Managing Angular Leaf Spot on Common Bean in Africa by Supplementing Farmer Mixtures with Resistant Varieties

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ABSTRACT

Pyndji, M. M., and Trutmann, P. 1992. Managing angular leaf spot on common bean in Africa by supplementing farmer mixtures with resistant varieties. Plant Dis. 76:1144-1147.

The effectiveness of supplementing local bean (*Phaseolus vulgaris*) mixtures with varieties resistant to angular leaf spot, caused by *Phaeoisariopsis griseola*, was evaluated in the Great Lakes region of Africa. The severity of angular leaf spot was lower ($P = 0.05$) in farmer mixtures supplemented with 25% or more of resistant lines BAT76 or A285 in three of four seasons than in mixtures without resistant lines. Significant decreases in angular leaf spot severity were also obtained in the new mixtures when measuring both original farmer and new resistant lines. The results suggest that important foliar diseases can be controlled with modern plant breeding products in systems where varietal mixtures predominate through supplementation rather than displacement of existing genetic diversity by new varieties. However, the supplementation strategy is also limited, because its indiscriminate use in managing multiple diseases could lead to severe erosion of local genetic diversity.

In many African countries common bean (*Phaseolus vulgaris* L.) is an important protein source (4) and is cultivated predominantly as varietal mixtures. The genetic diversity in mixtures is large; the mean number of seed types and colors per farmer mixture has been estimated at 20 in Rwanda (15) and 13 in Malawi (7). Each farmer has a different mixture and often has various mixtures. Diseases are a major constraint to bean production in the central African highlands, which principally encompass Burundi, Rwanda, and Zaire (11,12,13), and are also important in other African countries (1). Angular leaf spot, caused by *Phaeoisariopsis griseola* (Sacc.) Ferraris, is considered to be one of the most important biotic constraints to on-farm yield in the Great Lakes region of Africa (13), and its control is a high priority of national programs in the region.

Wolfe (16) reviewed the literature on disease control with multilines and varietal mixtures and noted that host mixtures may restrict the spread of pathogens and their diseases considerably, relative to the mean of their components, provided components differ in their susceptibility. Lyimo and Teri (10) supported this principle for *P. vulgaris* in Africa. However, work in the literature exclusively discusses mixtures as a means of diversification from a monoculture standpoint. No reports have specifically investigated the addition of resistant varieties to farmer varietal mixtures for management of disease.

The objectives of this study were to determine whether angular leaf spot severity could be reduced in farmer mixtures by supplementing them with new varieties resistant to angular leaf spot, to ascertain whether farmer components can be protected, and to determine what proportions of new resistant material are required to obtain a protective effect in farmer mixtures.

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Accepted for publication 7 March 1992.

MATERIALS AND METHODS

Studies were conducted at the Mulungu station of l'Institut National pour l'Etude et la Recherche Agronomiques (INERA), in the Kivu region of Zaire. Its geographical and climatological characteristics are 02° 19′ S, 28°45′ E; altitude of 1,700 m; mean temperature of 16.2°C; and 1,845 mm of rainfall per annum in a bimodal pattern. Angular leaf spot is severe and is the dominant common bean disease. On 16 m^2 plots a local farmer bean mixture was sown, supplemented with various proportions of angular leaf spot–resistant material from the Centro Internacional de Agricultura Tropical (CIAT) breeding line BAT76 (growth type II, small-grained, black-seeded) or A285 (growth type II, small-grained, yellow-seeded). Seeds were sown in a geometric pattern 20 cm apart, which simulated local sowing methods. Seed of the resistant variety was evenly distributed as either 10, 20, 25, 50, 75, or 100% of seed sown in each treatment, depending on the trial. Each resistant plant was tagged with a long peg to distinguish it from the components of farmer mixtures. Plots were separated by twice the distance of the plot length to reduce interplot interference. Soybean (*Glycine max* (L.) Merr.) was planted between plots. The trial was replicated six times in the first season and four times in subsequent seasons, with treatments arranged in a randomized block design. Trials were repeated three times with proportions of resistance of 25–100% and once with proportions of 10–20%.

Angular leaf spot severity was evaluated as the percentage of surface area infected. To measure the effect of resistant varieties on the local bean mixture component, 40 local mixture plants per plot were selected at random. On each selected plant, leaves on the third, fifth, and seventh nodes were evaluated at flowering, pod fill, and grain fill (5). At each of these times, leaves on each node differed in age. Leaves on node 3 at flowering were 28 days old; on node 5, 14 days at flowering, 28 days at pod fill, and 49 days at grain fill; and on node 7, 7 days at flowering, 21 days at pod fill, and 42 days at grain fill. In the third season whole local mixture plants, not individual leaves, were evaluated. For whole plants the time from the first leaf stage, when leaf tissue becomes available for infection, to flowering was 30 days; to pod fill, 44 days; and to grain fill, 65 days. In treatments containing only resistant plants, these plants, rather than local mixture components, were evaluated. The terms *flowering, pod fill*, and *grain fill* were used following CIAT (5). Overall angular leaf spot severity (i.e., the combined disease level of resistant and local mixture components) was obtained by a general angular leaf spot evaluation of all plant foliage in each plot. Results were analyzed using an analysis of variance, and treatments were compared with Duncan's multiple range test. The apparent infection rates (14) were calculated for the logistic model using the third trial when plants were evaluated for total foliar area infected.

RESULTS

Angular leaf spot severity in supplemented local mixture components. Supplementation of local mixtures with 25, 50, or 75% of either BAT76 or A285 resulted in reductions ($P = 0.05$) of disease severity in the local mixture components of new mixtures as compared to disease severity in the pure local mixture treatments, measured both as leaves on individual nodes (Table 1) and as total plant foliage (Fig. 1). Confidence levels of differences between treatments improved with time. Defoliation of older leaves on nodes 3 and 5 from disease severity prevented measurement of infection of leaves over all plant growth stages (Table 1).

The apparent infection rate of *P. griseola* in farmer mixture components was most rapid between the primary leaf stage and flowering (Table 2). The incorporation of 25% of A285 into the local mixture reduced the average apparent infection rates on local mixture components and reduced the rate further at

Table 1. Angular leaf spot development on farmer bean mixture components supplemented with a resistant variety, using individual leaf evaluations

Testing season	Variety	Variety in mixture (%)	Diseased leaf surface area (%) Leaf node number[w] 3 F[x]	5 F	5 P	7 F	7 P
Early 1987	BAT76	0	5.9 a[y]	2.1 a	6.3 a	1.4 a	2.6 a
		25	4.5 ab	2.0 a	4.1 b	1.3 a	1.6 b
		50	5.1 ab	1.7 a	3.5 bc	1.0 b	1.5 b
		100[z]	1.2 b	1.4 a	1.8 c	0.4 c	0.3 c
Mid 1987	A285	0	5.5 ab	1.3 a	5.7 a	0.1 a	2.3 a
		25	3.6 bc	0.7 a	2.8 b	0.1 a	0.8 b
		50	6.7 a	1.0 a	4.1 ab	0.1 a	1.3 ab
		75	4.8 ab	0.5 a	2.7 bc	0.1 a	0.1 a
		100[z]	1.0 c	0.0 a	0.1 c	0.0 a	0.0 b

[w] On susceptible plants.
[x] F = flowering, P = pod fill.
[y] Values in the same column and the same season followed by different letters are significantly ($P = 0.05$) different using Duncan's multiple range test.
[z] Disease severity recorded on resistant plants.

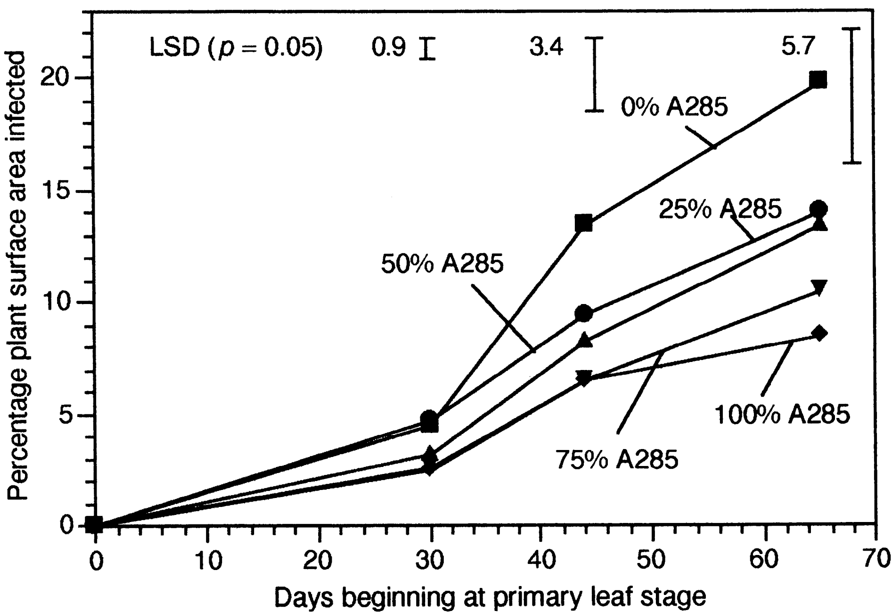

Fig. 1. Development of angular leaf spot on local bean mixture components supplemented with CIAT breeding line A885 in March 1988.

Table 2. Rate of angular leaf spot development on farmer components in bean mixtures supplemented with resistant variety A285

A285 in mixture (%)	Infection rate: First leaf to flowering	Flowering to pod fill	Pod fill to grain fill	Mean	Difference in rate per day[z]
0	0.128	0.086	0.021	0.085	...
25	0.131	0.057	0.020	0.078	−0.007
50	0.117	0.072	0.025	0.077	−0.008
75	0.109	0.068	0.024	0.073	−0.012
100	0.108	0.071	0.013	0.070	−0.015

[z] Compared to local mixture.

Table 3. Effect of adding low proportions of resistant variety BAT76 to a farmer bean mixture on angular leaf spot severity

BAT76 in mixture (%)	Diseased leaf surface area (%)							
	Node number of leaf							
	3	5			7		General[w]	
	F[x]	F	P	G	P	G	P	G
0	16.6 a[y]	0.8 b	19.0 a	20.4 a	9.6 a	12.1 a	32.2 a	37.5 a
10	16.9 a	0.8 b	19.0 a	19.0 a	8.1 a	10.9 a	27.2 a	33.3 a
20	18.6 a	0.9 b	19.1 a	20.8 a	8.3 a	11.8 a	20.3 ab	29.1 a
100[z]	3.1 b	0.5 b	5.1 b	5.9 b	0.3 b	0.4 a	11.3 b	11.3 b
LSD ($P = 0.05$)	3.2	0.2	1.9	2.7	3.7	2.0	12.3	12.6

[w] Local mixture and BAT76 components evaluated together as a plot estimate.
[x] F = flowering, P = pod fill, G = grain fill.
[y] Values in the same column and the same season followed by different letters are significantly ($P = 0.05$) different using Duncan's multiple range test.
[z] Disease severity recorded on resistant plants.

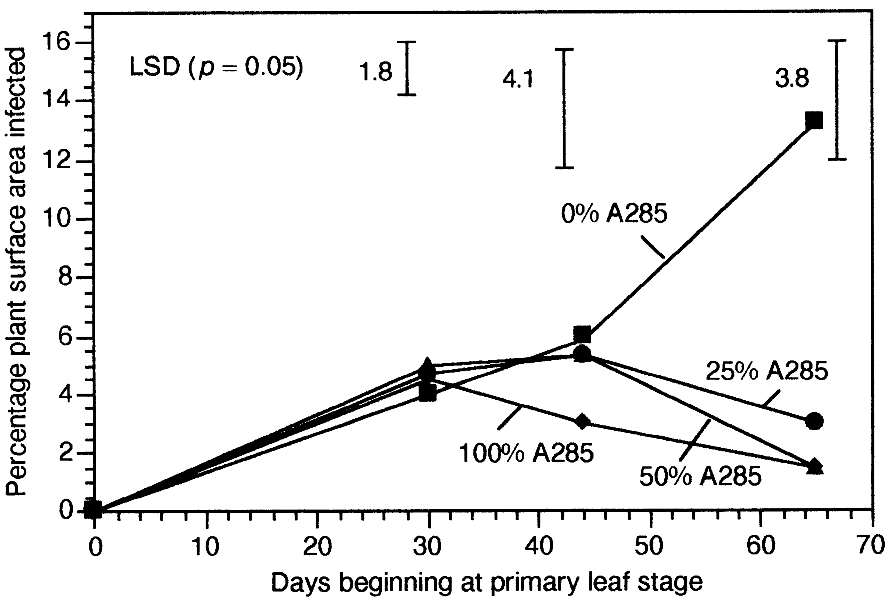

Fig. 2. General angular leaf spot development in mixtures consisting of a local mixture supplemented with proportions of CIAT breeding line BAT76 in March 1987.

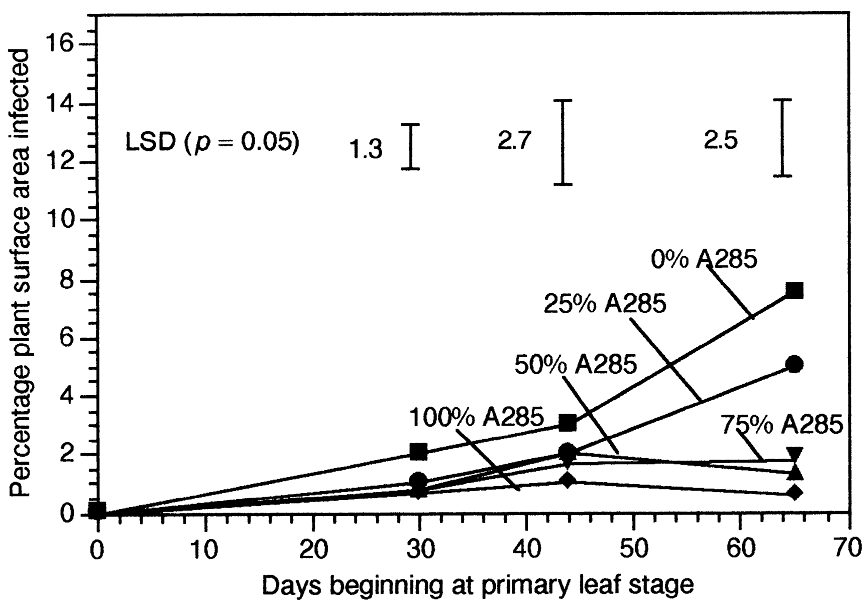

Fig. 3. General angular leaf spot development in mixtures consisting of a local mixture supplemented with proportions of CIAT breeding line A285 in September 1987.

higher supplementation levels.

No significant differences in angular leaf spot severity were observed in local mixture components when the local mixture was supplemented with 10 and 20% of BAT76 (Table 3). Disease pressure was considerably higher in the trial compared to that in other seasons.

Effect of resistance-supplemented mixtures on disease severity in new mixtures. The mean angular leaf spot severity over four seasons of testing was 20, 8, 14, and 40% of total leaf area of plants in plots from 1986 to 1988. Significant reductions in angular leaf spot severity in the new mixtures were observed when 25, 50, or 75% resistant variety BAT76 or A285 was added to the local mixture (Figs. 2 and 3). No significant differences were observed when a farmer mixture was supplemented with 10 and 20% BAT76, but lower trends of angular leaf spot in new mixtures containing BAT76 were observed (Table 3).

DISCUSSION

Incorporation of relatively low proportions of angular leaf spot resistance in local mixtures reduced disease severity in the farmer components of mixtures supplemented with resistant varieties in three out of four seasons. These results are significant because they show for the first time that disease can be controlled in local bean mixtures by supplementing them with resistant varieties. This suggests that rapid impact on angular leaf spot can be achieved with modern plant breeding products in systems in which varietal mixtures and angular leaf spot predominate without eliminating the existing genetic diversity.

The physical presence of a resistant variety in a farmer mixture protected farmer mixture components and itself contributed directly to the overall level of disease in the mixture. When no protective effect is achieved on local mixture components, perhaps because of very high disease pressure, the physical presence of a resistant variety would provide the farmer with some assurance of production.

In this study, supplementation of local mixtures with 25% of a resistant variety reduced angular leaf spot. The results are encouraging, since many previous studies, particularly on rusts of various cereals, suggest higher proportions of resistance are required to adequately protect a host crop. Browning and Fry (2) estimated that to restrict crown rust of oats adequately, the proportion of the resistant component in the mixture must be between 40 and 50%. Jensen and Kent (9) found that no less than 40% of partial protection in a population might provide full protection. Burdon and Chilvers (3) also calculated that a 50% resistant mixture was needed to substantially reduce the rate of spread of *Pythium* *irregulare* Buisman. One of the few reports in which lower proportions of resistance effectively protected susceptible components was published by Jeger et al (8), working with the wheat-*Septoria nodorum* Berkeley and the barley-*Rhynchosporium secalis* (Oudem.) J. J. Davis disease systems. It may be that the resistance already available in farmer mixtures helps reduce the amount of additional resistance needed to obtain adequate disease reduction.

Single sources of resistance to angular leaf spot were used in this study. However, to ensure diversity of resistance in the future, because significant pathogenic variability of angular leaf spot exists (6), it is desirable to use a broader range of sources. An assortment of productive resistant varieties could be offered to individual farmers, which would encourage the use of diverse resistant sources over a region. Preconstructed mixtures are not likely to be accepted by farmers, because this interferes with the flexibility of farmers to tailor mixture composition to specific needs (Trutmann, Voss, and Faihead, *unpublished*). Multilines are unnecessary where beans are grown in varietal mixtures, but it would be highly desirable to backcross certain competitive, productive, and preferred local varieties with different sources of angular leaf spot resistance.

Concurrent studies have shown disease reduction to be translated into significant yield increases (Trutmann and Pyndji, *unpublished*), but many questions still need to be resolved. It was evident that under experimental conditions the major inoculum source originated from within the plots; otherwise, no protective effect would have been visible (16). Will this phenomenon still hold on farms where fields are often less than an eighth of a hectare and bordered by a different bean mixture? Protective effects have been demonstrated for angular leaf spot; however, it is not known whether similar effects will be observed when farmer mixtures are supplemented with varieties resistant to other important bean diseases.

Supplementation of local mixtures with resistant varieties appears to be a feasible strategy for control of a single important disease, but it is unlikely to be feasible or desirable for multiple disease control. Attempts to control multiple diseases by the supplementation strategy are likely to lead to a large displacement of local varieties and erosion of local germ plasm, if substitution of a quarter to one half of local mixture seed is required to obtain protection against each disease. The problem might be managed partly through the development of varieties resistant to multiple diseases, but pyramiding resistance is at present not feasible in many national programs, because of a lack of resources and infrastructure. More realistically, approaches in systems where varietal mixtures predominate should incorporate integrated management strategies that control multiple diseases and conserve genetic diversity.

ACKNOWLEDGMENT

We thank the technical staff at Mulungu for their invaluable help.

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