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Biology of *Sesbania pachycarpa* DC. and its fallow potentials: Germination ecology and Biomass accumulation

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Abstract
Sown fallow and green manure plants when integrated into the soil and decompose enhance the soil health by increasing organic matter content and possibly involved in the biological nitrogen fixation. *Sesbania pachycarpa* is a woody low-growing legume that can be used innovatively as sown fallow plant in conservation agriculture. The fallow potentials of *S. pachycarpa* were investigated in Ibadan in 2010 and 2011, by studying the germination biology, longevity of acid-scarified seeds in storage and effect of depths of sowing on seed germination and rate of biomass accumulation, in two trials and in a completely randomized design. *Sesbania pachycarpa* seeds were acid-scarified for durations ranging from 0-60 minutes and later up to 120 minutes. Acid-scarified seeds were tested for longevity of storage at ambient temperature for up to 12 weeks, and were sown at varying depths up to 16 cm. Seedlings of *S. pachycarpa* were raised in pots, with three pots randomly selected for the assessment of seedling performance at 2-week intervals for 14 weeks. The seed germination increased with duration of acid scarification, reaching the peak (about 96.67%) at 50 minutes, which was maintained up to 120 minutes. Acid-scarified *Sesbania* seeds stored for 4 weeks and the seeds lost viability at 12 weeks. The seeds did not germinate at depth more than 4 cm. The plants were fast growing, nodulating, not precocious and accumulated about 55.90 g/plant over 14 weeks. The tolerance of seeds of *Sesbania pachycarpa* for 120 minutes acid treatment may indicate its tolerance of acid soils. The plant will enhance soil biomass and fix atmospheric nitrogen into the soil, thus increasing carbon sequestration and reducing input of inorganic nitrogen fertilizer into the soil. Therefore, the plant may be ideal to establish sown fallow and green manure to restore fertility to degraded farmlands.

Keywords: Conservation agriculture, Biological Nitrogen Fixation, Seed germination, *Sesbania pachycarpa*, Biomass accumulation, Carbon sequestration

Introduction

Woody and herbaceous species such as *Leucaena leucocephala*, *Gliricidia sepium, Flemingia congesta* and *Sesbania rostrata* have shown good potentials for inclusion in alley cropping systems aimed at achieving ecological balance in the farming system. Weeds have potentials in checking erosion, preventing moisture loss, ameliorating soil temperatures and effectively suppressing growth of other plants (Awodoyin and Ogunyemi, 2005a). If such plants are nodulating and form effective symbiotic association with *Rhizobium* bacteria, they can replenish the nitrogen content of the soil (Lannetta *et al.*, 2010). The use of green manure crops that have weed-smothering capability would have the additional benefit of adding biomass to soil (Lazzeri and Manici, 2000). This is because the introduction of legumes have been shown to improve fallow system through nutrient cycling, litter fall, biomass input and biological nitrogen fixation (Gathumbi *et al*., 2002).

Sesbania pachycarpa is a member of the plant family Fabaceae in the sub-family Faboideae. It is an annual tropical plant with origin traced to Africa. *Sesbania* consists of about 50 species of fast growing trees, perennial shrubs and herbaceous annuals. Thirty three (33) species are found in Africa, 20 of which are in eastern Africa. Tanzania, where 15 of these are found, is considered a major centre of diversity of these species (Otieno, 1987; Lugenja, 1988). The most important use of the plant is in nitrogen fixation as a green manure and the auxiliary uses are as sources of fuel wood, pulpwood and fiber (Evans and Rotar, 1987). The majority of *Sesbania* species are annuals, and some are relatively short-lived perennials. The ability of *Sesbania* species to grow in heavy metal-polluted soils, withstand waterlogging, and tolerate soil salinity, often made it the preferred green manure crops for rice and wheat (Evans and Rotar, 1987). *Sesbania rostrata*, native to tropical West Africa, is an annual species which bears stem as well as root nodules associated with *Azorhizobium caulinodans,* a specialized fast-growing strain of *Rhizobia* which can fix nitrogen in its free-living form (Somasegaran and Hoben, 1994). A pigment in the root nodules called leghemoglobin, which supplies oxygen to the bacteria is responsible for the colour change. Ibeawuchi *et al*. (2004) reported that nodule weight, nodule numbers and total dry matter are all indices of nitrogen fixation since they have either direct or indirect relationship. *Sesbania pachycarpa* as an upland species may need to be studied for its potentials in conservation agriculture. Therefore, this study was conducted to investigate the improved fallow potentials of *Sesbania pachycarpa* by studying its germination biology and dry matter accumulation.

Materials and methods

Experimental site and materials

The studies were conducted in 2010 and 2011. Germination study was carried out in Petri dishes in the Ecology Laboratory, Department of Crop Protection and Environmental Biology, University of Ibadan (CPEB, UI). The seeds used for dormancy verification study were freshly collected from the wild in each year on Ibadan-Iwo-Osogbo (7^{o}31\`N; 4$^{o}$10\`E) and Ibadan-Abeokuta (7^{o}15\`N; 3$^{o}$18\`E) transport routes. The seeds of *S. pachycarpa* scarified in tetraoxo sulphate (VI) acid for 50 minutes were used for the duration of storage, depth of sowing and growth studies. Depth of sowing and early growth studies were carried out in pots in the screen house (latitude 7^{o}27\`N; longitude 3$^{o}$35\`E; altitude 218 m above sea level), Department of CPEB, UI. The topsoil used for the pot studies was collected from the crop garden with each pot (20 cm top diameter and 22 cm depth) filled with 4.0 kg (dry weight) of the soil. The soil is slightly acidic (pH=6.2) and belongs to sandy loam textural class.

Experimental design and treatments

Germination study on the seeds of Sesbania pachycarpa

The seeds of *Sesbania pachycarpa* were subjected to acid scarification by steeping in concentrated tetraoxosulphate (VI) acid in a 250 cm^3 beaker for 0, 5, 10, 15, 20, 30, 40, 50, 60 minutes and later up to 120 minutes. At the end of each test time some seeds were scooped out into a plastic cup with perforated base and placed under running water for five minutes to wash off the acid. Twenty (20) seeds were counted and placed in a Petri dish (9-cm diameter) lined with Whatman No. 1 filter paper. The treatments were replicated three times in a completely randomized design. The Petri dishes were arranged on laboratory table where they received light averaging 425.81±89.53 Lux during the day for about 13 hrs (Dispart & Coalescent digital lux meter model) and 6.88±1.26 Lux during the night for about 11 hrs. Daily moistening of filter papers was done and germination, taken as protrusion of radicle, was monitored each day for seven days. The study was conducted in two trials. Percentage seed germination was calculated as:

$$\frac{\text{No. of germinated seeds}}{\text{Total no. of seed sown}} \times 100\ (\%)$$

ANOVA and LSD (p = 0.5) were used to compare the treatments in each of the two trials.

Longevity of viability of acid-treated seeds of S. pachycarpa

Seeds of *S. pachycarpa* treated in acid for 50 minutes as above were thoroughly washed, air-dried, packed into an air tight container and kept on laboratory table at ambient temperature (28±2 ^{o}C) for durations 0, 4, 8 and 12 weeks (treatments). At each timeline, 20 seeds were counted and placed in a Petri dish (9-cm diameter) lined with Whatman No. 1 filter paper. The treatments were replicated three times in a completely randomized design. Daily moistening of filter papers was done and germination, taken as protrusion of radicle, was monitored daily. Number of seeds that germinated was recorded as a cumulative number on 3, 6 and 9 days after setting. The study was conducted in two trials. Percentage seed germination was calculated as above. ANOVA and LSD (p = 0.5) were used to compare the treatments in each of the two trials.

Depth of sowing as it affects seed germination

The study was a pot experiment with five depth treatments, which included 0, 2, 4, 8 and 16 cm. Fifteen pots were filled with soil (4 kg each) collected from the crop garden of the Department of CPEB, UI. The pots were arranged in a completely randomized design with three replicates. With the use of a dribbling stick, four holes were made to the test depths in three (replicates) randomly assigned pots. Five acid-treated seeds were sown in each hole to have 20 seeds per pot. The holes were covered with soil. The pots were adequately watered and excess water drained off from the perforations at the base of each pot. Germination, taken as emergence of shoot, was recorded as a cumulative number on 3, 6 and 9 days after sowing. Percentage germination was calculated as above. ANOVA and LSD (p = 0.5) were used to compare the treatments in each of the two trials.

Early Growth Study

It was a completely randomised design study involving 21 pots. Three acid-scarified seeds of *S. pachycarpa* were sown per pot. At two weeks after sowing, the seedlings were thinned to one per pot. At two weeks interval for 14 weeks, three pots were randomly selected for the assessment of growth and dry matter accumulation. At each assessment the height and stem diameter of each plant were taken with meter rule and electronic digital vernier caliper (Powerfix ® model), respectively. Each seedling was lifted out with the ball of earth and lowered in bucket filled with water to loosen the soil and recover nodules on the roots. Each plant was mopped dry, enveloped and oven-dried at 80 ^{o}C to a constant weight. Each dried plant sample was weighed using a top-loading Metler balance (model P1210) to determine the total dry matter. ANOVA and LSD (p = 0.5) were used to compare the treatments in each of the two trials.

Results and Discussions

Germination response to acid-scarification

The seed germination increased with duration of acid scarification, reaching the peak (93.3% - First trial and 100% - Second trial) at 50 minutes (Table 1). However, substantive germination (about 65%) was obtained at 40 minutes duration. The 50 minutes and 60 minutes durations were not significantly different in the two trials but significantly better than other durations (Table 1). The seeds tolerated acid treatment up to 120 minutes with high germination ranging between 70% and 93.3% across the treatments (Table 2). The percentage germination at 50 minutes up to 120 minutes were not significantly different but better than control (Table 2).

The seed germination studies showed that there is inherent dormancy in *Sesbania pachycarpa* seeds, and it is probably associated with impervious seed coat. A seed is dormant if it does not germinate when conditions are favourable for germination and subsequent growth of that species (Das, 2011). Many weed seeds of Cucurbitaceae, Fabaceae, Poaceae and Convolvulaceae are known to exhibit dormancy periods for many years (Das, 2011).

Table 1. Mean cumulative number of germinated seeds (square root transformed) of *Sesbania pachycarpa* scarified in concentrated tetraoxosulphate (VI) acid (H_2SO_4) at varying duration up to 60 minutes on the 6th day after scarification. (Values in parenthesis are percentage germination).

Duration (Minutes)	Trials	
	1	2
0	0.07(0.00)	0.07(0.00)
5	0.07(0.00)	0.07(0.00)
10	0.07(0.00)	0.07(0.00)
15	1.13(10.00)	0.07(0.00)
20	0.07(0.00)	4.53(20.00)
30	4.69(23.23)	6.36(40.00)
40	7.76(60.00)	8.39(70.00)
50	9.68(93.33)	10.02(100.00)
60	9.51(90.00)	9.67(93.33)
LSD $_{(0.05)}$	0.75	0.34

Table 2. Mean cumulative number of germinated seeds (square root transformed) of *Sesbania pachycarpa* scarified in concentrated tetraoxosulphate (VI) acid (H_2SO_4) at varying duration up to120 minutes on the 6th day after scarification. (Values in parenthesis are percentage germination).

Duration (Minutes)	Trials	
	1	2
0	0.07(0)	0.07(0)
50	8.35(70)	9.33(86.66)
60	9.15(83.33)	9.67(93.33)
70	8.53(73.33)	9.68(93.33)
80	9.33(86.66)	9.50(90.00)
90	9.50(90.00)	9.50(90.00)
100	9.33(86.66)	9.67(93.33)
110	9.33(86.66)	9.85(96.67)
120	9.50(90.00)	9.32(86.67)
$LSD_{(0.05)}$	1.13	0.79

Maximum germination was attained within six days of the treatment in the two studies. It has been reported that though all seeds may suffer enforced dormancy as a result of deep seed burial, seed coat impermeabilty is peculiar to legumes as a result of deposition of lignin and suberin (Copeland, 1976; Awodoyin and Ogunyemi, 2003). Extending scarification in acid in this study for longer periods, up to two hours, had no deleterious effect on germinability of *Sesbania pachycarpa* seeds nor vigour of resulting seedlings. Tolerance of long acid treatment was also reported in *Sesbania drummondii* seeds that had improved germination by soaking in acid for up to 4 hours (Easton, 1984). Alaniz and Everitt (1980) obtained 40 - 60% germination in anacua seeds by soaking them in acid for two hours. The result may also suggest that the plant will tolerate acid soils that are peculiar to the tropics.

Longevity of acid-scarified seeds of Sesbania pachycarpa in storage

The viability of acid-scarified seeds of *S. pachycarpa* significantly declined with increasing duration of storage. The control treatment (seeds sown immediately after acid-scarification) had the highest germination of 90 and 96.67% in the 1st and 2nd trials respectively (Table 3). The viability had dropped to about 70% at four weeks after acid scarification. The treated seeds had very low percentage germination (about 18%) at eight weeks of storage and lost viability within 12 weeks of acid scarification (Table 3). This may suggest that the impervious seed coat confers longevity on *Sesbania* seeds as they lost viability substantially within 12 weeks of acid-scarification. Lewis (1973) reported that the seeds of legumes can remain viable for a very long time.

Table 3. Mean germination (Square root transformed) on 6th day of acid-scarified seeds of *Sesbania pachycarpa* stored for 4, 8 and 12 weeks. (Values in parenthesis are percentage germination).

	Trials	
Weeks after acid treatment	**1**	**2**
0	9.51(90.00)	9.85(96.67)
4	8.57(73.33)	8.39(70.00)
8	4.53(20.00)	4.1(16.66)
12	0.71(0.00)	1.13(3.33)
$LSD_{(0.05)}$	1.29	1.14

Table 4. Mean cumulative germination (square root transformed) of *Sesbania pachycarpa* seeds as affected by depth of sowing in a pot experiment in the Screen house (Values in parenthesis are percentage germination)

	Trials	
Depth of sowing (cm)	1	2
0	9.15(83.33)	9.51(90.00)
2	9.51(90.00)	9.68(93.33)
4	8.35(70.00)	7.78(60.00)
8	0.07(0.00)	3.24(10.00)
16	0.07(0.00)	0.07(0.00)
$LSD_{(0.05)}$	0.74	0.37

Effect of various depth of sowing on seed germination of Sesbania pachycarpa

Germination of seeds of *Sesbania pachycarpa* at surface soil and 2-cm depth were not significantly different but significantly higher (about 90%) than germination at other depths (Table 4). Germination was still fairly high (about 65%) at 4-cm depth but dropped significantly (about 0-10%) at depths 8 and 16 cm. The reducing germination with increasing depth may be due to the fact that the oxygen supply is reduced at deeper soil layer and so seeds sown at such depth had reduced oxygen supply which is necessary for germination (Das, 2011). Seeds sown at greater soil depth usually do not germinate and remain dormant until they are brought back to the soil surface (Akobundu, 1987). Also, small weed seeds usually (less than 2 mm), do not usually germinate below 5 cm soil depth (Das, 2011). Awodoyin and Ogunyemi (2003) reported that sickle pod seed germinated at 1-8 cm depth but no emergence at 16 cm depth. There was no additional germination at 6 days after sowing.

Early seedling growth

Within 14 weeks of growth, *Sesbania* seedlings had attained an average height of 169 and 177 cm and stem diameter of 11.23 and 13.20 cm, and had accumulated 52.10 and 59.70 g total biomass during the 1st and 2nd trial respectively (Table 5). The seedlings were observed to produce nodules from 5 weeks after planting and did not produce flowers and seeds (not precocious) within the 14-week study. The implication of this may be that the plant can be grown for up to 10 weeks for use as green manure or as interplant mulch source. The observed rapid dry matter accumulation in *Sesbania pachycarpa* is peculiar to most tropical green manure legumes. Lathwell (1990) reported that under favourable conditions in the tropics, dry matter accumulation is rapid in legume green manure plants and in a few weeks, large amount of both dry matter and nitrogen are present. Yamoah and Getahun (1989) suggested that *Sesbania* tree and shrub species are promising for alley cropping because they are easy to establish and they grow rapidly, coppice readily and provide high nutrient mulch.

Table 5. The growth and biomass accumulation of *Sesbania pachycarpa* over 14 weeks in Ibadan, Nigeria.

Age (Weeks After Planting)	Plant Height (cm/plant)		Stem Diameter (cm/plant)		Plant Dry weight (g/plant)	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
2	20.00	19.00	0.98	1.38	0.33	0.37
4	43.00	54.00	2.40	3.22	5.08	6.24
6	62.00	72.00	3.77	3.90	10.30	12.11
8	86.00	93.00	5.10	5.87	21.73	24.38
10	111.00	125.00	7.68	8.32	37.34	36.90
12	132.00	140.00	9.75	10.54	44.10	47.05
14	169.00	177.00	11.23	13.20	52.10	59.70
$LSD_{(0.05)}$	7.98	5.69	9.34	4.53	8.03	9.15

Conclusion

To obtain uniform germination in *Sesbania pachycarpa*, this study has revealed that the seeds must be scarified in Conc. H_2SO_4 for at least 50 minutes. Also, the seeds once acid-scarified should be sown within four weeks and within 2-cm depth to obtain high percentage seed germination. The fast-growing attribute of the plant might have conferred on it superior competitive ability, which is relevant in suppressing weeds. As a result of the rapid biomass production, if the plant is integrated into the soil it will increase the organic matter content, and its nodule production may suggest its atmospheric nitrogen-fixing potential. These will increase the carbon sequestration potential of the soil and reduce input of inorganic nitrogen fertilizer into agriculture, thus reducing nitrogen-pollution of ground and surface waters; and reducing the release of nitrous oxide (a greenhouse gas) into the atmosphere. These will contribute to the mitigation of global warming. Since the plant is not precocious, it can be used to establish sown fallow and green manure without the fear of multiplying its seeds in the soil seed bank. From the observed rapid dry matter accumulation, and nitrogen fixing ability of *Sesbania pachycarpa*, it will be a good sown fallow and green manure plant.

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