Effect of Wart Disease on Survival and Yield of the Tropical Pasture Legume *Desmodium ovalifolium*

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ABSTRACT

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Desmodium wart, caused by *Synchytrium desmodii*, severely reduced soil seed reserves, seedling survival, and recruitment of adult plants of *Desmodium ovalifolium* 'CIAT 350' to the pasture sward from 1985 to 1988 at Carimagua in the eastern plains of Colombia. Under nonflooded conditions, wart did not reduce yield of adult plants of CIAT 350, while under intermittently flooded conditions, yield of CIAT 350 was reduced by 72.5%. Dry matter production of five accessions of *D. ovalifolium* was also greatly reduced in intermittently flooded, wart-inoculated treatments in another experiment. CIAT 13089 was distinguished by high dry-matter production under the same conditions. These serious effects of wart on legume yield and persistence will reduce long-term productivity and quality of perennial pastures based on *D. ovalifolium*.

Desmodium ovalifolium Wall. is a productive perennial pasture legume of Asiatic origin that is well-adapted to infertile soils and tolerant of intermittent flooding in humid regions of the tropical American lowlands (1,2,9,10). Because of its stoloniferous growth habit, it associates well with aggressive grasses, such as *Brachiaria* species (1,9). Wart disease, caused by *Synchytrium desmodii* Munasinghe, was first reported in South America in 1981 at Carimagua in the eastern plains of Colombia (5). It has since spread throughout pastures of *D. ovalifolium* in Brazil, Colombia, Ecuador, Peru, and Central America on contaminated pods associated with seed imported from Asia and infected vegetative planting material (5,6).

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Wart is manifested in shortening of internodes and proliferation and deformation of trifoliolate leaves, which gives affected plants a rosetted appearance (5). Affected stem apices and young plants often die, but adult plants usually regrow healthy stems even after severe attack. Yellow-orange to yellow-brown galls filled with sporangia and zoospores form on all warted tissues (5,7).

The distribution and severity of wart in pastures of *D. ovalifolium* is temporally and spatially variable, therefore, various strata of the perennial pasture population are affected differently. Adult plants in low-lying, poorly drained areas are severely warted, while plants in better drained areas appear to grow vigorously in spite of wart. Seedlings are usually severely diseased under both nonflooded and intermittently flooded conditions (5). Although the importance of moisture in liberation and germination of sporangia and zoospores and infection by *S. desmodii* has been investigated in detail (7,8), the difficulty of accurately evaluating damage caused by wart has delayed attempts to quantify losses. This study was undertaken to determine the effects of wart on 1) soil seed reserves and survival and recruitment to the adult plant population of seedlings of *D. ovalifolium* 'CIAT 350,' and 2) adult plant yield of six accessions of *D. ovalifolium* under nonflooded and intermittently flooded conditions.

MATERIALS AND METHODS

Effect of wart on soil seed reserves, seedling survival, and recruitment. Two experiments were carried out at the ICA-CIAT Research Station in the eastern plains of Colombia. Experiment 1 was conducted in a 4-yr-old pasture of *D. ovalifolium* associated with the grass *Brachiaria decumbens* Stapf from April 1985 to 1987, while experiment 2 was carried out in a 2-yr-old pasture associated with *B. humidicola* (Rendle) Schweick. from April 1986 to 1988. Soil

seed reserves (viable seed present in the soil) were measured in the top 5 cm of the soil according to the method of Jones and Bunch (3) in April 1985, 1986, and 1987 for experiment 1 and in April 1986, 1987, and 1988 for experiment 2. At the beginning of both experiments, existing adult plants were marked with small wire tags to avoid confusion with recruited plants. At the beginning of the second year of each experiment, recruited adult plants from the previous year were also marked.

In both experiments, 32 1-m^2 permanent quadrats were randomly located in both wart-affected and wart-free areas to assess seedling survival and recruitment. At the beginning of the wet season in May and at monthly intervals, seedlings were counted in each quadrat from May to December 1985 and 1986 in experiment 1 and from May to December 1986 and 1987 in experiment 2.

Effect of wart on yield under intermittently flooded and nonflooded conditions. Two experiments, designated experiments 3 and 4, were carried out at Carimagua, Colombia. From May 1985 to November 1986, *D. ovalifolium* 'CIAT 350' was evaluated in experiment 3, while from May 1987 to October 1988, six accessions of *D. ovalifolium* (CIAT 350, 3776, 3794, 13089, 13092, and 13129) were tested in experiment 4. In experiment 3, 3 × 3 m plots, sown with scarified seed, were allocated to four treatments (nonflooded, inoculated; nonflooded, noninoculated; intermittently flooded, inoculated; and intermittently flooded, noninoculated) in a randomized block design with ten replications. Intermittently flooded treatments were achieved by removing soil to a depth of 3 cm before planting in May 1985. After each rain shower, plants remained in standing water for one to several hours. Recommended fertilizer was applied (9) and plots were left to grow during 1985. All plants were cut to a height of 20 cm in November 1985. No visual differences in vigor and establishment were evident between nonflooded and intermittently flooded treatments before inoculation.

In May 1986, chopped, wart-affected leaves of CIAT 350 were evenly spread over inoculated treatments at about 500 g per plot. Chopped, healthy leaves of CIAT 350 were applied to noninoculated treatments at the same rate. Evaluations of wart severity were made each month from June to November 1986 according to a visual scale where 0 = no disease; 1 = less than 5% of plot affected; 2 = 5–25% of plot affected; 3 = 25–50% of plot affected; 4 = 50–75% of plot affected; and 5 = more than 75% of plot affected. Plots were cut to a height of 10 cm in July, September, and November 1986, and fresh and dry weights were determined.

In experiment 4, noninoculated treatments were not used and the number of replications was reduced to four. Two treatments were compared: intermittently flooded, inoculated and nonflooded, inoculated. Experiment 4 was planted in May 1987, recommended fertilizer was applied, and plots were left to grow during 1987. At the same time, a duplicate experiment was set up 500 m away. A cut to make plants uniform in height was made in October 1987, and all plots were inoculated in May 1987 with the same methodology used in experiment 3. Evaluations of wart severity were made each month from June to October 1988 with the use of the rating scale listed in experiment 3. In addition, percentage of soil cover and vigor were rated monthly. Vigor was rated according to a scale where 1 = poor, 2 = fair, 3 = good, and 4 = excellent. Yield assessments were made in July, August, and October 1988 in the same way as in experiment 3.

Table 1. Soil seed reserves of *Desmodium ovalifolium* 'CIAT 350' in wart-affected and wart-free areas of pastures from April 1985 to April 1988

Sampling date	Experiment 1		Experiment 2	
	Wart-affected	Wart-free	Wart-affected	Wart-free
April 1985	1,480[y] a	1,186 a	...[z]	...
April 1986	230 b	1,373 a	1,714 a	1,548 a
April 1987	8 b	1,240 a	562 b	1,352 a
April 1988	...	...	128 b	1,625 a

[y] Number of seed per kilogram of dry soil in the top 5 cm of soil according to the method of Jones and Bunch (3). In each experiment, numbers in vertical columns followed by different letters are significantly different at $P < 0.05$ by Duncan's multiple range test.
[z] Not measured.

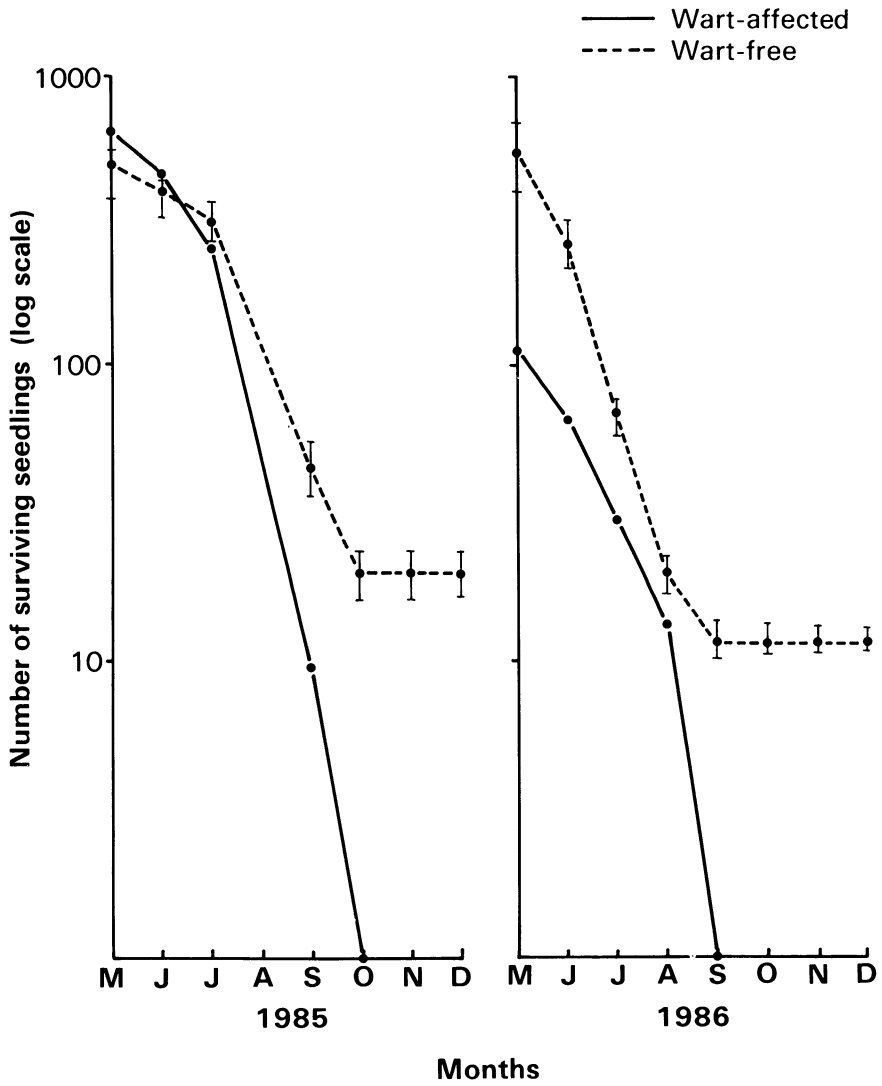

Fig. 1. Effect of wart on seedling survival of *Desmodium ovalifolium* 'CIAT 350' in 1985 and 1986. Each data point is a mean of 32 observations. Bars indicate LSD ($P < 0.05$).

RESULTS

Effect of wart on soil seed reserves, seedling survival, and recruitment. In experiments 1 and 2, soil seed reserves in wart-affected areas decreased substantially during the periods of assessment (Table 1). During the same sampling periods, soil seed reserves in wart-free areas remained the same in each experiment.

At the beginning of the wet season in the first year of experiment 1 (May 1985, Fig. 1) and experiment 2 (May 1986, Fig. 2), between 500 and 800 seedlings per square meter emerged in both wart-free and wart-affected areas. The number of seedlings decreased rapidly from May to September in wart-free and wart-affected areas in both experiments; however, the mortality rate was greater in wart-affected areas. By late December 1985 (experiment 1) and 1986 (experiment 2), all seedlings in wart-affected areas had died. In wart-free areas, 21 (Fig. 1) and 16 (Fig. 2) plants per square meter had been recruited to the adult plant population.

At the beginning of the wet season in the second year of both experiment 1 (May 1986, Fig. 1) and experiment 2 (May 1987, Fig. 2), between 500 and 800 seedlings per square meter again emerged in wart-free areas, however, less than 200 seedlings per square meter emerged in wart-affected areas. At the end of December 1986 in experiment 1 and December 1987 in experiment 2, all seedlings in wart-affected areas had died, while 11 and 14 plants per square meter, respectively, were recruited to the adult plant population in wart-free areas.

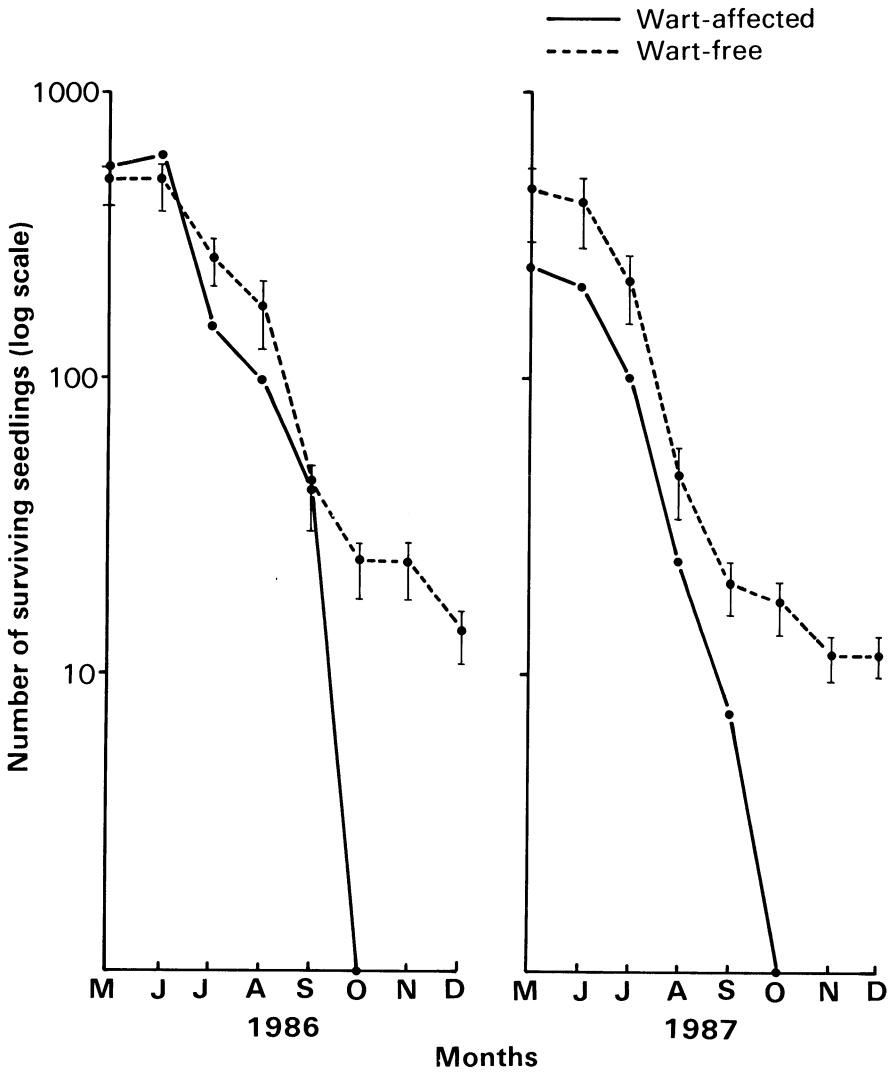

Fig. 2. Effect of wart on seedling survival of *Desmodium ovalifolium* 'CIAT 350' in 1986 and 1987. Each data point is a mean of 32 observations. Bars indicate LSD ($P < 0.05$).

Table 2. Adult plant yield of *Desmodium ovalifolium*, 'CIAT 350' under nonflooded and intermittently flooded conditions and in plots inoculated or not inoculated with *Synchytrium desmodii* in 1986

Treatment	Wart severity[y]	Dry matter production[z] (kg/ha)
Intermittently flooded		
Inoculated	3.4 a	911 b
Not inoculated	0 c	3,317 a
Nonflooded		
Inoculated	2.1 b	3,015 a
Not inoculated	0 c	2,891 a

[y]According to the scale 1 = no disease; 5 = greater than 75% of plot affected.
[z]Mean of three harvests in July, September, and November 1986. Numbers in vertical columns followed by different letters are significantly different by *t* test at $\propto = 0.05$ probability.

Effect of wart on yield under intermittently flooded and nonflooded conditions. In experiment 3, wart severity in CIAT 350 was significantly greater under intermittently flooded than nonflooded conditions in inoculated plots (Table 2). Adult plant yield was significantly reduced under intermittently flooded but not under nonflooded conditions (Table 2). Losses of 72.5% dry matter were measured under intermittently flooded conditions. Yield was not affected by flooding in noninoculated treatments.

Because growth and vigor of CIAT 350 were not reduced by intermittent flooding and, as yield was not reduced by wart in nonflooded, inoculated treatments, non-inoculated treatments were not included in experiment 4. In that experiment, all accessions of *D. ovalifolium* (except CIAT 3776 and 13092) were less affected by wart under nonflooded than they were under intermittently flooded conditions (Table 3). The same levels of wart were recorded in CIAT 3776 under both conditions. Percentage soil cover and vigor of CIAT 350, 3776, 3794, and 13129 were lower than those of CIAT 13089 under intermittently flooded conditions (Table 3). CIAT 13092 showed intermediate levels of soil coverage and vigor under the same conditions. CIAT 13089 showed lowest wart severity under nonflooded conditions.

Under intermittent flooding, dry matter production of CIAT 13089 was greater than CIAT 13092, which was greater than CIAT 13129 (Table 3). Lowest yields were recorded in CIAT 350, 3776, and 3794. Under nonflooded conditions, CIAT 13089 produced the highest, while CIAT 350, 3776, and 3794 produced the lowest dry matter (Table 3). In the presence of wart, dry matter production of all accessions except CIAT 13089 was reduced under intermittent flooding in comparison to nonflooding. The correlation between yield and wart severity was significant ($r = -0.69$, $P < 0.05$). Dry matter production of CIAT 350 was similar in the presence of wart in both experiments 3 and 4 (Tables 2 and 3). Experiment 4 was repeated nearby with similar results.

DISCUSSION

Desmodium ovalifolium is a free-seeding legume with good annual seed production in humid areas (1), a quality important for long-term persistence in perennial pasture plants. Findings of soil seed reserves as high as 1,186 to 1,625 viable seed per kilogram of dry soil in wart-free areas (Table 1) support this. Seedlings of *Desmodium* species are, however, susceptible to competition (2). In wart-free areas with 500–800 seedlings per square meter of CIAT 350 emerging in the first month of the wet season, only 21 and 11, and 16 and 14 plants, respectively, were recruited to the adult legume population in 1985 and 1986 in experiment 1 (Fig. 1) and in 1986 and 1987 in experiment 2 (Fig. 2). Interseedling competition for light, moisture, and nutrients was apparently the major cause of death, although insect predation and damage from stem gall nematode (4) were also noted. In spite of high seedling mortality in wart-free areas, recruitment of new adult plants to the legume sward increased the potential long-term persistence of CIAT 350 in both experiments.

In wart-affected areas, however, all CIAT 350 seedlings died in both experiments (Figs. 1 and 2). No new plants were recruited to the adult legume population from 1985 to 1988. In both experiments, soil seed reserves severely declined during the sampling period (Table 1), which suggests that wart also considerably limits the seed production capability of adult plants.

The capacity of wart to severely reduce soil seed reserves and eliminate seedling populations of CIAT 350 seriously threatens long-term persistence of *D. ovalifolium* in wart-affected pastures. Seedling screening has as yet failed to find sufficient resistance among over 100 accessions of *D. ovalifolium* (J. M. Lenné, *unpublished*). Refined screening techniques currently being developed may enable better distinction of levels of resistance.

Wart reduced yield of adult plants of CIAT 350 by 72.5% dry matter under intermittently flooded conditions in experiment 3 (Table 2). The semi-prostrate growth habit of this legume ensures frequent prolonged contacts of plant surfaces with water under intermittently flooded conditions. As *S. desmodii* is dependent on free water for zoospore release and infection (7,8), this environment was most conducive to continual zoospore release, infection, and wart development. Although moderate wart levels were recorded, yield of CIAT 350 was not reduced under nonflooded conditions. Most basally infected laterals were able to grow away from the source of infection under nonflooded conditions.

Dry matter production, vigor, and soil coverage were lower and wart severity higher in most accessions of *D. ovalifolium* under intermittent flooding than in nonflooding in experiment 4. Under intermittent flooding in the presence of wart, CIAT 13089 appeared less susceptible, produced more dry matter, and was more vigorous than other accessions. This could be related to growth habit. CIAT 13089 grows more erectly than CIAT 350, 3776, and 3794 (9), which were severely damaged by wart under intermittently flooded conditions (Table 3). A more erect growth habit would reduce contact of lateral branches with water, thereby reducing infection by *S. desmodii* and wart development. CIAT 13089 is also highly resistant to stem gall nematode, another important pathogen of this legume (11).

The manifestation of wart by significant yield reduction of adult plants of *D. ovalifolium* under intermittently flooded conditions severely reduces legume productivity and, as a result, nitrogen fixation capability. Not only is legume forage lost, but the grass may become less productive over time because of nitrogen deficiency. In addition, reduced vigor caused by wart decreases the ability of *D. ovalifolium* to compete with aggressive stoloniferous *Brachiaria* species and weeds, which rapidly colonize bare ground caused by reduced soil coverage by the legume.

In a mixed perennial pasture, if a disease affects the legume component of the sward, it not only reduces the productivity and persistence of the legume, it also reduces the total pasture productivity and persistence. Because of reduced legume competitive ability, the pasture could soon become grass-dominant, weedy, and of lower overall productivity and quality for animal production.

Methodology is now available for accurately evaluating the effect of wart on the various strata of perennial pastures based on *D. ovalifolium*. Although total pasture loss assessments are in progress, a minimum of 5 yr of data is deemed necessary for realistic quantification of losses in a perennial pasture.

Table 3. Wart severity, adult plant yield, cover, and vigor of six accessions of *Desmodium ovalifolium* under nonflooded and intermittently flooded conditions in plots inoculated with *Synchytrium desmodii* in 1988

CIAT accession number	Flooded condition[w]	Wart severity[x]	Cover (%)	Vigor[y]	Dry matter production[z] (kg/ha)
350	+	2.1 ab	50.0 cd	1.9 cd	1,356 e
	−	0.7 d	70.5 ab	2.8 ab	3,740 bc
3776	+	1.8 b	52.8 cd	2.0 cd	1,310 e
	−	1.8 b	67.1 b	2.4 bc	3,514 bc
3794	+	2.1 ab	38.8 e	1.7 d	803 e
	−	1.3 c	61.0 bc	2.5 bc	2,904 c
13089	+	0.8 d	72.3 ab	2.9 ab	4,350 ab
	−	0.3 e	82.6 a	3.2 a	5,312 a
13092	+	1.5 bc	58.7 bcd	2.4 bc	2,789 c
	−	1.2 c	71.3 ab	2.7 ab	4,082 b
13129	+	2.5 a	49.0 d	2.1 cd	2,005 d
	−	1.3 c	70.0 ab	2.8 ab	4,073 b

[w] Flooded condition + = intermittently flooded; − = nonflooded. Numbers in vertical columns followed by different letters are significantly different at $P < 0.05$ by Duncan's multiple range test.
[x] According to the scale 1 = no disease; 5 = greater than 75% of plot affected.
[y] According to the scale 1 = poor; 4 = excellent.
[z] Mean of three harvests in July, August, and October 1988.

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