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Weed Seed Bank of Parthenium Weed (*Parthenium hysterophorus* L.) in Batang Kali, Selangor, Malaysia

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ABSTRACT

The newly detected noxious weed (*Parthenium hysterophorus* L.) is an invasive alien species in Malaysia. The degree of seriousness of the invasion of parthenium weed can be predicted from the condition of weed seed bank in the soil. A study was conducted to investigate the soil seed bank of parthenium weed at different soil depths in five different locations of Ulu Yam Baru, Batang Kali, Selangor, Malaysia. The soil samples were collected from four depths, 0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm; and five sampling areas were chosen, namely a waste disposal site, a vegetable farm, a cattle farm, a stretch of roadside and an undisturbed area of fallow land. The seeds were extracted using sieve shakers at the laboratory of Universiti Malaysia Kelantan, Jeli Campus. On average, 1321 seeds/m^2 (13.21 million seeds/ha) were found at the depth of 0-5 cm, 218 seeds/m^2 (2.18 million seeds/ha) at the depth of 5-10 cm and 121 seeds/m^2 (1.21 million seeds/ha) at the depth of 10-15 cm. No seed was found at the depth of 15-20 cm. The number of seeds varied in different locations as well. The highest number recorded, 1108 seeds/m^2 (11.08 million/ha), was from the sample taken from the waste disposal site, followed by the vegetable farm, with 514 seeds/m^2 (5.14 million seeds/ha). The maximum number of weed seeds (3547 seeds/m^2) was from the surface layer of the waste disposal site and the total number of seeds varied from 4432-396 seeds/m^2, and seeds remained within 15 cm soil depth. The collected seeds from the different soil depths showed 70.6% viability in a seed germination test. The total accumulation of 8300 seeds/m^2 (83.00 million seeds/ha) in soil of 15-cm depth in Batang Kali is a threat to the environment.

Keywords: Parthenium weed, weed seed bank, sieve shaking, soil depth

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INTRODUCTION

Parthenium weed (*Parthenium hysterophorus* L., locally called 'Rumpai Miang Mexico') is an invasive alien species in Malaysia. It is an environmental pollutant weed species that was accidentally introduced to many countries and later became a serious problem in the agriculture sector, affecting biodiversity and human and animal health (Karim, Norhafizah, Maszura, Fatimah, & Alam, 2016, pp.1006–1015). Weed is known as allergenic and lethal to cattle if consumed in large amounts. Human beings may also suffer allergies from long-time contact with this weed and from pollen intake during breathing (Karim, Norhafizah, & Maszura, 2017, pp. 175–182). There is no effective treatment for severe parthenium allergic diseases and the only thing to do would be to avoid contact with the weed and if possible, to leave the place (Anon., 2003). Cropton (2014) regarded parthenium weed as the worst weed of all on the planet.

Parthenium weed seeds are striped grey to black in colour, have a narrow diamond shape and are 1.5-2.5 mm long and flattened. The seeds are tightly grasped in a brown outer coat, which gives them a tufted triangle appearance (Lusweti, Wabuyele, Ssegawa, & Mauremootoo, 2017, p.1). The seeds of parthenium weed are very small and light with a wing-like structure that allows them to be carried easily to different places by the wind and other vectors (Navie et al., 1996). The biological characteristic contributing to the aggressiveness of parthenium weed is its special reproductive ability. Under stressed conditions, it can complete its life cycle within four to five weeks. The plant can produce four or more cohorts of seedlings in a single season and can add a lot of seeds to the soil in a year (Frew et al., 1996; Tamado, 2001). It was first detected in Batang Kali, Selangor in 2013 (Karim, 2013, p. 28) and has now spread to 10 states of Malaysia including Sabah, covering more than 70 hectares of land in Peninsular Malaysia (DOA, 2015). As it is spreading to other areas of the country, it is now necessary to implement proper measures for control of this weed (Maszura, Karim, & Norhafizah, 2016, p. 37). The Plant Biosecurity Division of the Department of Agriculture (DOA) is responsible for sustainable management of weed eradication. Currently, in Malaysia, it is a national agenda to control this invasive species (DOA, 2015).

A weed seed bank is a reserve of viable weed seeds that present on the soil surface and in soil profile that indicates the past history of weed vegetation. After viable seeds are produced, the dispersal of weed seeds takes place and is distributed over different distances via different agents e.g. birds, the wind, flood water etc. (Shabbir, 2013, p. 1). Finally, these seeds are accumulated in the soil in different layers depending on the time period and soil management activities. Seeds in the seed bank are subject to a different fate. Some seeds germinate, grow and produce more seeds and others germinate and then die, while some are attacked by predators and yet others remain dormant under certain environmental conditions (Menalled, 2008). Whyte (1994, p. 1–15) confirmed that parthenium weed seeds remain viable in the soil seed bank for four to six years. Tamado et al. (2002) stated that parthenium seeds were buried in the soil for 26 months and observed that the viability of seeds was more than 50% and the ‘half-life’ of seeds in soil was three to four years. The weed seed bank in soil is an indication of the possibility of future infestation. Destroying weed seeds from the soil seed bank is an important aspect of weed management. Information on the weed seed bank in an area helps in predicting the degree to which crop-weed competition or environmental degradation may occur in that area. Data on the soil seed bank can also be used to calculate new plant recruitment in the area. Knowledge about seed banks is, therefore, important as it provides valuable data for developing weed management strategy (Golafshan & Yasari, 2012, pp. 1-9). The objective of this study was to examine weed seed density in four different soil depths in five locations in Batang Kali, Selangor, Malaysia.

MATERIALS AND METHOD

Collection of Soil Samples

Soil samples were collected using soil core of 7.5 cm diameter from four soil depths (0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm) in five different locations (waste disposal place, vegetable farm, cattle farm, roadside and an undisturbed area of fallow land) in Batang Kali (03° 25.781’ N, 101° 39.212’ E) in the Hulu Selangor district (Figures 1 & 2). An area of 400 X 400 square metres in a parthenium-infested area was selected as the sampling area. Five locations, which were located more or less 200 metres away from each other within this area, were marked following a ‘W’ pattern. In every location, a 2 X 2 square metre area was selected during sample collection (Golafshan & Yasari, 2012). Within each sampling spot, five randomly selected sub-spots were marked for sample collection. Soil samples were collected from four soil depths in each sub-spot, and each core was separated with a differently marked plastic bag. The samples of five sub-spots from each area of each soil depth were then mixed together uniformly and from these composite samples, four working samples, which were regarded as four replications, were obtained. The experiment was laid out in randomised block design with four replications. Collected soil samples were taken to the UMK laboratory for seed analysis using a sieve shaker. The weed seeds were then extracted in the laboratory using the direct seed extraction technique (Mesgaran, Mashhadi, Zand, & Alizadeh, 2007, pp. 472–478).

Seed Extraction from Soil Samples

The collected soil samples were dried in an electric oven at 70ºC for one hour to improve dispersal of clay aggregates. The parthenium weed seeds were then extracted using a sieve shaker with sieves of different dimension e.g. 2.36 mm, 1.10 mm, 600 µm, 150 µm and 75 µm. The sieve shaker with different sizes of mesh was used to remove all unwanted plant root, debris and different sizes of other particles from the weed seeds settled at the bottom of the sieve. When the fine particles had passed through the sieves, the remainder of the sample-like sand particles, organic debris, clay soil and seeds that had not fully dispersed from the soil remained on the top sieve. The parthenium seeds were separated from other seeds. They were identified through observation by noting their small size, triangular shape and black colour. The number of seeds on the sieves was counted and recorded.

The number of seeds was estimated using the following formula:

Number of seeds/m^2 = (Number of seeds/core) x (10000/Area of core in cm^2)

The area of core = πr^2
where π is a constant and is equal to 3.14, r = d/2, where d = diameter of the core (7.5 cm)

The collected seeds were tested for viability in the laboratory using paper towels and distilled water in Petri dishes and placing the Petri dishes in a seed germinator at 27^0C for seven days. The data then collected were tabulated for statistical analyses using the Statistical Package for the Social Sciences (SPSS) (Landau & Everitt, 2004, pp. 339). Analysis of variance (ANOVA) of the data was determined to discover the significant differences between the means. The Duncan New Multiple Test was used to indicate the significant difference between the treatment means.

Figure 1. Map showing Hulu Selangor, Malaysia

Figure 2. Sampling area at Batang Kali

(*Source*: The Internet)

RESULTS AND DISCUSSION

Weed Seed Bank in Different Locations

The number of weed seeds (mean values) in the different locations of the sampling area of Ulu Yam Baru, Batang Kali are presented below (Figure 3). Figure 3 makes it obvious that the size of the weed seed bank significantly differed between the different locations. Location 1, which was near a waste disposal area, recorded the highest number of weed seeds in the soil; on average, there were 1108 seeds/ m^2 (11.08 million/ha) seeds in the soil. In an earlier survey, it was noted that the area was heavily infested with parthenium weed plants (Karim, 2013, p. 28). It is possible that local residents who had disposed of waste in the area had also thrown parthenium plants with seeds at the same time. When the seeds germinated, no one was concerned about the plant due to lack of knowledge about the dangers posed by the weed.

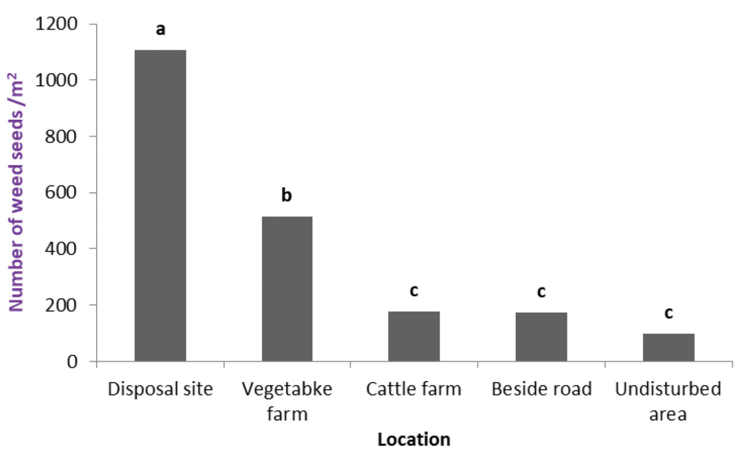

Figure 3. Number of weed seeds in different locations of the sampling area (bars bearing dissimilar letters indicate significant difference)

The plants were established slowly in the particular area, but over time, the plant community grew tremendously due to lack of disturbance. After the plant achieved maturity, it shed seeds, with each emerging as a new plant. The second location was a vegetable farm near the first location (the waste disposal site). On average, 514 seeds/m^2 (5.14 million/ha) were found in the location. This vegetable farm might have been the first source of parthenium infestation in Ulu Yam Baru. The owner of the farm might have imported the seeds from a parthenium-infested country either directly or via another seed trading company, with the parthenium seeds being carried to the farm in the form of vegetable seeds (Karim, 2013). Although the farm owner controlled the weed to some extent to reduce competition with the planted vegetables, the parthenium weed was still present. However, the size of the weed seed bank was smaller than that of the waste disposal site. However, tillage practices on the farm had enhanced the growth of the weeds.

The other three locations had fewer seeds, between 179 and 99 seeds/m^2 (1.79 million to 0.99 million/ha), due probably to the greater distance from the main source of infestation in Ulu Yam Baru. These locations were probably infested through seed dispersal from the main source of parthenium infestation at Ulu Yam Baru. Seed dispersal might have been due to wind flow, vehicles or human activities. The seeds are easily dispersed via water, wind, vehicles, machinery and other vectors (Anon., 2003). According to Noroozi, Alizadeh and Mashhadi (2012, pp. 1–6), the factors that influence the rate of dispersal might be the habitat, environmental conditions, weed species, seed characteristics, seed density and also the seed distribution pattern.

Weed Seed Bank at Different Soil Depths

It is clear from Figure 4 that the number of seeds per unit area varied significantly among the different soil depths. The highest number of parthenium seeds, 1321 seeds/m^2 (13.21 million/ha), was noted to have come from the shallower depth, 0-5cm. This was the surface layer of the bed where all the seeds fell initially. Later on, the seeds were moved to different depths due to tillage activities, the action of insects or through rain water. There are many factors that can alter the location of seed dispersal such as animal movement, social behaviour, dispersal agents, the wind, relative humidity and pattern of rainfall (Willson & Traveset, 2000, pp. 85–110). Around 60% of the total number of weed seeds were found at the soil depth of 0-5 cm, with the number of weed seeds decreasing logarithmically with soil depth (Buhler, Kohler, & Thompson, 2009, pp. 70–76).

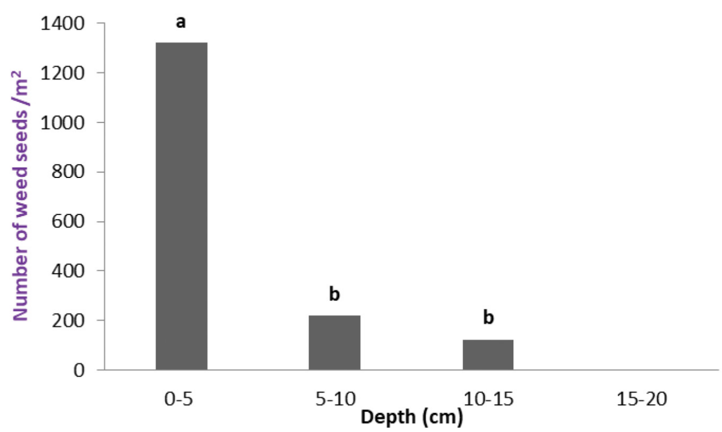

Figure 4. The number of weed seeds in different soil depths of Ulu Yam Baru, Batang Kali (bars bearing dissimilar letters indicate significant difference)

The second layer i.e. at the soil depth of 10-15 cm, contained about 17% of the total number of seeds in the first layer i.e. 5-10 cm. The number of parthenium seeds in the third layer, was around 55% of the number found in the second layer. In Ulu Yam Baru, the sampling spots, particularly the waste disposal area, was undisturbed, and only the land in the vegetable farm was disturbed to some extent. In a similar study in northern Sri Lanka, the number of parthenium seeds found in the soil depth of 5-10 cm was 5-9 seeds per square metre (Nishanthan, Sivachandiran, & Marambe, 2013, pp. 56–68). However, in this study, on average, 121 seeds/m^2 (1.21 million/ha) were found in the soil depth of 10-15 cm. It is not clear why the seeds were moved to the deeper layer of 10-15 cm depth. This might have been due to human activities on the soil like mulching, tillage and soil turning, which pushed the seeds at the top layer deep into the soil. According to Mulugeta and Stoltenberg (1997, pp. 706–715), the vertical distribution of weed seeds in the soil was influenced by tillage, with 43% to 74% of the total viable seeds found in the soil depth of 5-10 cm. The number of weed seeds found differed between the tillage systems used, decreasing with the soil depth (Auškalnienė & Auškalnis, 2009, pp. 156–161). Skuodienė, Karčauskienė, Čiuberkis, Repšienė and Ambrazaitienė (2013, pp. 25–32) stated that primary soil tillage significantly influenced soil weed seed banks. No seeds were recorded in the next soil depth of 15-20 cm, which indicated that no heavy force such as deep tillage or other activities had been exerted on the soil. This is supported by Caroca, Candia and Hinojosa (2011, pp. 40–47), who had found that non-tillage soil had a higher number of seeds in the soil surface. In Sri Lanka, no parthenium seeds were also found at this level of depth (Nishanthan et al., 2013).

The results of the viability test indicated that 70.6% of the collected seeds were viable. When the seeds were collected directly from the mature plants and then tested, after proper drying, for viability, almost 90% of the seeds had germinated. Mulugeta and Stoltenberg (1997) noted 43% to 74% viable seeds in the sample from the soil depth of 5-10 cm.

Interaction Between Location and Soil Depth

Interaction effects indicated that the number of weed seeds varied in the different soil depths from the five different locations of Ulu Yam Baru (Table 1 and 2).

Table 1
Analysis of variance showing mean effects and interaction effects of location and depth of soils on number of weed seeds extracted

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9260.50*	19	487.395	36.669	0.000
Intercept	2420.00	1	2420.000	182.069	0.000
Location	1977.50	4	494.375	37.194	0.000
Depth	3924.40	3	1308.133	98.418	0.000
Location * Depth	3358.60	12	279.883	21.057	0.000
Error	797.50	60	13.292		
Total	12478.00	80			
Corrected Total	10058.00	79			

*R squared = 0.921 (Adjusted R squared = 0.896)

Table 2
Interaction effects of soil depth and location on the number of parthenium weed seeds (No./m^2) in Ulu Yam Baru, Batang Kali

Soil depth (cm)	Location						
	1	2	3	4	5	Total	Mean
0-5	3547	1698	453	548	358	6604	1321^a
5-10	527	208	188	131	38	1092	218^b
10-15	358	152	75	18	0	603	121^b
15-20	0	0	0	0	0	0	0
Total	4432	2058	716	697	396	8300	1660
Mean	1108^A	514^B	179^C	174^C	99^C		

Locations: 1 = Disposal site, 2 = Vegetable farm, 3 = Cattle farm, 4 = Beside road, 5 = Undisturbed area. (Dissimilar superscript small letters in the vertical column of means and superscript capital letters in the horizontal row of means indicate significant difference).

Based on Table 2, the number of weed seeds in the different depths of soil was significantly different in the five locations. The maximum number of weed seeds, 3547 seeds/m^2 (35.47 million/ha), was noted at the disposal site under the surface layer (Table 2). This might be due to different environmental conditions and human activities in the area. According to Kelton, Price, Van Santen, Balkcom, Arriaga and Shaw (2011, pp. 21–30), weed seed density is influenced by the level of tillage, manure application and depth range. The sample from the seed bank in the non-tillage area showed the highest number of seeds in the 0-5 cm depth i.e. in the top soil (Swanton, Shrestha, Knezevic, Roy, & Ball-Coelho, 2000, pp. 455–457).

Ezemvelo KZN wildlife ecologist, Ian Rushworth, stated that the parthenium weed could become the biggest natural disaster ever to befall communities and their lands in KwaZulu-Natal (South Africa). Many livelihoods are threatened by this weed than by any other disaster ever experienced (Compton, 2014). Navie, McFadyen, Panetta and Adkins (1996, pp. 76–88) estimated that the soil seed bank of parthenium weed had invaded pasture fields of Australia and reported that the seed bank size of 3200 to 5100/m^2 was a dangerous level for the environment.

Navie et al. (1996) stated that the presence of 3200 to 5100 seeds/m^2 in Australia was considered a danger and that it posed a threat to the environment. Moreover, a single mature plant can produce more than 20,000 seeds (Belgeri, Sheldon, & Adkins, 2012, pp. 727–731). The weed can produce four or more cohorts of seedlings in a year. The seeds germinate in different flashes, with some remaining dormant for more than five years (Tamado et al., 2002). All these plant traits of parthenium make the problem of the quick spread of this weed more serious in Malaysia.

CONCLUSION

The discovery of 13.21 million seeds/ha of the dangerous weed, parthenium, in the surface layer and the presence of the seeds in the soil depth of 15 cm in Ulu Yam Baru, Batang Kali is alarming. The total number of seeds in the soil depth of 15 cm was 8300 seeds/m^2 (83.0 million/ha). Continuous control and monitoring over a long period of time is required to solve this problem and to make sure that all the seeds are removed from the soil. The highest number of seeds at a shallower depth, 0-5 cm, was found in the waste disposal site near a vegetable farm. The farm owner needs to be aware of this weed as it can take over cultivated land on his farm. Any parthenium found on the farm must be immediately uprooted and burnt.

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