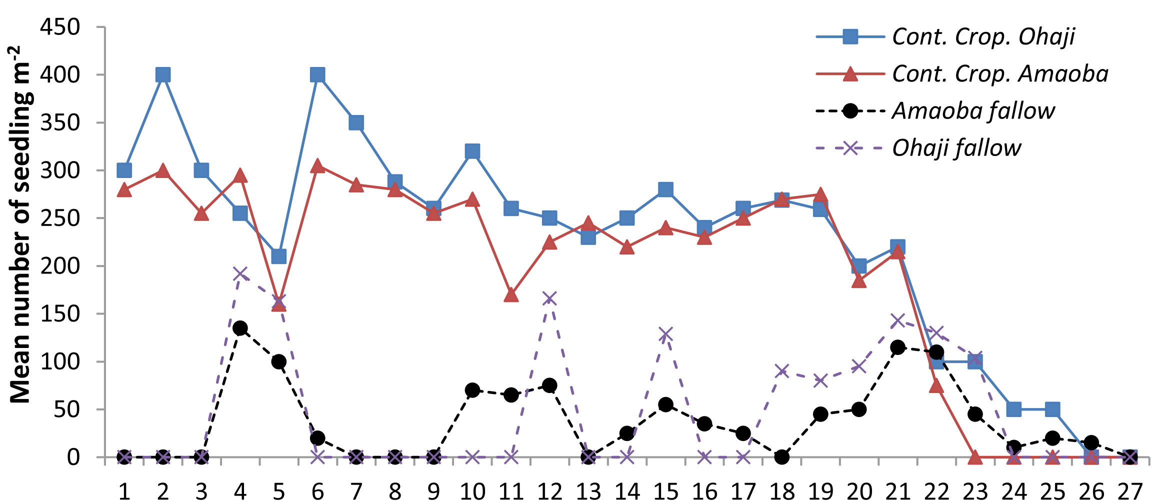

Figure 4: Periodicity of weed seedling emergence in fallowed and continuously cropped fields at Amaoba-Ime and Ohaji-Mgbidichi

Weeks of monitoring

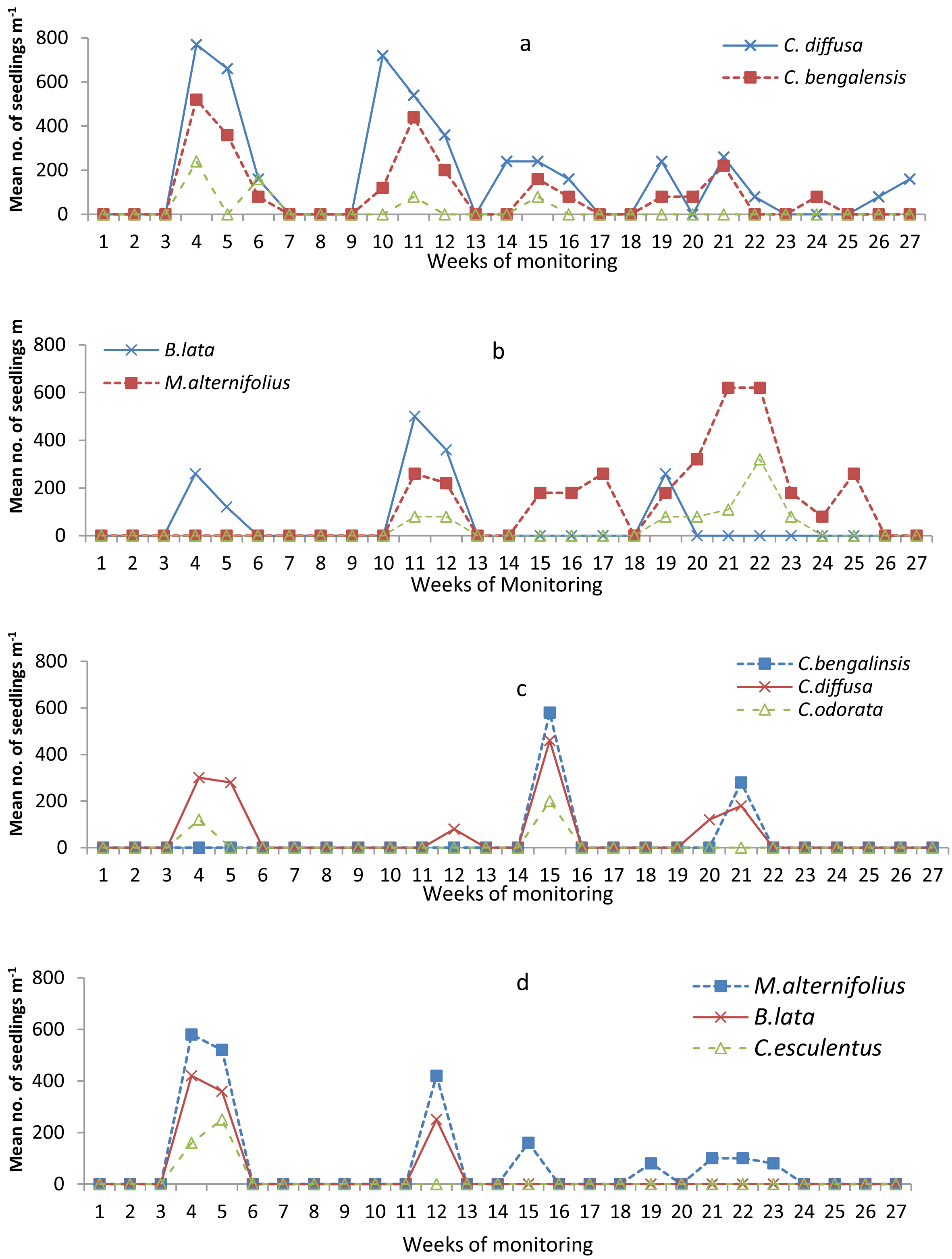

Figure 5: Weed seedling emergence pattern of *C. diffusa, C. bengalensis and C. odorata* **(a & c)** and*B. lata, M. alternifolius, C. esculentus***(b & d)** inAmaoba-Ime **(a & b)**andOhaji-Mgbidichi (**c**&**d**) after four years of fallow.