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Parthenium hysterophorus Weed Fecundity and Seed Survival at Different Soil pH and Burial Conditions

Mohd Norsazwan Ghazali*, Uma Rani Sinniah and Muhammad Saiful Ahmad-Hamdani

Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ABSTRACT

Parthenium hysterophorus L. is regarded as one of the most invasive weed species. This study evaluated the effect of soil pH on *P. hyterophorus* weed growth and fecundity, as well as the effect of burial depths on *P. hyterophorus* seed survival and emergence. The first study evaluated five soil pH levels (acidic, sub-acidic, neutral, sub-basic, and basic) in a randomised complete block design. Seed germinability and subsequent seedling growth (height, leaf area, biomass, and seed number/plant) were evaluated. This study showed that *P. hysterophorus* seeds have a similar germination capacity under varying soil pH conditions. However, acidic soil indicated accelerated growth (25% higher biomass with 15.2% more leaf area) and fecundity (13.4% faster to enter the flowering stage at 74 days after sowing). In the second study, two factors were tested; burial depths (0.5, 5, 10, and 20 cm) being nested into seven burial durations (0, 2, 4, 6, 8, 10, and 12 months). Seed viability (final germination percentage and germination rate index), electrical conductance, and emergence percentage were assessed with the burial conditions. The results showed that only seed buried at 0.5 cm depth indicated emergence (81.3% of cumulative emergence). Forty per cent of the seeds remained viable after exhumation at 0.5–5 cm depth, while only 19–27% survived as the burial depth increased beyond 10 cm depth within 12 months. The seed remained viable for more than 12 months as a seed bank, despite faster deterioration at increasing soil depth.

Keywords: *Parthenium hysterophorus*, seed, survival

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E-mail addresses:
mohdnorsazwan@upm.edu.my (Mohd Norsazwan Ghazali)
umarani@upm.edu.my (Uma Rani Sinniah)
s_ahmad@upm.edu.my (Muhammad Saiful Ahmad Hamdani)
*Corresponding author

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INTRODUCTION

Parthenium hysterophorus L. is one of the most invasive weeds from the Asteraceae family, which has spread and distributed throughout almost the entire globe (Kaur et al., 2014; Tanveer et al., 2015). It was originally native to North and South America (Bajwa et al., 2019; Kaur et al., 2014). In Malaysia, the invasion of *P. hyterophorus* was officially reported in 2013, which had then spread to several states, mainly Kedah, Perak, Negeri Sembilan, and a few other regions within Peninsular Malaysia (Karim et al., 2018). *Parthenium hysterophorus* infestations were mainly associated with human and animal health issues such as dermatitis, asthma, bronchitis, agricultural losses, and a significant threat to biodiversity (Allan et al., 2018; Kaur et al., 2014). Significant loss of grains and forage yields by 40 to 90% was reported, as it exhibited a strong allelopathic influence, which increased its competitive advantage for soil available moisture and nutrients. These allelochemicals, such as parthenin and hysterin, were proven to inhibit agronomic crops and vegetables germination and growth (Bajwa et al., 2019; Tanveer et al., 2015). Currently, an integrative management approach is utilised to control *P. hysterophorus* infestations, including the usage of chemical herbicides (mainly clomazone, metribuzin, atrazine, glyphosate, metsulfuron methyl, butachlor, bentazone, dicamba, and metsulfuron-methyl), extracts of allelopathic plants (herbs, grasses, and trees that showed inhibitory effect on seed germination), intercropping with competitive plant species, and usage of biological control agents such as Mexican beetle, seed-feeding weevils, leaf-mining moth, and sap-feeding plant hopper (Tanveer et al., 2015).

Parthenium hysterophorus is regarded as a highly prolific seed producer as a single plant could produce up to 28,000 seeds in a life cycle (Kaur et al., 2014; Tanveer et al., 2015), which in turn contributed to a large and persistent seed bank in the soil (Navie et al., 2004; Nguyen et al., 2017). The small sized seed (2 mm in length) are easily dispersed by water and wind, but most of the spread across the regions were mainly through farm vehicles and machinery and as contaminants in the exported animals' feed as well as other crop seed lots (Kaur et al., 2014). The rapid spread of *P. hysterophorus* can be attributed to its seed production's prolific nature and its high capacity to adapt to a wide range of environmental conditions (Annapurna & Singh, 2003; Bajwa et al., 2020). Nevertheless, some variation may persist from the plant-environment interactions, ultimately influencing weed invasiveness or infestations (Vilà et al., 2021). The soil conditions, including pH, moisture levels, and temperatures, affect seed germination, seedling growth, and the buried seedbanks' longevity (Merino-Martín et al., 2017; Schwartz-Lazaro & Copes, 2019).

From a seed germination perspective, studies have shown that the pH range can promote or suppress weed seed germination. Pierce et al. (1999) suggested that *Digitaria sanguinalis* seed showed higher germination and growth under acidic and sub-acidic conditions (pH 5-6). In contrast, *Cyperus esculentus* (L.) showed that acidic pH resulted in 33% less germination in comparison to neutral-alkaline conditions. Similarly, *Sida spinosa* (L.) seed germination was highest in alkaline (more than pH 8) soil (Singh & Singh, 2009). Interestingly, for *Eleucine indica*, a pH ranging from 5 to 10 did not influence seed germination (Chauhan & Johnson, 2008). From the seedling growth aspect, the plant characteristics such as heights, leaf area or lateral spread, dry biomass, number of flowers, and pollen quality are known to be influenced by soil pH conditions (Jiang et al., 2017). Gentili et al. (2018) reported that common ragweed (*Ambrosia artemisiifolia* L.) showed a higher growth rate with earlier flowering time, as well as more inflorescences and pollen production under acidic soil conditions. Based on these studies, soil pH may greatly affect weed fecundity and spread.

As mentioned previously, one of the main characteristics contributing to a weed's prolific nature is its persistence in the soil as a seed bank. However, it is important to note that the seed's survival upon burial will be influenced by the soil's specific conditions (such as moisture and temperature). In arid, semi-arid, or temperate regions, most of the seed could exhibit long seed bank persistence due to inconsistent rainfall, which reduces germination. A tropical region such as Malaysia, where the monthly rainfall ranges from 150–350 mm (Wong et al., 2009), could be an ideal condition for germination commencement, thus accelerating the seed-to-seed cycles. Nevertheless, for the same reason, the buried seed also may experience a higher level of deterioration due to the higher moisture level, reducing the seed's long-term survival. Thus, this study aims to determine the effect of soil pH on *P. hyterophorus* weed growth and seed production and the effect of burial depths and duration on *P. hyterophorus* seed survival and emergence.

MATERIALS AND METHODS

Seed Collection

The seed samples were collected from the Department of Veterinary Services Ladang Infoternak, Sungai Siput Perak (4.7844° N, 101.1089° E). Mature seeds of *P. hysterophorus* were collected and stored in labelled paper bags. The samples were immediately transported to Seed Technology Laboratory, Universiti Putra Malaysia (UPM), and kept inside desiccators prior to further analysis.

Study Location

The study was conducted at the Field 15, Universiti Putra Malaysia (UPM).

Seedling Growth and Seed Production as Influenced by Soil PH

Site Preparation. This study was conducted inside a 2 m × 10 m double-layered shelter unit at Field 15 UPM to prevent weed infestation. An organic soil mix was used, and the desired pH range was obtained by adjusting the soil's calcium magnesium carbonate (dolomite) amount. Two kilograms (kg) of soil mix was then transferred into a 36 cm × 30 cm plastic pot for each experimental unit. Triangular spacing of 0.5 m was used to minimise light competition along with ease of access for data collection and pest control application. Each of the pots was watered with approximately 500 ml of water daily.

Experimental Design. Five levels of soil pH were evaluated (5-acidic, 6-sub-acidic, 7-neutral, 8-sub-basic, and 9-basic) in a randomised complete block design (RCBD), with four replications; a total of 20 experimental units. The pots were blocked according to the sunlight direction in the field.

Seed Germination. Four replications of 25 seeds were directly sown into the pot and monitored for 14 days. Germination was counted upon radicle emergence from the seed. The germination parameters were assessed as described by Ranal et al. (2009), including:

Final germination percentage, FGP (%) = The total seeds germinated at the end of the trial/Number of initial seeds used × 100 %

Germination index, GI = $(20 \times n_1) + (19 \times n_2) + ... + (1 \times n_{14})$; where n_1, n_2 ...n_{14} is the number of germinated seeds on the first, second, and subsequent days until the 14th day and the multipliers are weights given to the days of the germination

Mean germination time, MGT (day) = $\Sigma Fx / \Sigma F$, where F is the number of seeds germinated on day x

Germination rate index, GRI (% / day) = G1/1 + G2/2 + ... + Gi/I, where Gn is the germination percentage on day n

Time spread of germination, TSG (day) = Differences between final dan first day of germination (days)

Seedling Vigour Index, SVI = Seedling length (cm) × Germination (%)

Seedling Evaluation. Seedling growth data were collected 4, 8, 12, and 16 weeks after sowing. Four replications of three seedlings were used in all data collection. Seedling height (cm) was measured using a measuring tape. The height was taken from the base of the stem until the base of the highest fully opened leaves. Stem diameter was also recorded by using callipers. Total leaf area (cm^2) was determined using a benchtop Li-COR Area Meter (model LI-3100, USA) at Plant Physiology Laboratory, UPM. Both shoot and root were dried separately using an oven at 70°C for at least 76 hr until no change in mass was observed. The dry biomass was measured using the Mettler Toledo balance (B303-S, USA). The numbers of developing inflorescences and seeds per plant were also recorded.

Seed Survival and Seedling Emergence at Different Burial Conditions

Site Preparation and Experimental Design. A nested design was used; the first factor was burial depths (0.5, 5, 10, and 20 cm), nested into seven burial durations (0, 2, 4, 6, 8, 10, and 12 months), with three replications. The 15 cm × 15 cm burial plots were made for 20 cm depth, with 30 cm spacing between plots. A nylon mesh bag (6 cm × 8 cm) containing 100 mg seeds was laid flat onto the bottom of the plot. The hole was covered with soil until 10 cm depth before placing another bag containing seeds onto it. The process was repeated until 0.5 cm depth before the surface was lightly topped with soil and labelled accordingly. This part will provide information on the ability of the seeds to be viable under buried conditions. It was followed by a seedling emergence study using polybags to prevent the possibility of spreading the species. Three replications of 25 seeds were placed inside 20 cm x 30 cm polybags at respective burial depths, with 0.5 m spacing between rows. The soil pH was taken using Takemura Soil pH Meter DM-15 (Japan) at each data collection point. The soil moisture was determined gravimetrically by drying 100 g of soil samples at 105°C for 24 hr, as a percentage of dry weight basis. The emergence test will reveal the ability of the seeds to emerge from different depths without tillage.

Seed Germination. Three replications of 25 seeds were exhumed and germinated using the top paper method (International Seed Testing Association [ISTA], 2016). The final germination percentage and rate index were calculated as described previously (Ranal et al., 2009).

Seedling Emergence. Seedling emergence was monitored at 2 monthly intervals for 12 months. Cumulative emergence is the total number of seedlings from the soil/25 × 100 (%). At each count, emerged seedlings were removed due to limited space in the polybag.

Electrical Conductivity. Measured on three replications of 100 seed samples (approximately 50 mg) per lot weighed on an analytical balance (0.0001 g) and soaked in a container containing 50 ml deionised water for 24 hr at 20°C (Dutra & Vieira, 2006). Reading was made using a digitised conductivity meter. Results were expressed as $\mu S{\cdot}cm^{-1}{\cdot}g^{-1}$.

Statistical Analysis

Analysis of variance (ANOVA) was performed by Microsoft Excel and Statistical Analysis Software, SAS 9.4 (SAS Institute, USA). Significance levels of $p \leq 0.05$ were used to calculate the least significant differences (LSD) throughout this study. Pearson correlation analysis was performed among studied parameters by CORR procedure using SAS 9.4

RESULTS

Germination, Seedling Growth, and Seed Production as Influenced by Soil PH

Parthenium hysterophorus seeds showed similar final germination (FGP) values for all the soil pH, ranging from 78 to 88% (Table 1).

No mean germination time (MGT) differences were recorded, as most seeds germinated between days 6 and 7

Table 1

Final germination (FG), germination index (GI), mean germination time (MGT), germination rate index (GRI) and time spread of germination (TSG), and seedling vigour index (SVI) for seeds germinated under acidic and basic soil condition

pH	FGP (%)	GI	MGT (day)	GRI (%/day)	TSG (day)	SVI
5 (Acidic)	79.00 ± 4.43[a]	171.25 ± 9.36[abc]	6.33 ± 0.10[a]	14.56 ± 0.83[abc]	8.25 ± 0.48[a]	407.00 ± 18.62[bc]
6 (Sub-acidic)	87.00 ± 4.12[a]	184.75 ± 12.60[ab]	6.53 ± 0.24[a]	15.76 ± 1.08[ab]	6.25 ± 0.58[b]	510.90 ± 22.64[a]
7 (Neutral)	88.00 ± 2.83[a]	192.25 ± 10.08[a]	6.26 ± 0.33[a]	16.45 ± 0.92[a]	7.00 ± 0.91[ab]	508.87 ± 15.96[a]
8 (Sub-basic)	80.00 ± 5.16[a]	162.75 ± 10.61[bc]	6.82 ± 0.47[a]	13.28 ± 1.01[bc]	6.00 ± 0.87[b]	469.10 ± 32.40[ab]
9 (Basic)	78.00 ± 2.58[a]	155.50 ± 6.65[c]	7.02 ± 0.30[a]	13.25 ± 0.57[c]	8.25 ± 0.63[a]	393.07 ± 18.62[c]

Note. Mean with different letters indicate significant differences between treatments

after sowing. In terms of time spread of germination (TSG), no specific pattern was observed as the seeds germinated within 6 to 9 days after sowing. However, based on the germination index (GI) and germination rate index (GRI) values, seeds sown at pH 7 and below showed slightly higher yet significant GI (more than 171.25) and GRI (more than 14% per day). Interestingly, the seedling vigour index (SVI) was higher for soil pH ranging from 6 to 7 (more than 469 SVI), as compared to acidic (pH 5) and basic (pH 9) conditions. Within the first 8 weeks, generally, no differences were observed for all treatments, except for plant height, where acidic soil recorded a significantly higher value of 17.17 cm compared to less than 15.2 cm, as shown by another soil pH (Table 2).

Table 2

Plant height, stem diameter, florets, and seed number of Parthenium hysterophorus *seedlings under different soil pH conditions (Note: no florets and seeds were recorded in week 4 and 8)*

Time (weeks)	pH	Plant height (cm)	Stem diameter (mm)	Florets number/plant	Seed number/plant
4	5 (Acidic)	5.87 ± 0.03[a]	2.92 ± 0.19[a]	0	0
	6 (Sub-acidic)	5.14 ± 0.02[b]	2.75 ± 0.12[a]	0	0
	7 (Neutral)	5.78 ± 0.05[a]	3.08 ± 0.19[a]	0	0

Table 2 *(Continue)*

Time (weeks)	pH	Plant height (cm)	Stem diameter (mm)	Florets number/plant	Seed number/plant
	8 (Sub-basic)	5.85 ± 0.04[a]	2.91 ± 0.23[a]	0	0
	9 (Basic)	5.06 ± 0.20[b]	2.83 ± 0.17[a]	0	0
8	5 (Acidic)	17.17 ± 0.61[a]	5.75 ± 0.18[a]	0	0
	6 (Sub-acidic)	13.92 ± 0.51[bc]	5.03 ± 0.23[ab]	0	0
	7 (Neutral)	13.42 ± 0.57[c]	4.42 ± 0.23[b]	0	0
	8 (Sub-basic)	15.17 ± 0.55[b]	4.59 ± 0.19[b]	0	0
	9 (Basic)	13.42 ± 0.51[c]	5.08 ± 0.26[ab]	0	0

Note. Mean with different letters indicate significant differences between treatments

However, at 12 weeks after sowing, a marked increase in height and stem diameter was recorded by acidic soil, with 20 and 13% higher than the average treatment values, respectively. At 16 weeks, this trend continued where acidic soil showed 14 and 10% higher values of plant height and stem diameter, respectively—the average days to flowering commenced as early as 74 days after sowing for acidic soil, followed by sub-acidic and sub-basic (83 days), basic (86 days), and neutral pH soil (90 days). By the end of the 16th week, acidic soil recorded an average of 2,850 total seeds/plant, followed by neutral, sub-acidic, and sub-basic (ranged from 647–1,258 seeds/plant), and basic soil conditions (740 seeds/plant). All soil pH conditions showed similar shoot and root growth values and the total leaf areas within the first 4 weeks (Table 3). At 8 weeks after sowing, acidic soil (pH 5) indicated a significantly higher leaf area of 304.58 cm^2, whereas other treatments recorded less than 268.00 cm^2. By the 12th week, acidic soil generally showed 10% higher total biomass and 14% more leaf area values than other treatments. This pattern remained until 16 weeks after sowing, when the acidic soil showed a 25% higher overall biomass with 15.2% more leaf area values.

Table 3

Total dry biomass and leaf area of Parthenium hysterophorus *seedlings under different soil pH conditions*

		Biomass (g)		
Time (weeks)	pH	Shoot	Root	Leaf area (cm^2)
4	5 (Acidic)	0.112 ± 0.004^a	0.045 ± 0.003^b	42 ± 1.73^{ab}
	6 (Sub-acidic)	0.116 ± 0.006^a	0.047 ± 0.006^b	37.083 ± 1.83^b
	7 (Neutral)	0.113 ± 0.006^a	0.044 ± 0.002^b	43.58 ± 2.18^a
	8 (Sub-basic)	0.109 ± 0.004^a	0.038 ± 0.001^b	42.08 ± 2.06^{ab}
	9 (Basic)	0.11 ± 0.005^a	0.066 ± 0.007^a	41.583 ± 2.39^{ab}
8	5 (Acidic)	1.971 ± 0.0450^a	0.211 ± 0.007^a	304.58 ± 11.06^a
	6 (Sub-acidic)	1.545 ± 0.077^c	0.183 ± 0.015^{ab}	246.58 ± 12.42^b
	7 (Neutral)	1.774 ± 0.077^{ab}	0.16 ± 0.008^b	245.33 ± 10.59^b
	8 (Sub-basic)	1.745 ± 0.079^{bc}	0.182 ± 0.011^{ab}	267.5 ± 10.25^b
	9 (Basic)	1.792 ± 0.088^{ab}	0.199 ± 0.014^a	258.08 ± 11.04^b
12	5 (Acidic)	9.135 ± 0.189^a	4.407 ± 0.196^a	491.67 ± 10.11^a
	6 (Sub-acidic)	7.867 ± 0.341^b	3.536 ± 0.164^b	410.33 ± 18.07^b
	7 (Neutral)	8.425 ± 0.22^{ab}	3.726 ± 0.09^b	428.58 ± 13.90^b
	8 (Sub-basic)	8.327 ± 0.313^{ab}	3.765 ± 0.111^b	425.83 ± 13.54^b
	9 (Basic	7.911 ± 0.396^b	3.609 ± 0.126^b	393.5 ± 15.16^b
16	5 (Acidic)	16.975 ± 0.376^a	7.195 ± 0.153^a	792.5 ± 20.23^a
	6 (Sub-acidic)	12.467 ± 0.20^{ab}	5.392 ± 0.183^{ab}	670.58 ± 18.03^{bc}
	7 (Neutral)	13.859 ± 0.883^a	6.116 ± 0.212^{ab}	619.83 ± 19.97^c
	8 (Sub-basic)	11.601 ± 0.430^b	4.921 ± 0.153^b	684.25 ± 17.36^b
	9 (Basic)	12.551 ± 0.58^{ab}	5.299 ± 0.269^{ab}	672.5 ± 25.14^{bc}

Note. Mean with different letters indicate significant differences between treatments

Seed Survival and Seedling Emergence at Different Burial Conditions

In terms of seedling emergence, only seeds buried at 0.5 cm depth indicated emergence throughout the 12 months evaluation period. Cumulative emergence of 81.3% was recorded at 2 months after burial, with no additional emergence recorded afterwards (Figure 1).

At the beginning of this study, the FGP and GRI ranged from 81–88% and 11.4–16.4, respectively (Figure 2). As the

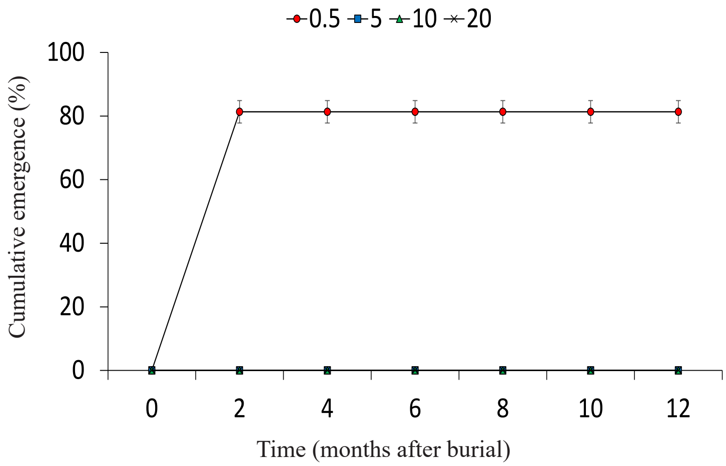

Figure 1. Percentage of seedling emergence for *Parthenium hysteropho*rus at 0.5, 5, 10, and 20 cm depths upon 12 months of burial

burial duration increased, it was evident that *P. hysterophorus* viability decreased by an average of 25.5% after 6 months and 59.2% towards the end of 12 months burial period. Higher seed viability loss was found at a deeper burial depth of 10 and 20 cm. At 10 months of burial, the differences in FGP between 0.5 and 20 cm burial was more than 25%. The seed electrical conductance values were positively correlated with burial time and depth. Initially, the seeds recorded 8–11 $\mu S \cdot cm^{-1} \cdot g^{-1}$ of EC, and the values increased up to 60 $\mu S \cdot cm^{-1} \cdot g^{-1}$ within 4 months, with no significant differences among depths. However, at 6 months onwards, higher EC values were recorded for 10 and 20 cm depths compared to less than 5 cm burial.

By 12 months after burial, 10 and 20 cm depth indicated higher than 200 $\mu S \cdot cm^{-1} \cdot g^{-1}$ of EC. The soil moisture content was positively correlated with depth, and the values remained consistent throughout the study period. Both 0.5 and 5 cm depths generally showed 3–13% soil moisture, whereas, for 10 and 20 cm depths, the values were between 7–25%. Based on the Pearson correlations values, there was a strong positive correlation between FP with GRI (R^2 = 0.914) and moderate negative correlations between FGP and GRI with EC (R^2 = 0.627 and 0.683, respectively) values. The seed EC value was found to have a moderate positive correlation (R^2 = 0.684) with the soil moisture levels.

DISCUSSION

This study showed that *P. hysterophorus* seeds had a similar capacity to germinate for most germination parameters under varying soil pH conditions, except for GI and GRI, which were found to be slightly higher when the pH was 7 or lower. Pérez-Fernández et al. (2006) suggested that pH generally had no significant effect on total

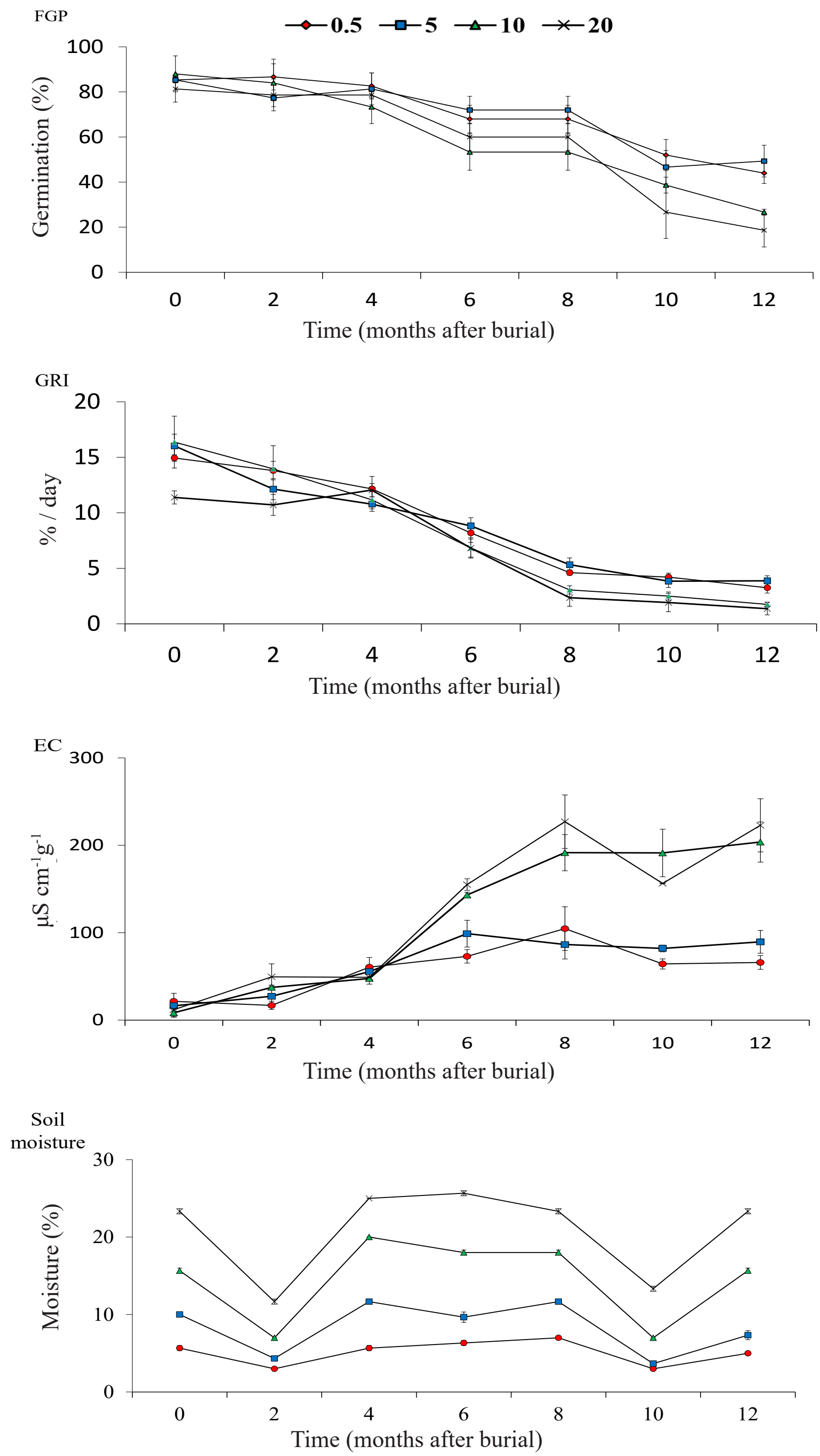

Figure 2. Final germination percentage (FGP), germination rate index (GRI), electrical conductivity (EC), and soil moisture content of *Parthenium hysterophorus* at 0.5, 5, 10, and 20 cm depths upon 12 months field burial

germination percentage, but the reduction in germination speed was found particularly in high pH environments. It simply means that *P. hysterophorus* can germinate under a wide range of soil pH, giving it a competitive advantage compared to other seeds, hence facilitating its spread. On the other hand, Laghmouchi et al. (2017) reported that *Origanum compactum* seed favours a more neutral pH as maximum germination of 71% was obtained at pH 7. The influence of soil pH was more prominent as the germinated seed entered the early seedling stage. It is widely known that soil pH affects plant growth based on its influence on nutrient availability. Generally, most micronutrients, including iron, manganese, boron, and copper, are more available to plants under acidic and sub-acidic conditions than neutral-basic ones, thus favouring growth (Lončarić et al., 2008). Findings from the subsequent seedling analysis indicated that *P. hysterophorus* seedlings showed accelerated growth and fecundity in acidic soil conditions. As a result, the seedling enters the flowering stage at 74 days after sowing, resulting in a 13.4% quicker rate compared to pH 6 and above (with 85 days average).

It, in turn, shortens the seed-to-seed cycle as each seedling enters maturity significantly faster compared to higher soil pH conditions, again providing means for quick infestation. Gentili et al. (2018) reported similar findings as *A. artemisiifolia* seedlings showed faster growth (larger size, more dry weight) at pH 5 and 6, along with a higher number of inflorescences and pollen production. This study showed that *P. hysterophorus* seeds buried at 5 cm depth and below could not emerge from the soil. However, the non-emerged seeds were generally still viable upon exhumation, at a varying level, depending on the burial conditions. More than 40% of the seeds survived when buried at 0.5–5 cm depth, while only 19–27% survived as the burial depth increased beyond 10 cm at 12 months. The lower germinability observed at increasing burial depth can be linked to a higher rate of deterioration from higher soil moisture levels. It is generally known that seed longevity is influenced by several factors, including relative humidity or moisture, temperature, and oxygen level (Rajjou & Debeaujon, 2008).

Low relative humidity could reduce the deterioration rate even with high storage temperature conditions, suggesting that moisture level might play a larger role in determining seed longevity. In general, seed EC value could indicate membrane integrity perseverance which protects the seed tissue from oxidative damage; and can be linked to the seed germinability. From the Pearson correlation analysis, both EC and soil moisture indicated a moderate positive correlation, which could explain the higher reduction in exhumed seed viability for 10 and 20-cm burial depths. Higher EC values recorded at both depths suggested that the electrolytes were leached out due to a higher degradation level of the outer membrane (Nakagawa et al., 2020; Wang et al., 2018). These findings suggest that *P. hysterophorus* weed seed bank emergence and survival would vary depending on the burial depth, regional rainfall, and soil moisture level. It may exhibit secondary dormancy that relates mainly to water availability. Navie et al. (2004) suggested that *P. hysterophorus* does not confer the typical physical dormancy characteristics since the seed can emerge immediately within two weeks upon exposure to moisture or rainfall.

In the case of *Parthenium argentatum* seed, the onset of prolonged rainfall was reported to trigger germination immediately in desert conditions. It ensures that germination inhibitors are leached when there is sufficient water level to prevent untimely germination of seeds, particularly in arid environments. As a consequence, the emerged seedlings would be able to sustain the growth stages and reproduce. The results obtained in this study on the viability of seeds upon burial showed that only seeds at the 0.5 cm depth can germinate, while the rest will remain viable for slightly more than a year before total deterioration occurs. It, however, is the situation if no-tillage is done.

CONCLUSION

The overall findings from this study suggested that *P. hyterosphorus* seed could survive a wide range of conditions with high germinability. However, the environment affected the subsequent seedling growth and flowering time. Higher plant height, leaf areas, and overall seedling biomass were recorded in lower pH conditions, enabling the seedlings to enter the earlier flowering stage. It reduces the seed-to-seed cycle and increases overall weed fecundity. The seed, however, showed a marked decline in viability if buried for more than 12 months without tillage.

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