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EFFECT OF SUBSTRATE MOISTURE AND INVASIVE GRASS COMPETITION ON NATIVE FIG (*Ficus fistulosa*) SEEDLING RECRUITMENT IN LIMESTONE QUARRIES

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ABSTRACT

This study was conducted to determine the possibility of native fig (*Ficus fistulosa*) for rehabilitating degraded habitats in limestone quarries. A greenhouse experiment was carried out to test the effect of different substrate moisture levels and competition between native fig (*Ficus fistulosa*) and invasive grass *Pennisetum polystachyon* on the native fig's growth and survival. *Ficus fistulosa* was chosen as the studied species because it has high Importance Value Index (IVI) compared to other fig species tested in Ciampea limestone hill. The results showed that the substrate moisture levels did not affect the native fig biomass and the invasive grass biomass was not reduced by drought. The interaction of substrate moisture levels and competition from invasive grass reduced overall fig biomass, but not the leaf numbers and individual plant size. This study suggested that for quarry rehabilitation, invasive species management should be advocated along with soil treatment.

Keywords:*Ficus fistulosa* competition, quarried limestone, rehabilitation, substrate moisture

INTRODUCTION

Limestone regions over the world along with their biodiversity are threatened mainly by limestone quarrying causing land degradation problems due to soil depletion and alteration of land topography. Vegetation removal and lack of available soil on steep slopes induce a very high risk of erosion in limestone ecosystems (Clemente *et al*. 2004). The common method of limestone quarrying increases drainage, physical and chemical erosion of the substrate which hinder natural germination and establishment of seedlings, thus delaying re-colonization (Clemente *et al*. 2004).

During the rainy season, water run-off is high, while the open sites are easy to dry up. Plant recruitment in newly disturbed areas, like in an over-quarried limestone, is determined by water availability and soil moisture (Soliveres 2012). The large number of abandoned quarries in many countries presents challenges for restoration of these degraded habitats (Yuan *et al*. 2006). Revegetation is among common strategies to restore the abandoned quarries (Zhang & Chu 2011). Limestone quarries revegetation is challenging because not all plants are able to cope with relatively barren rock cliff and absence of topsoil or humus. Substrate moisture is the most limiting environment variable influencing seedling emergence and survival, particularly in arid ecosystems (Soliveres 2012), such as of these abandoned limestone quarries. In addition to water availability, competition against fast growing invader such as exotic grass can be critical during the seedling stage of the desired native plants.

Understanding factors that restrict the establishment and growth of native plant species can aid efforts for species conservation in their habitats and can expand options for species recovery, including restoration, translocation and *ex-situ* conservation (Maschinski *et al.* 2004).

Native plant species is favoured for rehabilitating disturbed ecosystems (Khater *et al.* 2009). *Ficus* is potential for limestone quarries rehabilitation. In the abandoned limestone quarries in Ciampea, Bogor, West Java, Indonesia,

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Ficus is abundant in the remaining limestone forests (Satyanti & Kusuma 2010).

Previous study conducted by Satyanti and Kusuma (2010) ranked fourteen *Ficus* species from Ciampea limestone hill, i.e. *Ficus annulata*, *F. fistulosa*, *F. grossularoides*, *F. hirta*, *F. montana*, *F. pinnata*, *F. sagittata*, *F. septica* and six other unidentified *Ficus* species based on their Importance Value Index (IVI). *Ficus fistulosa* was found to have the highest IVI value in the limestone habitat in Ciampea (Satyanti & Kusuma 2010) and hence, it is selected as the studied species in the current experiment.

This study was conducted to determine the possibility of native fig (*Ficus fistulosa*) for rehabilitating degraded habitats in limestone quarries. A greenhouse experiment was carried out to test the effect of different substrate moisture levels and competition between native fig (*Ficus fistulosa*) and invasive grass *Pennisetum polystachyon* on the native fig's growth and survival.

MATERIALS AND METHODS

Study Site

The limestone site in Ciampea is a long coral reef raised to above 350 m above sea level, located at 106°41'00.0" E and 06°33'00.0" S. The formation of limestone is of the Bojongmanik formation which is equal to a middle Mioscene age (Effendi *et al.* 1998). The forest used to have numerous *Dipterocarpus hasseltii* (Dipterocarpaceae), *Stelechocarpus burahol* (Annonaceae) and a number of *Diospyros* (Ebenaceae), but no single species was dominant (van Steenis 1931 in Whitten & Soeriaatmadja 1996).

Study Species

Native Fig (Ficus fistulosa *Reinw. Ex. Blume*)

Common yellow stem fig (Moraceae) is an evergreen tree and grows to about 10–15 cm in trunk diameter. It is native to Malesia floristic region, including Indonesia. It has a straight trunk with smooth bark ranging from light grey to yellowish in colour. The young twigs are hollow and easily breaks. Leaves of this tree are alternately arranged, the young leaves are pale pink in colour. Figs are pear shaped ± 2.5 cm wide, borne on 2.5–5 cm long stalks and in cluster on woody knobs on the trunk and branches. Figs ripened from yellow to green yellow. The flowers are found within the figs; with male and female flowers located at different trees. Individual trees bears 4–7 crops a year. In Java and Borneo, fig is pollinated by fig wasps, *Ceratosolen constrictus* and seed dispersal is mainly carried out by bats (genus *Dyacopterus*). *Ficus fistulosa* does not have aggressive roots like other strangler *Ficus*. Hence, it is an excellent tree to attract wildlife back to both native habitat and urban environment. It is also ethno-botanically important; in some parts of Indonesia the young leaves are eaten as salads. A decoction of the leaves is given to women after childbirth and the latex has been used to treat headache (Corner 1988).

Invasive grass (Pennisetum polystachyon (*L.*) *Schult*)

Pennisetum polystachyon or widely known as mission grass is native to tropical Africa. It is an annual or perennial plant; the culm is simple or branched; the branches are often flowering. Spikelet length is 3–5 mm; false spike is 8–10 mm, excluding the bristle; the longest bristle is 15–55 cm long. When mature the spikelets break off at the control axis together with the bristles. It produces few tillers per plant. The distribution of this grass is throughout the tropics up to 1,500 m asl (above sea level). This grass requires high rainfall, but it is also grown in semi-arid regions. It tolerates both acid and alkaline soils. *Pennisetum polystachyon* spreads readily by seeds which survive annual burning. Seedling vigour is good, even in poor soil conditions (Clayton *et al.* 2006). In Indonesia it is considered invasive species (Tjitrosoedirdjo 2005).

Seed Germination of the Native Fig and the Invasive Grass

Fruits of the native fig and panicles of the invasive grass were collected from the limestone quarry in Ciampea, Bogor-West Java. The limestone hill in this site is a long coral reef raised to above 350 m asl and has been quarried for more than thirty years. *Dipteroacarpus hasseltii* (Dipterocarpaceae), *Stelechocarpus burahol* (Annonaceae) and a number of *Diospyros* (Ebenaceae) species were used to be abundant in this limestone forest, but no single species was dominant (van Steenis 1931 in Whitten & Soeriaatmadja 1996). The above mentioned species are now infrequently present in this habitat.

The fruits of *Ficus fistulosa* and panicles of the grass and limestone substrate were subsequently brought to the greenhouse of the Bogor Botanical Garden, where further experiment was conducted.

The fruits of the native fig were then cut open and seeds were collected. Seeds were then air dried for 1–2 hours prior to sowing. Seeds were sown on sand in a tray. After 10–14 days seeds of the native fig were germinated and were kept to grow in the sowing tray before being transplanted to limestone substrate for competition experiment.

In parallel, panicles of the invasive grass were sown on sand in different sowing tray. After 3–4 weeks, seeds were germinated and grass seedlings were kept until leaf sheaths reached 5–10 cm length or about a week after sowing. Fig and grass seedlings were subsequently transplanted to the treatment pots and watered until substrates were fully saturated and substrate moisture treatment was applied from the next watering top-up.

Competition Experiment

Factors involved were substrate moisture and competition. Substrate moisture treatments were 34 mL/week and 68 mL/week, inducing water stress (drought) for the low moisture treatment. This water volume was chosen based on personal observation that 68 mL/week was able to keep the substrate well saturated and the surface was adequately moist. Each pot contained limestone substrate weighing 250 g. Limestone substrates were collected from the quarried in Ciampea. The substrate from these abandoned quarries was in the form of a mixture of coarse and fine gravel of limestone. Two levels of competition were employed, i.e. with and without grass competition. In a competition pot, one seedling of native fig was planted with two seedlings of invasive grass. One-month-old native fig seedlings with 2–3 true leaves, ±2–3 cm tall were transplanted to limestone substrates in 9 cm (diameter) and 12 cm (depth) free draining pots for competition experiment. Invasive grass seedlings were transplanted to competition pots at the same time.

The experiment set–up was a factorial block design assigning each treatment and its combination within each block. For each treatment combination, six replicates were used and all were arranged in five blocks. Thus, each block consisted of 24 pots, in which six pots of low soil moisture and no competition, six pots of low soil moisture and with competition, six pots of high soil moisture and no competition, and six pots of high soil moisture and with competition, leading to a total number of 120 pots. The competition experiment were maintained and observed for eight months. At the end of the experiment, measurements were made for native fig seedlings' height, leaf number and biomass. Grass above- and below- ground biomass were also measured.

Data Analysis

In order to disentangle the effect of substrate moisture and competition on native fig seedling growth, a two-way ANOVA was carried out. In addition, the interactions between substrate moisture and competition against invasive grass were also tested to determine whether or not those two factors affect the growth of native fig. For competition pot, invasive grass above- and below-ground biomass were also tested against substrate moisture. Subsequently, correlation between the native fig and invasive grass biomass was analysed. All calculations were performed using software SPSS ver. 15.0.

RESULTS AND DISCUSSION

Substrate Moisture Effect on Native Fig and Invasive Grass

Growth of native fig during the eight month observation period was relatively slow considering their nature as a woody tree growing in tropical climate. Watering at 68 mL/pot/week significantly reduced native fig biomass compared to the 34 mL/pot/week but the effect of substrate moisture on native fig plant size and leaf number was on the other hand benign (Fig. 1). Grass biomass, however, was independent from the substrate moisture suggesting that invasive grass might be quite resistant to drought or water availability fluctuation (Fig. 2).

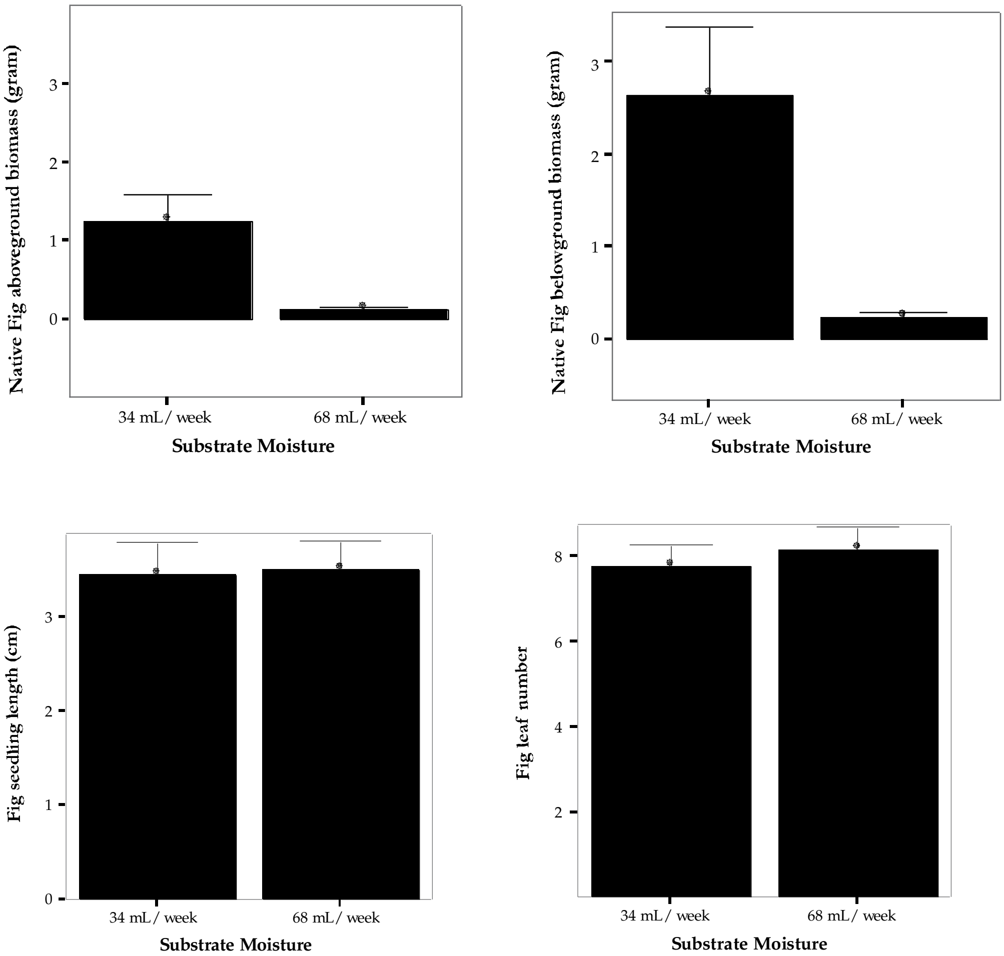

Figure 1 Native fig preferred lower water regime between competition treatments ($F_{38.537}$ = 462.02, p = 0.16 and $F_{173.251}$ = 250.605, for above- and below-ground, respectively). There is no effect of substrate moisture on fig seedling length and leaf number between competition treatments

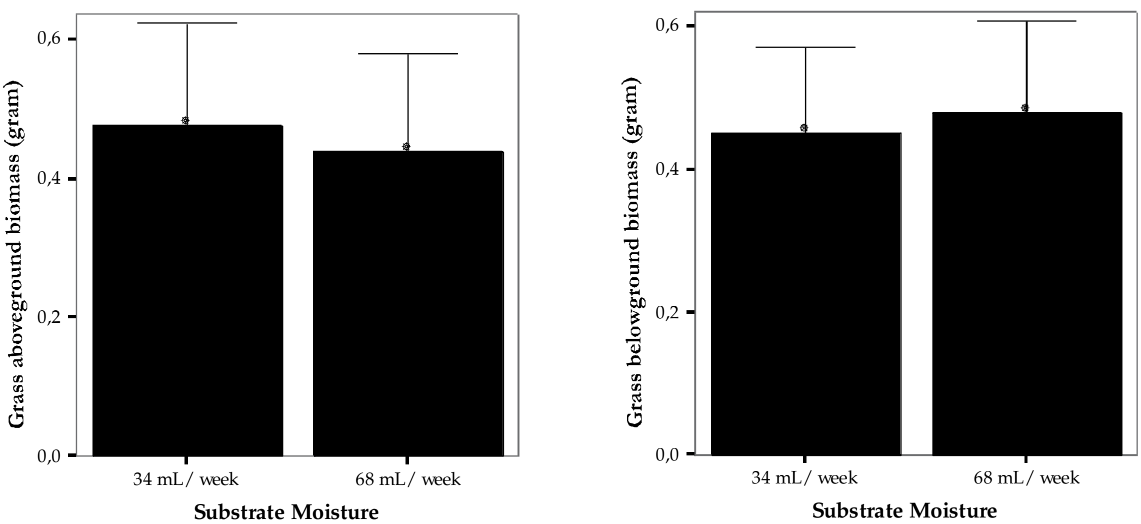

Figure 2 Above- and below-ground grass biomass were not affected by the substrate moisture

Even though the pots were freely drained, the bulky and clayish nature of the limestone substrate may lead to biomass reduction of the native fig. *Ficus*, in general, tends to grow better in aerated substrate and intolerant to submersion, even temporarily (Parolin & Wittmann 2010). There was no significant effect of substrate moisture to *Ficus* above- and below-ground biomass when grass was present. However, there was a significant reduction in biomass under higher moisture treatment in the absence of grass (Fig. 3).

Effect of Presence of Invasive Grass on Native Fig

Native fig above- and below-ground biomass, leaf number and seedling length were reduced because of the presence of invasive grass (Fig. 3 and 4).

From the competition point of view, invasive grass contribution in suppressing native fig growth can either be from water and nutrients competition or light competition. Moreover, at the end of the experiment *Ficus* seedlings height were mostly exceeded by grass leaf sheaths. However, there was no correlation between native fig and invasive grass growth (Table 1). It might be that other variables that were not measured had more influence. For instance, allelopathy from exotic grass had more influence on native fig biomass than merely moisture and neighbour growth. *Pennisetum* grass roots are known to have allelopathic chemicals (Zain *et al.* 2013) and adversely affects *Cyperus indica* (Tan *et al*. 2012), *Leptochloa chinensis* and *Hedyotis verticillata* (Norhafizah *et al*. 2012). *Ficus* is, on the other hand, known to have phytotoxic effect on grasses (Siddiqui *et al*. 2009).

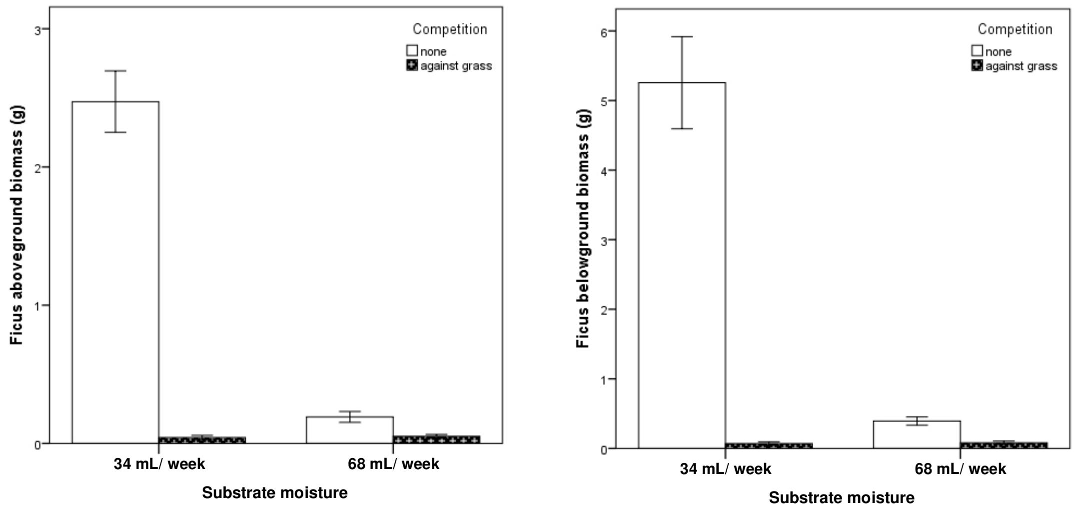

Figure 3 Invasive grass significantly reduced native fig above- and below-ground biomass ($F_{49,353}$ = 592.572, p = 0.000 and $F_{222,965}$ = 322.514, p = 0.000, respectively). Both above- and below-ground biomass were very small at the presence of grass. There was a significant interaction effect between competition and substrate moisture to fig above-ground ($F_{39,144}$ = 469.997; p = 0.000) and below-ground biomass ($F_{174,851}$ = 252.918; p = 0.000). For both above- and below-ground biomass, there was no significant effect of substrate moisture when grass was present, while there was a significant reduction in biomass under higher moisture treatment in the absence of grass

Table 1 Significance value for relationship between biomass

Biomass	R^2	*p*	Significance
Grass below-ground – Fig below-ground biomass	0.010	0.436	ns
Grass below-ground – Fig above-ground biomass	0.002	0.769	ns
Grass above-ground – Fig above-ground biomass	0.001	0.770	ns
Grass above-ground – Fig below-ground biomass	0.009	0.477	ns

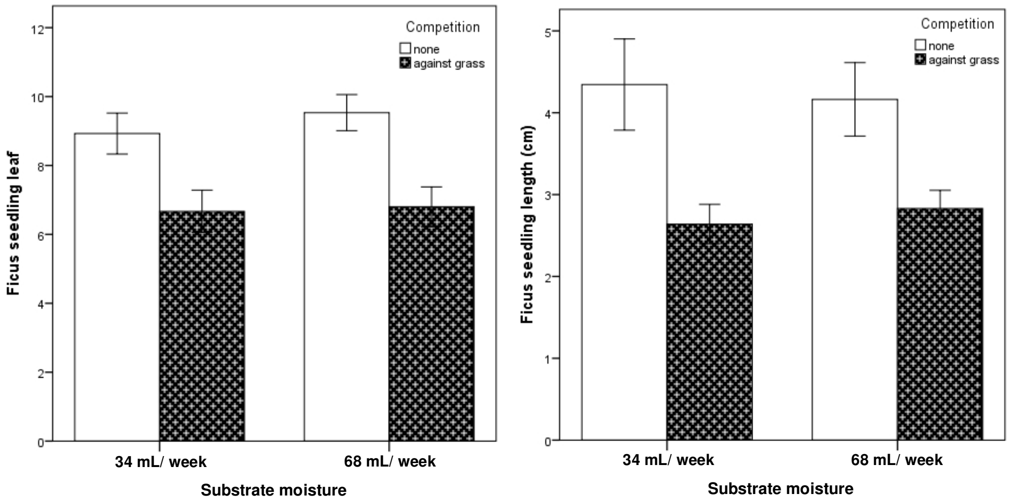

Figure 4 Competition against grass also significantly reduced the size of seedling and leaf numbers ($F_{64.827}$= 60.054; p = 0.000 and $F_{182.533}$ = 76.056; p = 0.000, respectively). There was no interaction effect between competition and substrate moisture to fig seedling size

Interaction Effect of Substrate Moisture and Competition to Fig Growth and Survival

It was apparent that the interaction of substrate moisture and presence of competition from grass reduced biomass of fig above-ground and below-ground (Fig. 3). There was no significant interaction effect on fig seedling size and leaf number even though it was evident that fig seedling leaf was reduced under the presence of grass (Fig. 4). In general, native fig seedling length and number of leaf were not adversely affected by substrate moisture (Fig.1), but rather by competition ($F_{64.827}$ = 60.054; p = 0.000 and $F_{182.533}$= 76.056; p= 0.000, respectively; Fig. 4). Our current study showed that the effect of grass competition was larger than the differences in substrate moisture (Fig. 1, 3 and 4).

Under greenhouse conditions, the native fig seeds germinated well on sand. The seedlings were able to grow on limestone substrates without addition of humus, but it was unknown whether seeds could germinate in novel soils under field conditions. Until the end of the experiment, all fig seedlings survived regardless their small growth increment. It is not clear whether or not the seedlings will be able to cope further when the experiment is prolonged or when they are transplanted in the field. Field trial showed that seedling establishment in limestone quarries varies dramatically with abiotic and biotic factors and it is often difficult to successfully reintroduce the seedling in the field (Maschinski *et al.* 2004).

As the native fig species showed very limited growth in this study, one perhaps would argue to use other fast growing species regardless the fact that they are non-indigenous. The use of native rhizobia-symbiosis forming plants can be used to enhance the success rate of limestone revegetation (Jha *et al*. 1995). Nevertheless, the use of native plants has many benefits in restoration schemes, such as their high adaptability to environmental stresses and low ecological risk (Ballesteros *et al.* 2012; Kirmer *et al.* 2012).

In the field, it is quite challenging to find recognizable number of native fig recruitment in the quarried areas. Besides inhospitable soil moisture and surface characteristics (Soliveres *et al.* 2012) natural establishment and reintroductions on unoccupied limestone field has probably been limited by poor natural dispersal.

CONCLUSIONS

This study showed that the above- and below-ground native fig biomass was reduced mainly due to competition against invasive grass. The effect of grass was also pronounced to other fig traits, leaf number and seedling size. Grass biomass, however, was not affected by substrate moisture. The effect of grass competition was larger than the differences in substrate moisture.

Study on the effect of allelopathy from invasive grass and neighbouring plants in a field experimental set-up as well as other potential native plants for limestone revegetation need to be carried out to develop better management of quarried limestone hill.

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