Influence of Moisture, pH, Depth of Burial and Submerged Conditions on Seed Germination and Seedling Emergence of Major Weed Species in Coconut Plantations of Sri Lanka

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ABSTRACT The laboratory and green house studies evaluated the effect of three different environmental factors on the seed germination, seedling emergence and survival of four major weed species in coconut plantations, *Mimosa pudica, Ureana lobata, Panicum maximum* and *Pennisetum polystachyon*. Germination percentage of all the weed species was significantly reduced with increasing soil moisture stress, no germination was observed at -0.9 MPa. Germination of both grass seeds ranged from 8% to 25% and 10% to 45% as moisture stress decreased from -0.4 MPa to 0 MPa, respectively. In contrast, seeds of *M. pudica,* and *U. lobata* were moderately tolerant to soil moisture stress and best adapted to moist environment. All the weed species seeds germinated over a wide range of soil pH values with the highest germination occurring at pH 6. In all the species, seedling emergence was declined rapidly with increasing depth with the exception of *U. lobata*. Seedling emergence significantly declined when the duration of flooding was three days or longer in dicotyledonous weed species and two days or longer in monocotyledonous weeds. This study illustrates the adaptability of these weeds to different environmental conditions which would enable the development of management strategies to reduce their populations below economic threshold levels in coconut plantations.

Key words: burial depth; coconut; moisture stress; pH; seed germination; weed.

INTRODUCTION

The growth habit of the coconut palm and the canopy structure requires a wide spacing between palms, which permits the penetration of abundant sunlight to the ground vegetation. Thus, a wide range of perennial and annual weed species invade the unutilized space beneath coconut palms (Senarathne

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et al. 2003). Among these weed species, *Mimosa pudica, Ureana lobata, Panicum maximum* and *Pennisetum polystachyon,* are the most problematic dicotyledonous and monocotyledonous weeds in coconut plantations in Sri Lanka. In recent years, knowledge of weed biology has aroused increasing interest in the context of developing weed management strategies (Bhowmik 1997). This is essential to maximize the effectiveness of agronomic practices to manage weeds (Forcella 1993).

Germination is one of the most critical phases in plant development. It is the result of complex interactions between numerous internal and external controls (Bewley and Black 1994). The internal control of seed dormancy relates to the state of the seed itself. External control relates to environmental factors that removes seed dormancy, an attribute common to nearly all weed species and influences the persistence of seeds in soil and affects the germination patterns in natural ecosystems (Benech-Arnold *et al.* 2000; Egley and Duke 1985).

Several environmental factors are known to promote or inhibit weed seed germination (Egley and Duke 1985; Taylorson 1987). Moisture, temperature, light and pH requirements for germination vary considerably depending on the species (Shaw *et al.* 1997). Burial depth of seeds also affects germination and seedling emergence (Shaw *et al.* 1997; Koger *et al.* 2004) and the availability of moisture, diurnal temperature fluctuation, and light exposure varies with depth. All of these attributes of the microenvironment potentially influences the behavior of weed seeds. Therefore, it is critical to procure information on seed germination, persistence and seedling emergence to improve the management systems for specific weed species (Mennan and Ngouajio 2006). There is little information on the seed biology of *M. pudica, U. lobata, P. maximum* and *P. polystachion* which affects the development of strategies for the management of these weeds. Therefore, the objective of this study was to determine the effect of osmotic stress, pH, flooding and burial depth on germination of these species using laboratory and green house experiments.

MATERIALS AND METHODS

The experiments were carried out in the plant house of the Coconut Research Institute located in the Low country Intermediate Zone of the North Western province of Sri Lanka from May 2005 to May 2006. In the plant house, the experimental pots received photosynthetically active radiation (PAR) ranging from 500-1150 μmolm^{-2} s^{-1} and the average day and night temperatures were in the range of 30-34℃ and 26-30℃ respectively. Relative humidity varied between 35-60% during the day and 20-27% during the night. Seeds of the selected weed species namely *P. maximum, P. polystachion, M. pudica,* and *U. lobata* were collected from five different locations in the major coconut growing regions of Sri Lanka between February to March 2005 and were stored at 5℃ under dark conditions. The selected treatments of the experiments were arranged in a Complete Randomized Design (CRD) with ten replicates (each Petri dish and pot representing one replication of a single species in each trial) in the respective studies.

Effect of moisture stress

Aqueous solutions of polyethylene glycol (PEG) (average molecular weight of 6000) were prepared to obtain osmotic potentials of 0, -0.3, -0.4, -0.6, -0.9 and -1.3 MPa by dissolving 0, 154, 191, 230, 297, or 350 g of PEG in 1 liter of deionized water (Michel and Kaufmann 1973). Thereafter, 50 seeds of each species were placed in 9 cm diameter Petri dishes containing two filter papers. The filter papers were moistened with 5ml deionized water or test solution and the Petri dishes were placed in a green house. Seed germination was counted once in two days for a period of 30 days.

Effect of pH

All the selected weed species seeds were placed in Buffer solutions having pH values of 4, 5, 6, 7, 8 and 9 with distilled water as a control. The buffer solutions were prepared as described by Reddy and Singh (1992), using potassium hydrogen pathalate, and were adjusted to pH 4 with HCl. 2-(N-morpholino)ethanesulfonic acid (MES) solutions were adjusted to pH 5 and 6 using NaOH. N-(2-hydroxymethyl)piperazine-N-(2-ethanesulfonic acid) solution was adjusted to pH 7 and 8 with NaOH. N-Tris (hydroxymethyl)methylglycine (Tricine) solution was adjusted to pH 9 with NaOH. Fifty seeds of each species were placed on two sheets of filter papers in 9 cm diameter Petri dishes and moistened with 5 ml of each pH solution. Seed germination was counted once in two days for a period of 30 days.

Effect of seeding depth

Fifty seeds from each weed species were placed in a sandy clay loam soil in polythene pots (15 cm diameter) at depths of 0, 1, 3, 5, 7, 9 and 11 cm, and placed in a green house. The green house temperatures were 30 ± 4℃ during the day and 26 ± 4℃ during the night. Pots were watered as needed to maintain adequate soil moisture. Seedlings were counted every 7 days for 30 days. Seedlings emergence were considered when the cotyledons could be visually discerned and were removed after counting at 7 day intervals.

Effect of submerged time period (flooding)

Fifty seeds of each weed species were planted 1cm deep in a sandy clay loam soil in sealed plastic pots (9 cm diameter). Flooding was imposed by maintaining water at a height of 1.5 cm above the soil surface. The flooding condition was maintained for 1, 3, 5, 7, 9, 11, 13 and 15 days after planting. Flooding was discontinued after the indicated period and seeds were watered as needed to maintain adequate moisture. Emergence was recorded weekly for a period of 28 days after planting.

Statistical analysis

In all experiments except the pH test, percentage of germination data were transformed using the log (x + 1) transformation, where x is percentage of germination, to improve homogeneity. The ANOVA and regression analysis were performed on both transformed and non transformed percentages of germination. Means from experiments were separated using, the Fisher's protected LSD test at P = 0.05. The statistical program was the Statistical Analysis System (SAS 1999). The R^2 and residual mean squares were used to determine the goodness of the fit to the regression model.

RESULTS AND DISCUSSION

Effect of moisture stress

Germination of all the weed species seeds decreased when the osmotic potential increased from 0 to -1.3 MPa (Figs 1, 2). Seed germination of these two grass species was highest at osmotic potential of 0 and -0.3 MPa. An 8% germination at an osmotic potential of -0.4 MPa indicated that *P. maximum* and *P. polystachion* cannot germinate under higher moisture stress conditions. No germination occurred at an osmotic potential of -0.9 MPa (Fig. 1).

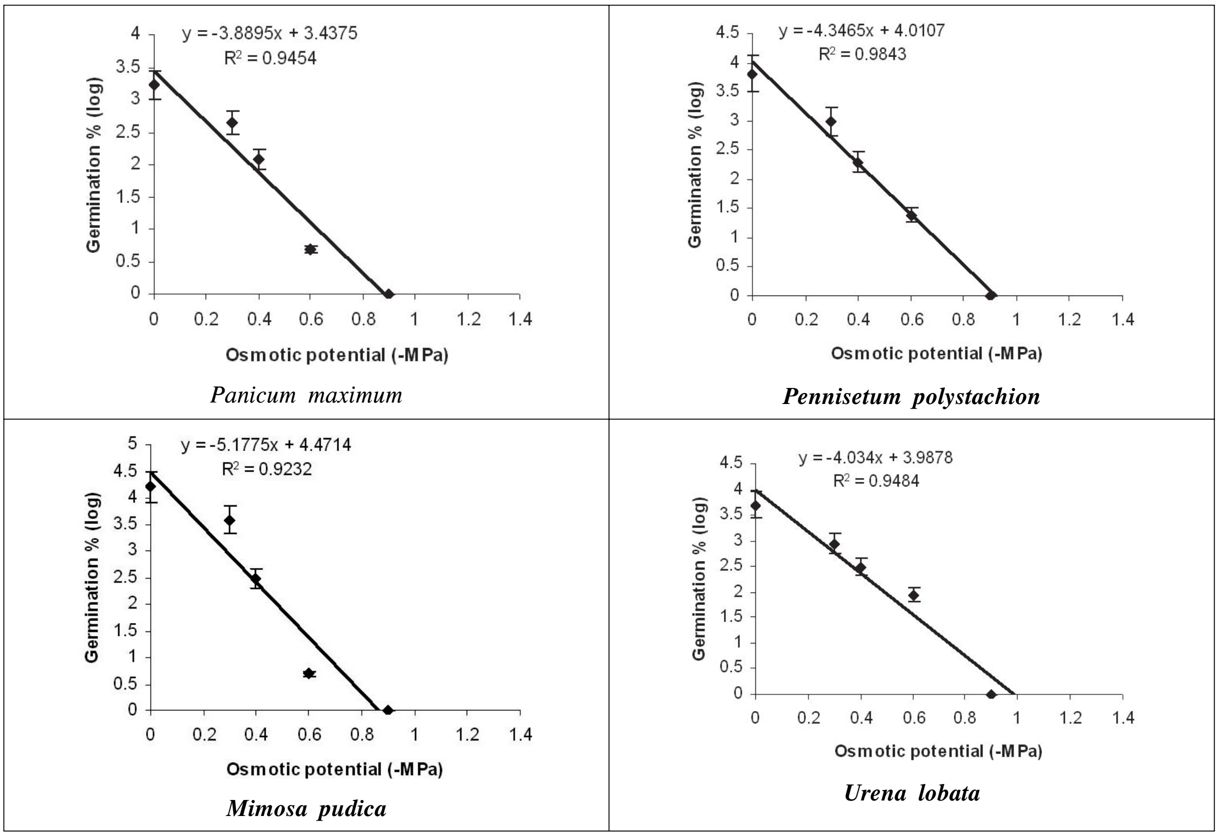

Fig. 1. Effect of moisture stress (osmotic potential -MPa) on seed germination of major weed species in coconut plantations.

Moreno and McCarthy (1994) found that crabgrass germination was reduced up to 70% at osmotic potential ranging from -0.4 to -0.8 MPa.

The germination of dicotyledonous weed species, *M. pudica* and *U. lobata* was sensitive to simulated water stress. Less than 12% of the *M. pudica* and *U. lobata* seeds germinated at osmotic potential below -0.4 MPa (Fig. 1). The highest seed germination percentages of these species (67% and 40%) were recorded at osmotic potentials of 0 MPa. These two weed species seems to be best adapted to a moist environment, and germination in the field may depend on adequate water availability.

Effect of seeding depth

Seedling emergence from different seeding depths varied with the species. Seedling emergence percentage was very high for seeds placed on the soil surface or at a depth of 1 cm (Fig. 2). Germination of *P. maximum* and *P. polystachion* seeds was very high when planted on the surface (25 and 39% at 0 cm depth) and very low seedlings emergence was observed when seeds placed at a depth of 5 cm (both monocot species 2%) (Fig.2). In previous research, emergence of buffalo grass (*Buchloe dactyloides*) was reduced as planting depth increased, with emergence less than 10% at depths greater than 5cm (Heckman *et al.* 2002).

In this study, *M. pudica* and *U. lobata* seedlings emerged when placed on the soil surface or buried up to a depth of 5 cm range. No seedlings emerged from seed placed below 7 cm (Fig. 2). In many species, seedling emergence declined with increasing depth of seed burial (Shaw *et al.* 1997; Qi and

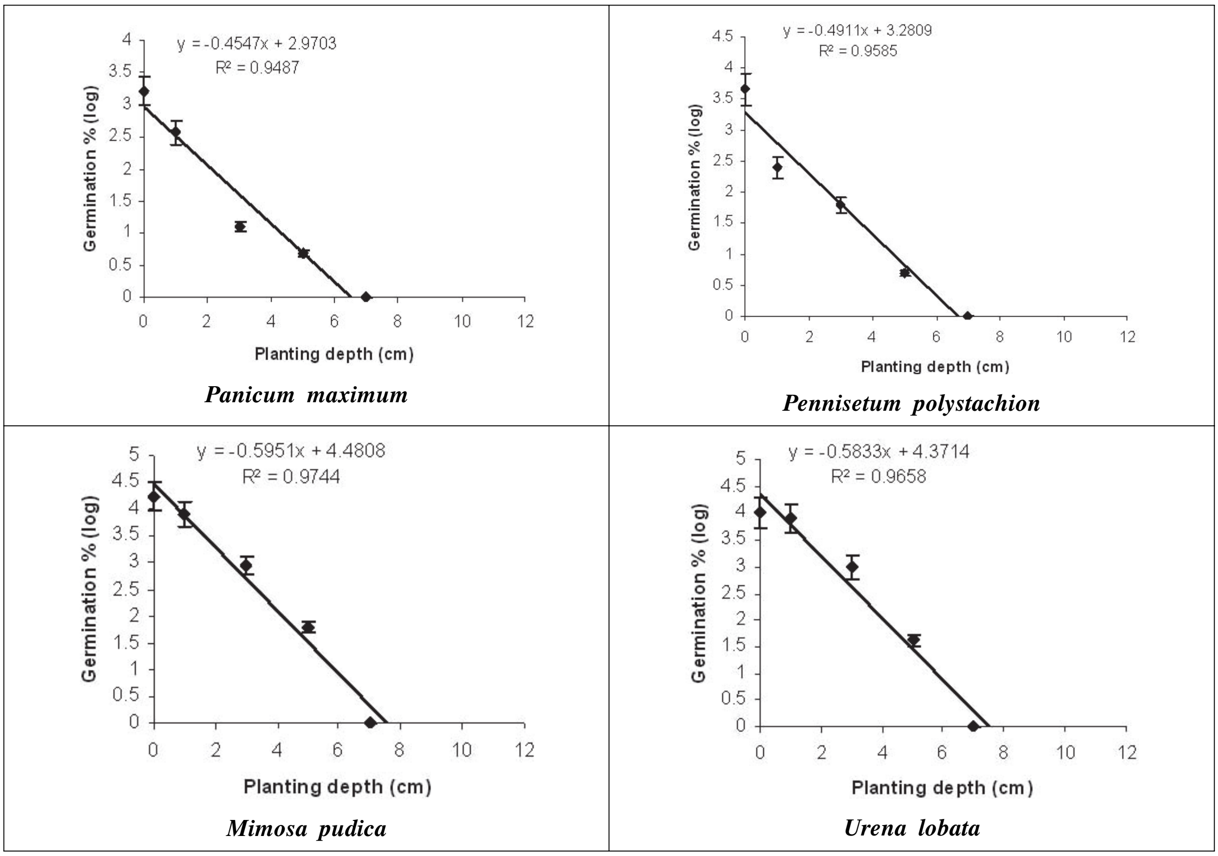

Fig. 2. Effect of planting (seeding) depths (cm) on seed germination of major weed species in coconut plantations.

Upadhyaya 1993; Cussans *et al.* 1996; Vleeshouwers 1997; Benvenuti *et al.* 2001). This could be linked to seed energy reserves (Mennan and Ngouajio 2006). Emergence after burial in soil depends in part on seed size and light conditions. Large seeds with greater reserves can emerge from greater depths of burial (Baskin and Baskin 1983), light usually does not penetrate more than a few millimetres into the soil, germination and emergence in species whose seed has a light requirement probably would be restricted to shallow depths. *U. lobata* has relatively large seeds (2 mm wide) when compared to the other selected weed species and do not have a light requirement for germination.

Effect of pH

M. pudica and *U. lobata* seeds germinated over a wide pH range, indicating that pH is not likely to be a limiting factor for germination in most coconut growing soil types (Fig. 3). Seed germination of broad leaved weed species seeds followed a quadratic response to increasing pH with increasing germination between pH 4 and pH 7 and decreasing germination at pH levels of 7 and 9 (Fig. 3). Maximum seed germination in *U. lobata* (48%) was at pH 6 (Fig. 3). The highest germination percentage of *M. pudica* (70%) was recorded at pH 5 and seeds did not germinate at pH 9 (Fig. 3). The seeds of *U. lobata* germinated at pH 4 and pH 9 which were acidic and alkaline conditions. However, the percentages of seeds of *U. lobata* that germinated at pH 4 were 10%, and at pH 9 was 8%. Therefore, the ability to germinate over a wide pH range supports the view that *U. lobata* and *M. pudica*

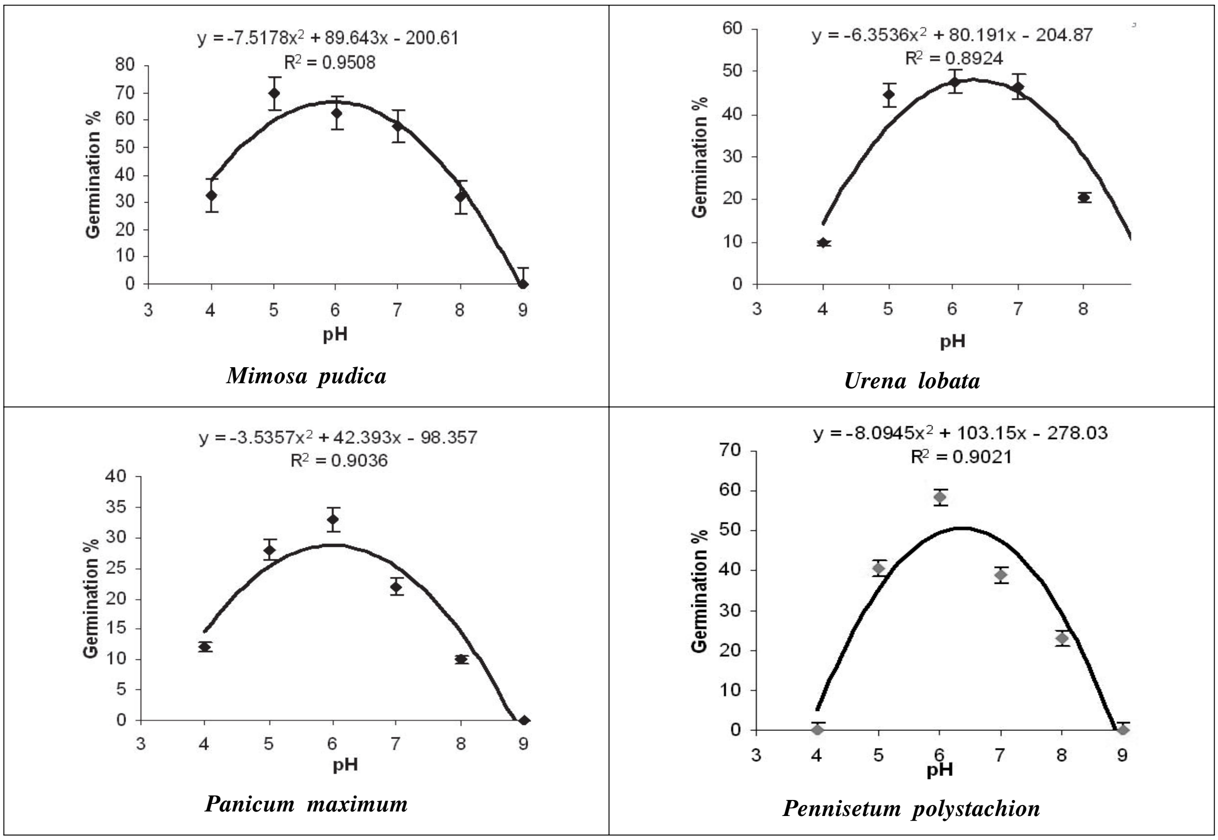

Fig. 3. Effect of pH on seed germination of major weed species in coconut plantations.

weeds are adapted to a wide range of soil conditions. This characteristic is common for many weed species such as *Asclepias syriaca* and *Scoparia dulcis* (Evetts and Burnside 1972; Jain and Singh 1989).

Germination of grass weeds *P. maximum* and *P. polystachion* seeds significantly increased from pH 4 to pH 6 and decreased pH from 6 to 9 (Fig. 3). Seed germination percentage of *P. maximum* was 33% at pH 6 and 10% at pH 8. No germination occurred at pH 9 in both species. However, *P. maximum* seeds germinated at pH 4 (12%). These results also suggest that *P. maximum* prefers neutral to slightly acidic soil conditions pH (4-7), indicating that pH may be a limiting factor for germination of these weeds in most soils. Maximum seed germination percentage of *P. polystachion* (59%) was observed at pH 6 and no germination occurred at pH 4 and 9. These results suggest that *P. polystachion* seeds cannot germinate over a wide range of pH from 5 to 8 when compared with *P. maximum*.

Effect of submerged time period (flooding)

Emergence of all weed species seedlings decreased with increasing duration of submergence (Fig. 4). The highest percentage of seedlings emerged from a depth of 1cm when seeds were not exposed to flooded conditions, or duration of flooding was one day. Seedlings emergence significantly declined when the duration of flooding was three days or longer in dicotyledonous weed species and two days or longer in monocotyledonous weeds. Seedling emergence was not observed when flooding was maintained for 9 days in monocotyledonous weeds

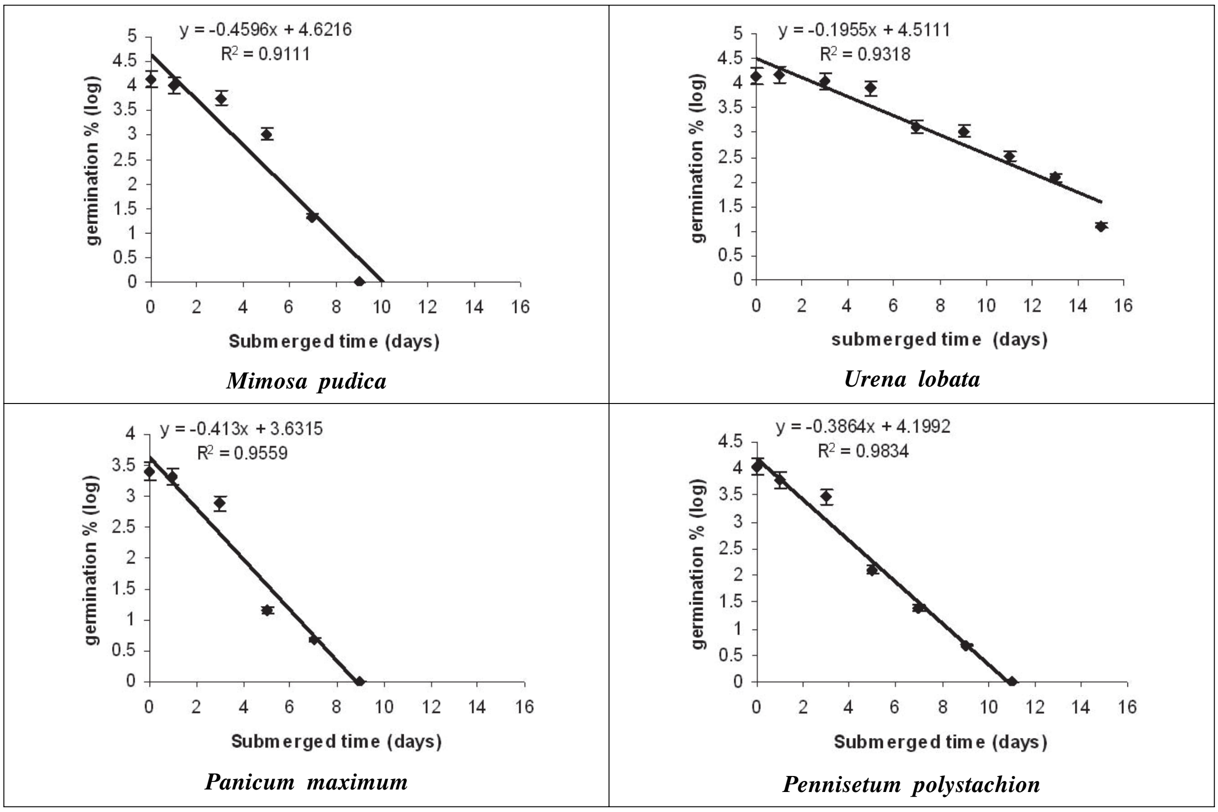

Fig. 4. Effect of submerged time period (flooding) on seed germination of major weed species in coconut plantations.

and for 9 days in dicotyledonous weed species except in *U. lobata* (Fig. 4).

Water logging conditions have profound effects on seed germination and seedling development and hence on species composition. Activation of the physiological process necessary for seed germination requires an O_2 supply; however, soil inundation restricts O_2 availability to the embryo and thereby prevents or delays seed germination in many species (Kozlowski and Pallardy 1997). In general, soaking seeds of upland species for several hours to a few days accelerates germination, whereas soaking for long periods inhibits germination (Kozlowski 1984; Kozlowski and Pallardy 1997). The maximum number of *P. maximum* and *P. polystachion* seedlings emerged (30.2 and 56.3%) when they were not exposed to flooded conditions and emergence percentage gradually decreased with time from 0 to 7days. In *P. maximum* some seeds germinated after the flooding conditions were removed. Although most of the weed seeds did not germinate in saturated or flooded soil, intermittent flooding does not appear to be a viable control option because seed could geminate when the soil dries. The results suggest that germination of monocotyledonous weed was greatly reduced when flooding was maintained. Consequently these two grass species may not persist in areas flooded for long periods.

CONCLUSION

According to the experiment results *M. pudica, P. maximum* and *P. polystachion* are more sensitive to moisture stress conditions than *U. lobata*. This study suggests that the germination of monocotyledonous species seeds are favoured by a moist environment. Due to this special character of these monocotyledonous species, they start germinating even during temporary rainy periods and to face to the dry periods; they develop a well developed root system within a short period. Therefore, they could survive under a wide range of weather conditions. Seed germination of *M. pudica* and *U. lobata* are sensitive to simulated moisture stress and they have some capacity to germinate under moderate moisture stress conditions and seem to be best adapted to moist environments.

Emergence of seedlings of the all selected weeds species decrease with increasing planting depth. Seedling emergence is the greatest for seed present on the soil surface due to favourable environmental conditions for seed germination. However, *U. lobata* has relatively large seeds and seedlings of this specie emerge from greater depths when compared to other selected other weed species. Therefore, ploughing and harrowing can be used to suppress these species but deeply buried seeds have the potential for germination when they are relocated near the soil surface by disturbances. All the selected dicotyledonous weed species germinate over a wide pH range, indicating that pH is not likely to be a limiting factor for germination of weeds in most of the coconut growing soil types.

The seedling emergence significantly decreased with three days of flooding or longer in dicotyledonous and two days or longer in monocotyledonous weeds. The monocotyledonous seed germination is greatly reduced when flooding is maintained and may not persist in areas flooded for long periods. However, dicotyledonous weed seed germination is more tolerant to flooded conditions than monocotyledonous species. The dicotyledonous seeds namely *U. lobata* seed is more resistant to long flooding periods. The warm climate and well drained sandy and sandy clay loam soils with abundant moisture lands are particularly ideal for *P. maximum*, *P. polystachion* and *M. pudica* seed germination and soils with less drainage and clay loam soils also create more favourable environment for *U. lobata* seed germination and establishment.

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