Effect of Mulching on Web Blight of Beans in Costa Rica

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ABSTRACT

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Mulching was highly effective and superior to chemical treatments for the control of web blight (WB) caused in beans by *Rhizoctonia solani*, the imperfect state of *Thanatephorus cucumeris*. Plots were established in fields with a history of repeated incidence of WB. Soilborne sclerotia and colonized debris spread by splashing rain were the main sources of inoculum for WB in these fields. Mulching with rice husks (2.5 cm thick) greatly reduced splashing of inoculum and lowered disease severity. At harvest, severity of WB in nontreated and mulched plots planted to cultivar Porrillo 70 was 100 and 13%, and seed yield was 0 and 655 kg/ha, respectively. In a second field with a lower level of inoculum, yield in the nontreated and mulched areas averaged 273 and 835 kg/ha, respectively. Similar results were obtained with cultivar Mexico 27. Mulching with rice husks was superior to PCNB soil drench (40 kg 75 WP/ha) in controlling WB. Seed treatment with benomyl (1 g benomyl, 50% WP, per kilogram of seeds) and soil application of paraquat (1 kg a.i./ha) were ineffective. The local production practice of "frijol tapado," in which seeds are broadcast in vegetation that is later cut and left as mulch, was as effective as rice husk mulching in reducing the incidence and severity of WB, but yields were lower.

Web blight (WB), which is caused in dry beans (*Phaseolus vulgaris* L.) by *Rhizoctonia solani* Kühn, the imperfect state of *Thanatephorus cucumeris* (Frank) Donk, is a major production problem in the warm humid tropical lowlands in Latin America and the Caribbean. Bean plants at any stage of development are attacked by the fungus, which causes very rapid defoliation and frequently complete crop failure (6,10,27). In 1980, an epidemic of WB that resulted in a 90% yield reduction occurred in the Guanacaste region in northern Costa Rica (1).

R. solani is an aggressive pathogen; no single control measure has been found effective against WB of beans (10,15,27). It is often recommended that the dates of bean planting in the tropics be adjusted so that beans complete their growth before the beginning of the following rainy season (10,27). However, most of the bean production in the tropics of Latin America is in nonirrigated farming areas (11). Other suggested control measures include rotation with nonsusceptible crops, planting clean seeds, the destruction of infected plant parts as soon as possible after harvest, and planting beans in rows rather than on a broadcast basis. The latter practice is to maximize air circulation and thus provide unfavorable microclimatic conditions for fungal development (10,27).

Foliar applications of selected fungicides have also been recommended (10,17,19,24), but these fungicides are ineffective in areas where favorable conditions for disease development prevail (17). Among the fungicides applied for control of *R. solani* in the soil, pentachloronitrobenzene (PCNB) has been highly effective in reducing postemergence damping-off even in soils heavily infested with the fungus (15). It has been shown that PCNB is accumulated in root and hypocotyl tissues of bean seedlings, resulting in reduction of both the size and number of lesions incited by *R. solani* (2). Benomyl also has been reported to give protection against infection of bean seedlings by *R. solani* when applied as a seed coat treatment (21). In addition, the dessicant herbicide paraquat (1,1′-dimethyl-4,4′-bipyridinium ion) has been observed under field conditions to reduce WB incidence and severity when applied at planting time. The herbicide also has been reported to inhibit the growth of *R. solani* under laboratory conditions (23).

It has been shown that bean cultivars differ in susceptibility to *R. solani*, but there are no reports of high levels of resistance to this pathogen among the bean germplasms tested (5,10,18,24). In tests conducted in El Salvador, bush-type cultivars were observed to be very susceptible compared to the pole and intermediate-type beans (26). Greenhouse tests conducted in Mexico showed that all the commercial cultivars that are used widely throughout the bean-growing areas were susceptible to *R. solani* (6).

The main source of inoculum for WB of beans in Costa Rica was found to be rain-splashed soil containing sclerotia and mycelial fragments of *R. solani* (9). It was also observed that the incidence and severity of WB was much less in a traditional cropping system ("frijol tapado") used by small farmers as compared to clean cultivation where beans are grown in rows. Under the frijol tapado system, bean seeds are broadcast in vegetation that later is cut and left as a mulch (3,4).

The objectives of this study were to evaluate the relative effect of the frijol tapado cropping system and the effect of mulches and chemicals applied to the soil or bean seeds on WB incidence and severity.

MATERIALS AND METHODS

Most experiments in this study were established in a bean field near Esparza, Puntarenas, Costa Rica, which will be referred to here as the experimental field. It is located at 208 m above sea level and has a mean annual temperature of 26.5 C, precipitation of 2,320 mm/yr and an average relative humidity of 79% (11). The rainy season in this area extends from the middle of May to November. Incidence of WB was uniform and severe during the 1979 growing season. WB was the only disease of significance observed on beans in this field. A test was also established in a nearby commercial field with a history of relatively low incidence of WB.

The dry bean cultivars Porrillo 70 and Mexico 27, previously reported as tolerant and susceptible, respectively, to WB (5,24), were used in this study. Generally, each plot was 4 m long and four rows wide with 0.6 m between rows. The spacing of plants in the

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row was 7 cm. Prior to planting, the field was plowed once and disked twice. Fertilizers (275 kg/ha; 10-30-10, N-P-K) and the insecticide carbofuran (25 kg 10% Gr./ha; Furadan, 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) for rootworm control were applied to the bottom of the furrow and covered lightly with soil. Bean seeds were then manually placed in the furrow and covered with soil. The following day, plots were treated with a mixture of the herbicides Herbon (dinoseb, 2-(1-methyl-*n*-propyl)-4,6-dinitrophenylacetate) at a rate of 3 kg a.i./ha and Lazo (alachlor, 2-chloro-2′-6′-diethyl-*N*-(methoxymethyl)-acetanilide)

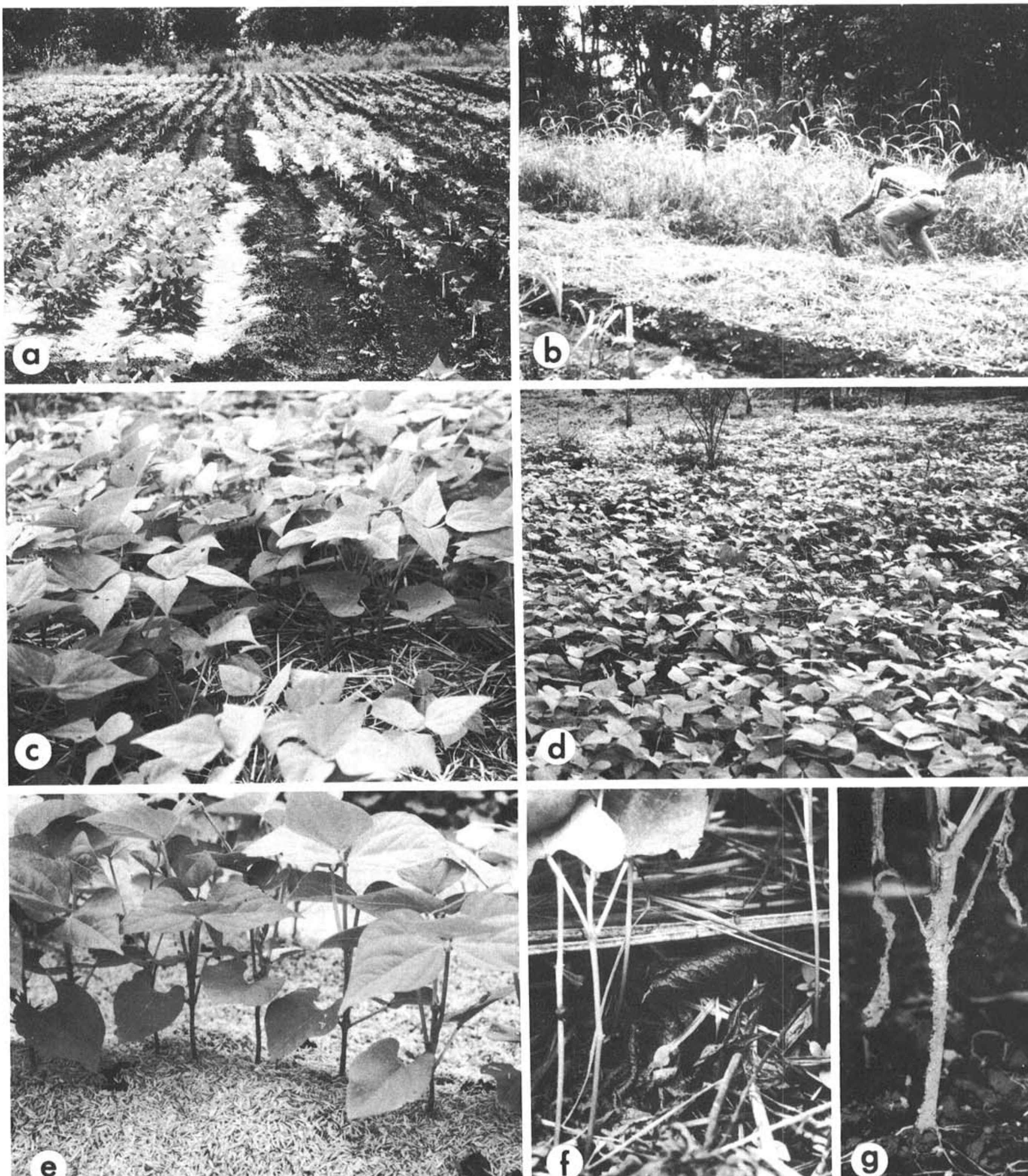

Fig. 1. Incidence and severity of web blight (WB) of beans on plants grown in mulched and nonmulched plots. **a,** Effective control of WB provided by mulching with rice husks (left foreground) as compared to the severe incidence of WB in the nonmulched check treatments (right foreground) at 5 wk after planting. **b,** Illustrates the effect of the "frijol tapado" (covered beans) cropping system in which bean seeds are broadcast in vegetation that is later cut with a machete and left as a mulch. **c,** Close-up of the mulch layer in the frijol tapado. **d,** General appearance of beans 3 wk after planting in a field under the frijol tapado. **e** and **f,** Close-up showing the healthy bean plants grown in plots mulched either with rice husk or the plant debris obtained by using the frijol tapado system, respectively. **g,** Close-up of a bean plant growing in nonmulched check plot exhibiting rain-splashed soil and severely infected primary leaves.

at a rate of 1 kg a.i./ha. Data were collected from the 80 central plants of the two central rows. Mulched plots received a 2.5-cm-thick layer of rice husks applied 1 day after planting.

The traditional cropping system, "frijol tapado" (Spanish for covered beans), was established by first allowing the natural vegetation to grow in the plot areas prior to planting date. Bean seeds and the recommended fertilizers and insecticides were then broadcast. Immediately after seeding, the weeds were cut with a machete and left as mulch (Fig. 1b). After emergence, bean plants were thinned to 35 seedlings per square meter. Data were collected from a central rectangle, which was 1.2 × 3.5 m. A split-plot randomized design was used, with chemicals or mulch treatments as main plots. Each treatment was replicated four times.

Two series of experiments were performed in 1980. In the first series, three treatments were evaluated during two bean growing seasons. The first growing season planting was established in the experimental field on 3 June. The second planting was made on 6 October in a commercial bean field. The three treatments evaluated consisted of frijol tapado, a rice husk mulch 2.5-cm thick, and nontreated check (clean cultivation).

In the second series, mulching and chemical soil treatments for WB control were evaluated during two growing seasons. Planting

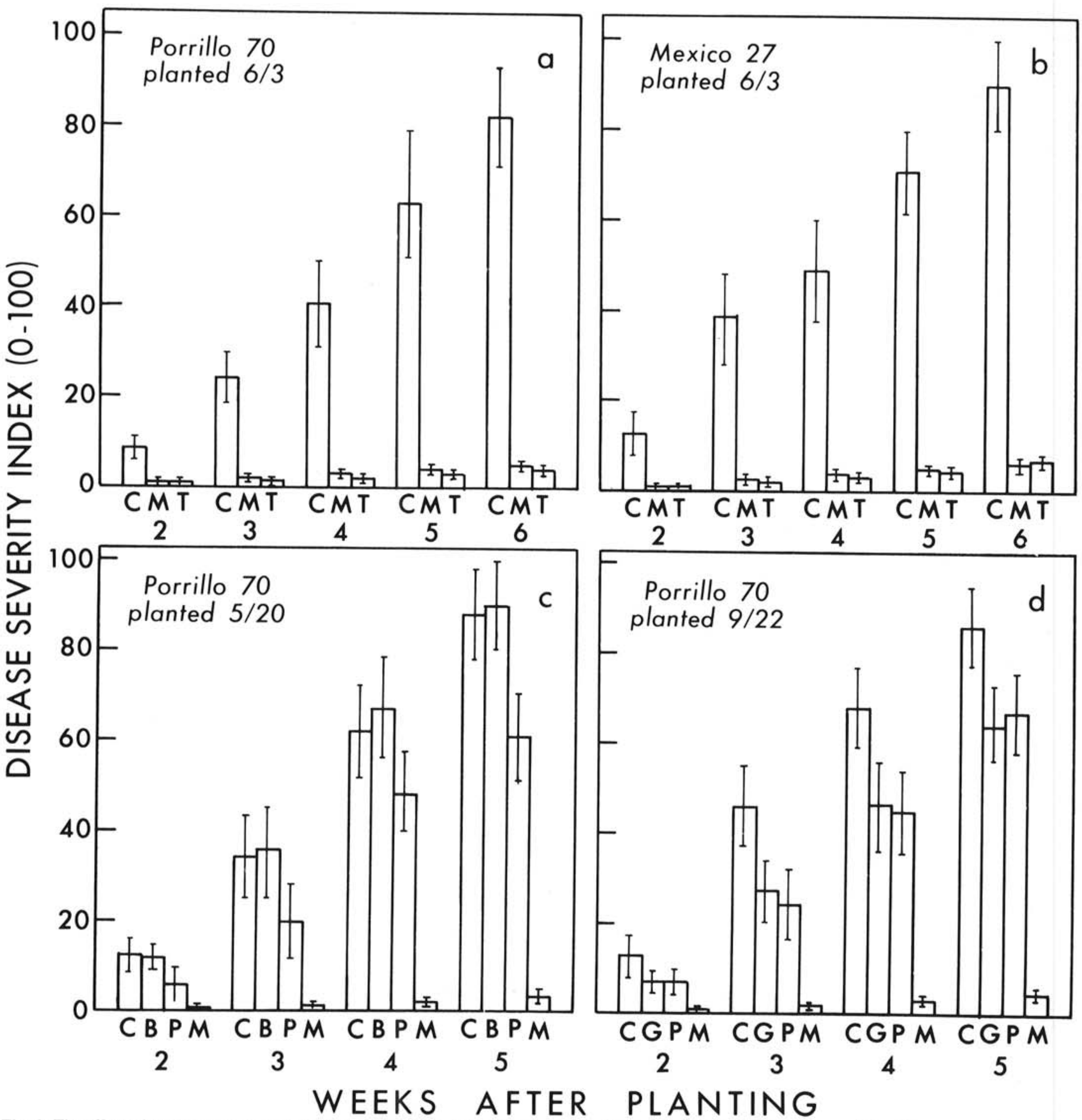

Fig. 2. The effect of mulching systems and selected chemical treatments on the development of web blight (WB) caused by *Rhizoctonia solani* in the experimental field. **a** and **b,** Refers to the effect of clean cultivation (C, nonmulched), mulching with rice husks (M), and mulching by the frijol tapado cropping system (T) on WB severity index on plants of cultivars Porrillo 70 and Mexico 27, respectively. **c** and **d,** Development of WB in a 20 May and a 22 September planting, respectively, in nonmulched check plots (C), benomyl-treated seeds (B), PCNB-treated soil (P), paraquat-treated soil (G), and rice husk mulch (M).

dates were 20 May and 22 September. Four treatments were evaluated at each planting date. The treatments in the first planting date consisted of PCNB 75% WP as a soil drench (40 kg/ha) 2 days prior to planting; benomyl 50% WP applied as seed dressing (1 g/kg of seed); a rice husk mulch 2.5-cm-thick applied to the plots 1 day after planting; and nontreated check. In the second growing season, the same treatments were repeated except the benomyl seed treatment was deleted and replaced with the paraquat treatment, which was applied at a rate of 1 kg a.i./ha 1 day after planting. The effect of paraquat on the population density of *R. solani* was evaluated by taking composite soil samples at 10 days after planting from the two central rows of nontreated and paraquat-treated plots, and assaying them using the selective medium and procedure of Ko and Hora (14).

WB severity ratings were determined at weekly intervals using a scale of 0 to 5. A rating of 0 refers to absence of disease symptoms; 1, up to 20% of plant tissues affected; 2, 21–40% of tissues affected; 3, 41–60% of tissues affected; 4, 61–80% of tissues affected; and 5, more than 80% of tissues affected or plants dead. The disease severity index was calculated following the procedure of Sherwood and Hagedorn (25).

RESULTS

Mulching of beans provided by either a layer of rice husks (Fig. 1a,e) or the frijol tapado method (Fig. 1b–d,f) was found to be highly effective in controlling WB of beans caused by *R. solani* (Fig. 1). No significant differences ($P = 0.05$) in disease incidence and severity ratings were observed between the two mulch treatments (Fig. 2a,b). Mulching of the cultivars Porrillo 70 and Mexico 27 with rice husks and frijol tapado resulted in greater than 80% reduction in disease severity index ratings as compared to the conventional clean cultivation method in the experimental field. Similar results were obtained with the two mulch treatments in the commercial field, although disease severity index ratings were lower. For example, the disease severity index for plants growing in the nonmulched plots, rice husk-mulched, and frijol tapado plots were 41, 6, and 6%, respectively, 8 wk after planting for the cultivar Mexico 27.

Bean seedlings in the clean cultivation plots in the experimental field were first observed to be infected 14 days after planting, and they became 100% infected 7 days later (Fig. 1a, right foreground). Prior to the detection of infection on the seedlings, splashed soil was observed on stem, petioles, and both primary and trifoliolate leaves (Fig. 1g). This rain-splashed soil was found earlier to be infested with sclerotia and mycelium of *R. solani* and served as the main source of inoculum for WB of beans (9). The primary leaves were generally the first to be infected and appeared completely necrotic 21 days after planting. Infection continued to advance rapidly as aboveground parts of plants of cultivar Mexico 27 became completely infected at 5 wk after planting. Generally, plants of cultivar Porrillo 70 became completely infected 1 wk later. Bean plants in the nonmulched plots in the commercial grower's field exhibited lower levels of incidence and severity of WB and plants of both cultivars reached maturity.

The mulch treatments prevented the rain from splashing soil that was infested with *R. solani* onto bean plants, and thus greatly reduced disease incidence and development (Fig. 1c,e,f) compared to that on plants growing in the nonmulched plots (Fig. 1a,g). However, a few plants in the mulched plots, generally on the borders, became infected as a result of contamination between plots. Nevertheless, infection in the mulched plots was considerably delayed, lesions were few and scattered generally on a few plants, and thus caused only light damage. Actually, primary leaves remained intact until they naturally became senescent and fell onto the surface of the mulch about 4–5 wk after planting. The mulch layer provided by the rice husks (Fig. 1e) was dense and compact, whereas that provided by the frijol tapado (Fig. 1c,f) was a loose and less dense layer that consisted mostly of decomposed tissues of weeds.

Large numbers of sclerotia were produced within 3 days after primary leaves were defoliated from plants growing in the nonmulched plots. However, no sclerotia were observed on primary leaves that fell onto the surface of mulched soil. In addition, the production of the hymenial layers of the perfect state (*T. cucumeris*) was not observed on any foliar tissues of bean plants or on the soil surface of mulched plots. In contrast, the hymenial layers of the fungus were often observed on the lower part of the stem and other tissues that also exhibited rain-splashed soil about 4–5 wk after planting. In a few instances, the perfect state was also observed on necrotic leaf tissues on the ground or on the soil surface adjacent to an infected bean stem. Lesions caused by basidiospores as described in the literature (9) were also observed during the second growing season, 35 days after planting on both mulched and nonmulched plots, but lesions remained restricted.

Generally, none of the chemical treatments evaluated significantly affected the incidence and severity of WB on the cultivar Porrillo 70 (Fig. 2c,d). Benomyl as a seed treatment was ineffective. Both the paraquat and PCNB treatments resulted in reduction of inoculum of *R. solani* in the top 15 cm of soil (Table 1) and also lowered WB severity early in the growing season. However, as the season progressed, WB severity increased rapidly and was not significantly different by harvest time from that on plants grown in the nontreated check plots. Similar results were obtained with the cultivar Mexico 27.

The yield of both bean cultivars (Mexico 27 and Porrillo 70) was significantly increased when the plots were mulched either by rice husks or by the frijol tapado system (Table 2). However, the yield of bean plants grown under the frijol tapado system was consistently lower than that of plants grown under the rice husk mulching system. None of the chemical treatments applied to the soil or the seeds was effective. Plants grown in the nonmulched plots in the experimental field with and without chemical treatments were completely destroyed (plants failed to produce seeds) by *R. solani*, in both the 3 June and 22 September plantings. In contrast, yield of the cultivar Porrillo 70 was 679 and 587 kg/ha and the cultivar Mexico 27 was 594 and 611 kg/ha in the plots mulched with rice husks at the 3 June and 22 September planting, respectively. In the nonmulched plots established in the commercial grower's field with only low inoculum density of *T. cucumeris*, bean plants reached maturity, but yields of plants infected by *R. solani* were

TABLE 1. Effect of soil treatment with paraquat and PCNB on population density of *Rhizoctonia solani*

Soil treatment	Colonies of *R. solani* per 15 g of soil[w] 14[x]	28	42
None	92 a	101 a	78 a
PCNB[y]	14 b	85 a	73 a
Paraquat[z]	26 b	72 a	87 a

[w] Each number is an average of five replicates. Estimates of the population were made following the procedure and the selective medium of Ko and Hora (14). Means in a column followed by the same letter are not significantly different ($P = 0.05$) according to the Waller-Duncan Bayesian *K*-ratio (LSD) rule.

[x] Refers to days after planting.

[y] PCNB at a rate of 40 kg/ha was applied as a drench treatment 2 days prior to planting.

[z] Paraquat at 1 kg a.i./ha was applied 1 day after planting.

TABLE 2. Effect of mulch treatments on bean yield of two cultivars planted in two fields near Esparza, Costa Rica, in 1980

Mulch treatment	Bean seed yield (kg/ha)[y] Experimental field: Porrillo 70	Experimental field: Mexico 27	Commercial field: Porrillo 70	Commercial field: Mexico 27
None	0	0	273 c	217 c
Frijol tapado	...[z]	...[z]	637 b	534 b
Rice husks	655	587	835 a	679 a

[y] Means in a column followed by the same letter are not significantly different ($P = 0.05$) according to the Waller-Duncan Bayesian *K*-ratio (LSD) rule.

[z] Plots were not harvested.

significantly reduced compared to those grown in the mulched plots (Table 2).

DISCUSSION

During this study in Costa Rica in 1980, the prevailing environmental conditions were highly favorable for WB incidence and development. Rainfall was especially heavy (with a mean of 580 mm/mo) during the growing season where the plots were located. Results showed that mulching was the most effective method for the control of WB caused in beans by *R. solani*. The mulching methods of control was effective in fields with low and high inoculum densities.

It appears that the mulch layer provided in the mulched plots served as a physical barrier to prevent or greatly reduce splashing of soil and debris onto bean tissues. Sclerotia and/or debris colonized by mycelium of *R. solani* contained in rain-splashed soil was recently found to be the main source of inoculum for WB of beans in Costa Rica (9). Mulch consisting of rice husks or natural vegetation, although differing in composition and in the density of the layer on the soil surface, were equally effective in reducing the severity of WB. Other possible sources of mulches that are available in the tropical areas are the by-products of coffee, sugarcane, cocoa, coconut, and corn. However, the effectiveness of these materials as mulches for the control of WB of beans and the long-term effect of these mulches on the bean plant and other pathogens needs to be thoroughly investigated. In addition, the minimum amount of any mulching material that can be used should be determined.

There are several reports (7,13,16) of mulching being an effective method for reducing the incidence and severity of foliar diseases incited by *R. solani* on several crop species. The use of a mulch of plastic film as a physical barrier to prevent contact of developing cucumber fruits with the soil was found to be highly effective for controlling cucumber fruit rot caused by *R. solani*. In addition, the plastic film mulch was superior to selected chemical soil treatments, microbial antagonism to *R. solani* by *Trichoderma* sp., or deep plowing in controlling cucumber fruit rot (16). Likewise, tomato fruit rot caused by *R. solani* was reduced significantly by the use of mulches provided either by biodegradable paper coated with a thin layer of polyethylene (13), or by a wax mulch applied as a spray to the soil surface around the tomato plants (7). Again, both of the latter treatments gave significantly better control than soil treatments with chemicals such as captafol and maneb (7,13).

An effect of mulching observed in this study was the reduction in the formation of new inoculum during the growing season. Large numbers of sclerotia were produced within 3 days on bean tissues that fell to the soil surface of the nonmulched plots. This additional new inoculum source can in turn be splashed onto bean tissues resulting in the increase of infection sites and thus the amount of necrotic tissue and eventually higher disease severity.

It has been previously reported that mulching of the soil may result in additional beneficial effects such as conserving soil moisture, providing weed control, preventing leaching of nutrients, preventing soil compaction, and sometimes favorably altering the soil temperature for plant growth (13,22). The mulch also may have direct or indirect effects on the pathogenic activities and population of *R. solani*. Addition of mulches to soil may result in changes in the C/N ratio of the upper layer of the soil; qualitative and quantitative changes in the composition of soil microflora and microfauna (increase competitors, antagonists, and/or mycoparasites of *R. solani*); or result in an adverse alteration in the composition of the gases in the soil atmosphere such as an increase in CO_2 concentration (20).

About 85% of the beans produced in Costa Rica (8,12) are grown on a large number of small farms under the frijol tapado system. Some changes in this system are warranted in order to increase the yield while maintaining the benefits of the mulch as documented in this study. One possible change that can be made is to replace bean planting from broadcasting the seeds to direct drilling of the seeds and, when appropriate, the fertilizers too. Drilling can be done after the vegetation has been cut or destroyed by the application of herbicides such as paraquat. This proposed change might be practical for the small holdings (1.5 ha or less) on which the bulk of the bean crop is produced in Costa Rica (12). In addition, planting dates can be adjusted to avoid the high peak periods of rainfall as the mulch layer provided in this system will preserve soil moisture (11,22) and extend the growing period of beans into the dry season. Changes in this system need to be further investigated under small farming conditions over several years.

Inoculum of *R. solani* has been shown to be largely confined to the top 5- to 7-cm layer of the soil where organic matter is generally abundant (16,20). Consequently, control measures that reduce the inoculum density of the fungus in this area have been demonstrated to be effective in reducing the incidence and severity of the disease (15,16). In previous reports (2,23) as well as this study, PCNB and paraquat have been shown to be effective against *R. solani* under laboratory and field conditions. However, these chemicals were generally ineffective in reducing WB incidence and severity in the experimental field used in this study. This is probably due to the unusually high inoculum density of the fungus in this field and to the prevailing weather conditions that were favorable to disease development throughout the growing season. These chemicals might well be effective against WB of bean plants exposed to lower inoculum density. Paraquat is economical and already has been used by small farmers in Costa Rica, and thus might become a component of an integrated pest control program. Further investigations dealing with the effectiveness of these chemicals and others as soil treatments are warranted under commercial bean-growing conditions. In addition, research efforts are urgently needed in order to develop an integrated control program for WB by combining measures aimed at reducing inoculum density, avoiding rain-splashing of infested soil onto bean tissues, and developing tolerant cultivars.

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