Farmers' participatory integrated management of foliar diseases of groundnut†

(*Keywords:* on-farm, farmers' participatory research, foliar diseases, IDM, groundnut)

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Abstract. Late leaf spot (LLS) caused by *Phaeoisariopsis personata* [(Berk and Curt) v. Arx = *Cercosporidium personatum* (Berk. & Curt.) Deighton] and rust caused by *Puccinia arachidis* (Speg.) are the two most destructive fungal foliar diseases of groundnut worldwide. Together, these two diseases can cause more than 50% yield loss in groundnut in many countries. Foliar disease management in groundnut often involves indiscriminate use of chemicals or total reliance on host plant resistance (HPR). On-station experiments on integrated disease management (IDM) at ICRISAT-Patancheru, India, have clearly demonstrated that when moderate levels of HPR are combined with seed treatment and affordable levels of chemical control, expected yields and economic returns are higher than obtained with chemical control of susceptible genotypes. We evaluated the performance of this combination in on-farm farmer-participatory research. The groundnut genotypes were ICGV 89104, ICGV 91114, TMV 2 and a local cultivar. Thirty farmers from Anantapur, Kurnool, and Nalgonda districts in the state of Andhra Pradesh, India, conducted the experiments during the 1995 and 1996 rainy seasons. Local agronomic practices were followed. Experiments were conducted under both high disease pressure [non-integrated disease management (non-IDM) i.e. natural] and low disease pressure [integrated disease management (IDM), i.e. seed treatment and fungicide, chlorothalonil sprayed once at 60 days after sowing, d.a.s.]. The severities of LLS and rust on test genotypes were significantly lower than on TMV 2 and the local cultivar up to 65 d.a.s. The increase in pod yield over the local cultivar and TMV 2 in IDM plots was 60% in ICGV 89104, and 55% in ICGV 91114. Farmers preferred these two genotypes because of their close phenotypic similarity to the local cultivar. Our studies also suggest that any technology developed for groundnut should offer a clear yield and foliar disease resistance advantage over farmers' current practices.

1. Introduction

Groundnut (*Arachis hypogaea* L.) is an important crop in more than 100 countries. The worldwide annual production of this crop is 30 million tons on 23 million hectares (FAO, 1998). Groundnut is produced predominantly in developing countries and about 26.7% of world production and 34.7% of total area is confined to India (FAO, 1998). Among developed countries, the USA is the major groundnut producer with 1.61million tons on 0.571million hectares (FAO, 1998). Groundnut yields in developing countries are very low (0.3–0.9 t ha^{-1}) compared with very high yields (2.8 t ha^{-1}) in the USA. In developing countries, groundnut is grown mostly by resource poor farmers, who can rarely afford to adequately manage the crop. The occurrence of diseases and pests, non-availability of improved technology including high yielding cultivars, and poor socio-economic conditions of farmers are the main causes for poor yields of groundnut in these countries (Jackson and Bell, 1969; Gibbons, 1980; Gorbet *et al.*, 1982). The crop is susceptible to foliar diseases, and a wide range of disease control methods are used. There may be uneconomical use of fungicides or total reliance on host plant resistance (HPR). In recent years there has been an increased effort to combine moderate levels of HPR with economical use of fungicide to achieve higher yields and net profit. On-station experiments at ICRISAT-Patancheru have clearly demonstrated that when moderate levels of HPR were combined with affordable levels of chemical control, yields and economic returns were higher than obtained with chemical control on susceptible cultivars. This paper describes how this combination has been evaluated on farms, with the involvement of farmers in areas where groundnut is grown extensively. We conducted the on-farm experiments on integrated foliar disease management during the 1995 and 1996 rainy seasons in three districts of Andhra Pradesh, India.

2. Materials and methods

2.1. *Collaborating institutions*

The on-farm research was conducted in close collaboration with Acharya N.G. Ranga Agricultural University (ANGRAU), Agricultural Research Station, Anantapur; Rural Development Trust (RDT), Anantapur, (district Anantapur); Krishi Vignan Kendra (KVK) Banganapalli (district Kurnool); and Krishi Vignan Kendra (KVK), Gaddipalle (district Nalgonda).

2.2. *Selection of sites*

The districts selected were Anantapur, the largest groundnut area (725 000 ha), Kurnool (291 000 ha), the second largest, groundnut growing districts in Andhra Pradesh and Nalgonda district (41 000 ha).

The villages selected were representative of these three districts in terms of topography and agro-ecological zones. The target villages in these districts were selected by informal visits to the villages and meetings with the village heads and farmers. During the 1995 rainy season, one village from each district was chosen and during the 1996 rainy season four villages each

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from Anantapur and Nalgonda, and three villages from Kurnool were chosen. The characteristics of the farm sites chosen for the trial as suggested by Ray *et al.* (1989) were as follows.

- Areas where groundnut is extensively grown traditionally and which have important production constraints and a high degree of uniformity.
- Areas where it was possible to group the participating farmers into units having similar management practices and which have been cultivating groundnut traditionally.
- Areas where the number of small farmers or farmer-groups was greater than the required number per replicate or block and where it was possible for each participating farmer to provide at least three 2 m × 2 m plots for yield analysis.
- Sites that were accessible through motorable roads.
- Sites that were scheduled to grow groundnut experiments.
- The community was not divided into factions.

2.3. Selection of farmers

In each village, a meeting was held with the farmers and rapid rural appraisals were conducted. The objectives and methodology of the experiment were explained and farmers' perception of production problems was discussed. Farmer participation was solicited on a voluntary basis. Efforts were also made to encourage female farmers to participate. During the 1995 rainy season, six farmers (including a female farmer) were selected and during the 1996 rainy season 24 farmers (including four female farmers) were selected from these three districts. Farmers selected to participate in these trials broadly possessed the following characteristics, as suggested by Ray *et al.* (1989).

- They were willing to accept the innovations (such as high yielding moderately resistant groundnut varieties and use of fungicides) and were concerned about biotic constraints.
- They were traditional groundnut farmers using normal agronomic practices and were ready to provide some labour under normal non-research situations.
- They were willing to be guided by research staff and to carry out operations as prescribed.
- They all agreed to co-operate without any financial incentives other than free seed and plant protection material.

2.4. Genotypes and design of the experiment

Four groundnut genotypes were evaluated. ICGV 89104, ICGV 91114, TMV 2, and a local cultivar. ICGV 89104 and ICGV 91114 are early-maturing (95 d.a.s.), high-yielding varieties with moderate levels of resistance to rust and LLS. Both were developed at ICRISAT-Patancheru. TMV 2 is susceptible to foliar diseases, and matures at around 105 d.a.s. The local cultivar is similar to TMV 2 in disease reaction and maturity. ICGV 89104 and ICGV 91114 have pod and seed characteristics similar to TMV 2 and the local cultivar.

The design of the experiment was a strip-plot with two replications. Farmers were provided with seeds of the three test genotypes, sufficient to plant 500 m^2 area. They provided their own seed of the local cultivar (control). Seeds of the test genotypes and local cultivar sown in IDM plots were treated with commercial seed dressing compound (3 g kg^{-1} seed) consisting of Thiram+Bavistin, while the seeds of the test genotypes and farmers' cultivar sown in non-IDM plots were not treated. The plot size ranged from 300 to 500 m^2 for each cultivar, depending upon the availability of land to the participating farmer. The crop was raised using normal local practices. Depending upon the on-set of rains most of the farmers plough their fields at least once before sowing. Generally, sowing of groundnut seeds is done in furrows behind the bullock-drawn plough. A few farmers also apply one or two cart loads (200 – 300 kg) of farmyard manure (FYM). Plant protection is negligible and rarely followed. The trials were sown only in the presence of a collaborating scientist or ICRISAT staff.

2.5. Fungicide and spray schedule

The fungicide Kavach® (chlorothalonil) 2 g l^{-1} water and 800 l solution ha^{-1} was used to control both LLS and rust. Each replication was divided into two halves. One half was protected against LLS and rust by spraying Kavach® [integrated disease management (IDM)] and the other half served as a control, with no fungicide spray [non-integrated disease management (non-IDM) treatment]. Fungicide was sprayed 8 – 10 days after the first appearance of LLS and/or rust symptoms (about 60–65 d.a.s.). Considering the early maturation of ICGV 89104 and ICGV 91114 only one fungicide spray was used. On-station experiments had previously shown that a single spray provided effective control in these short-duration cultivars.

2.6. Data collection

Thirty d.a.s., three spots (2 × 2 m^2 area) were randomly selected and fixed in each treatment in each field. The severity of LLS and rust were scored on 1 – 9 rating scale (where 1=no disease and 9=maximum disease) in the presence of the participating farmer at all locations. Disease severity was scored three times during the crop season, at 40 – 45 d.a.s., at 60–65 d.a.s., and 80 – 85 d.a.s.

These 2 × 2 m^2 blocks were harvested, and pods were stripped, dried, and yields pooled for each replication and treatment. After drying (moisture content < 8%), pods and haulms were weighed to calculate per-hectare yield. Farmers' perceptions were also recorded using a simple questionnaire, where farmers registered their response as 'yes' or 'no'.

2.7. Data analysis

Foliar disease severity, haulm, and pod yields were similar in the 1995 and 1996 seasons. Hence data for both years were pooled and analysed using restricted maximum likelihood (REML) analysis (Patterson and Thompson, 1971) assuming cultivar and treatment effects as fixed. The Wald test, which follows an approximate Chi-square distribution, was used to test the overall significance of differences among treatments at 5% level of significance (Thompson and Welham, 1993). Least significant difference (LSD) at 5% level of significance was used to perform a test of pair wise differences among treatments. All computations were carried out using the Genstat 5 statistical package. Costs and benefits were calculated using the mean cost of inputs and mean haulm and pod yields across all the participating farmers in all three districts.

3. Results

3.1. Late leaf spot (LLS)

The severity of LLS in ICGV 89104 and ICGV 91114 was significantly ($P < 0.05$) less than TMV 2 and the local cultivar in both IDM and non-IDM treatments up to 65 d.a.s., but not at 85 d.a.s. (table 1). In all cultivars, LLS severity was lower in IDM treatment compared with the non-IDM treatment both at 65 and 85 d.a.s. There was no significant differences in LLS severity between TMV 2 and local cultivar in either treatment.

3.2. Rust

The severity of rust was significantly ($P \leqslant 0.05$) lower in ICGV 89104 and ICGV 91114 than on TMV 2 and the local cultivar until maturity (~95 d.a.s.) in both IDM and non-IDM treatments (table 2). Severity of rust was lower in IDM treatment than the non-IDM treatment in all cultivars at both 65 and 85 d.a.s. There were no significant differences in rust severity between TMV 2 and the local cultivar.

3.3. Haulm yield

Groundnut haulm is an important cattle feed and an important by-product of groundnut production in semi-arid tropics. Late leaf spot in susceptible groundnut cultivars causes severe defoliation and substantial loss to haulm yields (Subrahmanyam *et al.*, 1984). The early-maturing ICGV 89104 and ICGV 91114 produced significantly ($P \leqslant 0.05$) greater haulm yields than TMV 2 and the local cultivar in both IDM and non-IDM plots (table 3). All the cultivars gave higher yields in IDM plots than in non-IDM plots (table 3). ICGV 89104 gave the highest yield in both treatments at all locations. There were no significant differences in haulm yields between TMV 2 and the local cultivar in either treatment. Under IDM, the increase in haulm yield over TMV 2 and the local cultivar was 45% in ICGV 89104 and 34% in ICGV 91114. But the increase was 95% in ICGV 89104 and 80% in ICGV 91114 in IDM treatment over TMV 2 and the local cultivar of non-IDM.

3.4. Pod yield

ICGV 89104 and ICGV 91114 produced significantly ($P \leqslant 0.05$) greater pod yields than TMV 2 and the local cultivar in both treatments (table 3). Also, greater pod yields were obtained in IDM treatment than non-IDM treatment at all locations. ICGV 89104 gave the highest pod yield at most

Table 1. Severity of late leaf spot disease of ICRISAT early-maturing groundnut cultivars in integrated disease management (IDM) on-farm trials in the three districts[a] of Andhra Pradesh, India

	Late leaf spot disease severity score (1–9 scale)[b] 65 d.a.s.[c]		85 d.a.s.	
Cultivar	IDM	Non-IDM	IDM	Non-IDM
ICGV 89104	3.1	3.9	6.2	7.0
ICGV 91114	3.0	3.8	6.4	6.9
TMV 2	4.2	4.8	6.9	7.8
Local cultivar	4.1	4.9	7.3	7.9
CD ($P < 0.05$)	0.84		0.67	

[a] Anantapur, Kurnool, and Nalgonda.
[b] 1 = No disease, all leaves healthy; 2 = lesions present largely on lower leaves; no defoliation; 1–5% leaf area damaged by the diseases; 3 = lesions present largely on lower leaves; very few on middle leaves; defoliation on some leaflets evident on lower leaves; 6–10% leaf area damaged by the disease; 4 = lesions on lower and middle leaves but severe on lower leaves; 11–20% leaf area damaged by the disease; 5 = lesions present on all lower and middle leaves; over 50% defoliation of lower leaves; 21–30% leaf area damaged by the disease; 6 = severe lesions on lower and middle leaves; lesions present but less severe on top leaves; extensive defoliation of lower leaves; defoliation of some leaflets evident on middle leaves; 31–40% of leaf area damaged by the disease; 7 = lesion on all leaves but less severe on top leaves; defoliation of all lower and some middle leaves evident; 41–60% of leaf area damaged by the disease; 8 = defoliation of all lower and middle leaves; severe lesions on top leaves; some defoliation of top leaves evident; 61–80% leaf area damaged by the disease and 9 = almost all leaves defoliated; leaving bare stems; some leaflets may remain; but show severe leaf spots; 81–100% leaf area damaged by the disease.
[c] d.a.s. = days after sowing.

Table 2. Severity of rust disease of ICRISAT early-maturing groundnut cultivars in integrated disease management (IDM) on-farm trials in the three districts[a] of Andhra Pradesh, India

	Rust disease severity score (1–9 scale)[b] 65 d.a.s.[c]		85 d.a.s.	
Cultivar	IDM	Non-IDM	IDM	Non-IDM
ICGV 89104	2.4	2.7	5.0	5.7
ICGV 91114	2.5	2.8	4.9	5.7
TMV 2	3.4	3.6	5.8	6.6
Local cultivar	3.5	3.7	6.2	7.0
CD ($P < 0.05$)	0.78		0.88	

[a] Anantapur, Kurnool, and Nalgonda.
[b] 1 = No disease, all leaves healthy; 2 = pustules sparsely distributed, largely on lower leaves, 1–5% leaf area damaged by the disease, 3 = many pustules on lower and middle leaves, necrosis evident, very few pustules on middle leaves, 6–10% leaf area damaged by the disease; 4 = numerous pustules on lower and middle leaves; severe necrosis on lower leaves, 11–20% leaf area damaged by the disease; 5 = severe necrosis of lower and middle leaves, pustules may be present on top leaves, but less severe, 21–30% of leaf area damaged by the disease; 6 = extensive damage to lower leaves, middle leaves necrotic, with dense distribution of pustules on top leaves, 31–40% of leaf area damaged by the disease; 7 = severe damage to lower and middle leaves, pustules densely distributed on top leaves, 41–60% of leaf area damaged by the disease; 8 = 100% damage to lower and middle leaves, pustules on top leaves which are severely necrotic, 60–80% of leaf area damaged by the disease; 9 = almost all leaves withered, bare stems seen, 81–100% of leaf area damaged by the disease.
[c] d.a.s. = days after sowing.

locations in all three districts. In the IDM treatment ICGV 89104 showed yield superiority of 60% over TMV 2 and local cultivar, while ICGV 91114 showed superiority of 55%. However, the increase was 144% in ICGV 89104 and 137% in ICGV 91114 in IDM treatment over TMV 2 and the local cultivar of non-IDM treatment (table 3).

3.5. *Costs and benefits*

The cost of total inputs per hectare was calculated (table 4). Haulm and pod yields were averaged across all locations to calculate the costs and benefits. Inputs cost and the market price of groundnut produce were similar in both years in all three districts. The total cost of inputs was around Rs 9010 (1 Rs = approximately 0.0.238 US $) in IDM and Rs 5800 in non-IDM treatments (table 4). The pods were sold at Rs 10 500 t^{-1}, and haulms as by-product were sold at Rs 750 t^{-1}. The total costs of the inputs were deducted from the total gross income obtained by selling pods and haulms to obtain net profit. Net profits of Rs 15 793 in ICGV 89104, Rs 14 988 in ICGV 91114, Rs 6778 in TMV 2 and Rs 6493 in local cultivar were obtained from IDM treatment (figure 1). But the returns of TMV 2 and local cultivar in non-IDM treatment were Rs 5500 and Rs 4600 respectively which are equivalent to the returns a resource poor farmer normally obtains in these districts (table 5).

Table 3. Pod and haulm yields of ICRISAT early-maturing groundnut cultivars in integrated disease management (IDM) on-farm trials in the three districts[a] of Andhra Pradesh, India

	Yield (t ha^{-1})			
	Pod		Haulm	
Cultivar	IDM	Non-IDM	IDM	Non-IDM
ICGV 89104	2.13	1.70	2.97	2.46
ICGV 91114	2.07	1.75	2.75	2.31
TMV 2	1.35	0.96	2.15	1.67
Local cultivar	1.33	0.88	2.05	1.52
CD ($P<0.05$)	0.48		0.62	

[a] Anantapur, Kurnool, and Nalgonda.

3.6. *Farmers' perceptions and preferences*

Farmers' perceptions and preferences for these test genotypes were collected during the study. Almost all the participating farmers expressed their preference for early-maturing high-yielding genotypes with resistance to foliar diseases. Throughout the growing season both participating and neighbouring farmers observed the performance of these varieties in on-farm trials. Right from the emergence stage almost all farmers (over 80%) appreciated ICGV 89104 and ICGV 91114 (figure 2) because of better emergence compared with the local cultivar. In both seasons farmers preferred the early-maturing genotypes because of their close similarity to the local cultivar in phenotypic characteristics, high shelling percentage and clear yield advantage and foliar disease resistance.

4. Discussion

The moderately resistant, early-maturing genotypes ICGV 89104 and ICGV 91114 showed less LLS and rust severities than TMV 2 and the local cultivar up to 60–65 d.a.s. (tables 1 and 2). Thereafter, the severities of these diseases in these two cultivars increased slowly. At maturity the disease severities were similar to the severities on TMV 2 and the local cultivar. Similar trends in the progress of the LLS and rust were also observed at on-station experiments at ICRISAT-Patancheru. These two early-maturing genotypes appear not to support rapid multiplication of the pathogen propagules and disease spread, at least up to 60–65 d.a.s. As expected, the increase in foliar disease pressure resulted in more defoliation in these genotypes, which is the main cause for yield loss in

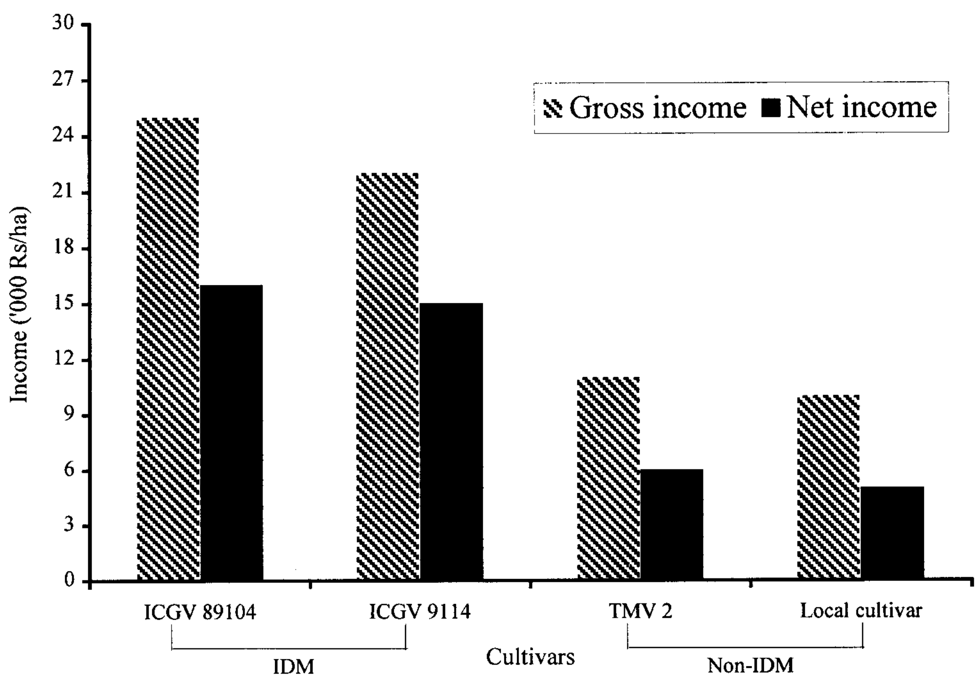

Figure 1. Gross and net incomes of groundnut test cultivars in IDM and non-IDM treatments, on-farm experiments. Andhra Pradesh 1995/96.

groundnuts. The one fungicide spray around 60–65 d.a.s. or 8–10 days after the appearance of the symptoms further delayed the increase in disease severity in the test genotypes. In general fungicide sprays remain effective on groundnut plants for 10–15 days.

High disease severity and defoliation was observed around 80–85 d.a.s. or about a week before harvest of ICGV 89104 and ICGV 91114, but this did not affect yield. The rate of disease progress and the maximum severity were higher in TMV 2 and the local cultivar than in the two early-maturing genotypes. As TMV 2 and the local cultivar mature in around 105 d.a.s., it appears that the pod filling was not completed by the time these diseases reached maximum severity. They require an additional 10–15 days to mature, and one more fungicide spray would be needed to achieve good yields. Thus the yield losses are higher in TMV 2 and the local cultivar than in ICGV 89104 and ICGV 91114. These findings validate the results obtained from our on-station experiments.

Drought is common in these areas, particularly in Anantapur and Kurnool districts. It may occur at different stages during crop growth, more frequently at the time of maturity. Such end-of-season drought causes particularly large yield losses in the local cultivars as they are still in the pod-filling stage. Also the local cultivar requires one or two irrigations to obtain good yields. The resource-poor farmer cannot afford supplementary irrigation during this drought period. Under these situations, the early-maturing genotypes are the best choice.

As expected yields and economic returns were higher in IDM treatment than in the non-IDM treatment in all the cultivars. The increase in returns was around three-fold in both the early-maturing genotypes in IDM treatment than TMV 2 and local cultivar of non-IDM treatment. These studies strongly suggest that early maturing, partially resistant cultivars grown with seed treatment and one spraying of fungicide at 60–65 d.a.s. offer higher pod and haulm yield, and economic returns than chemical control of susceptible local cultivars. Furthermore this also supports that when moderate levels of HPR are combined

Table 4. Cost of inputs for the cultivation of ICRISAT early-maturing groundnut cultivars in integrated disease management (IDM) on-farm trials in three districts[a] of Andhra Pradesh, India

	Costs (Rs ha^{-1})	
Activity	IDM	Non-IDM
Land preparation	1000	1000
Farmyard manure	500	500
Chemical fertilizer	500	500
Seed	2400	1600
Seed treatment	60	–
Sowing	600	500
Gypsum	–	–
Inter-cultivation	400	150
Irrigation	–	–
Fungicide	1200	–
Insecticide	750	750
Watching[b]	–	–
Pulling[c]	500	400
Stripping[d]	600	200
Transportation of the produce from field to home	500	200
Total inputs cost	9010	5800

a. Anantapur, Kurnool, and Nalgonda.

b. To guard the crop from cattle damage and theft.

c. Uprooting of plants at harvest.

d. Removal of pods from uprooted plants.

Table 5. Gross and net incomes (Rs) by adopting IDM treatments for the management of foliar diseases in on-farm experiments in the three districts[a] of Andhra Pradesh, India

	Gross income[b]		Net income[c]	
Genotype	IDM	Non-IDM	IDM	Non-IDM
ICGV 89104	24803	19695	15793	13895
ICGV 91114	24008	20108	14998	14308
TMV 2	15788	11333	6778	5533
Local cultivar	15503	10380	6493	4580

a. Anantapur, Kurnool, and Nalgonda.

b. Gross income obtained from selling groundnut pods, haulms as by-products.

c. Net income obtained by deducting cost of inputs from gross income.

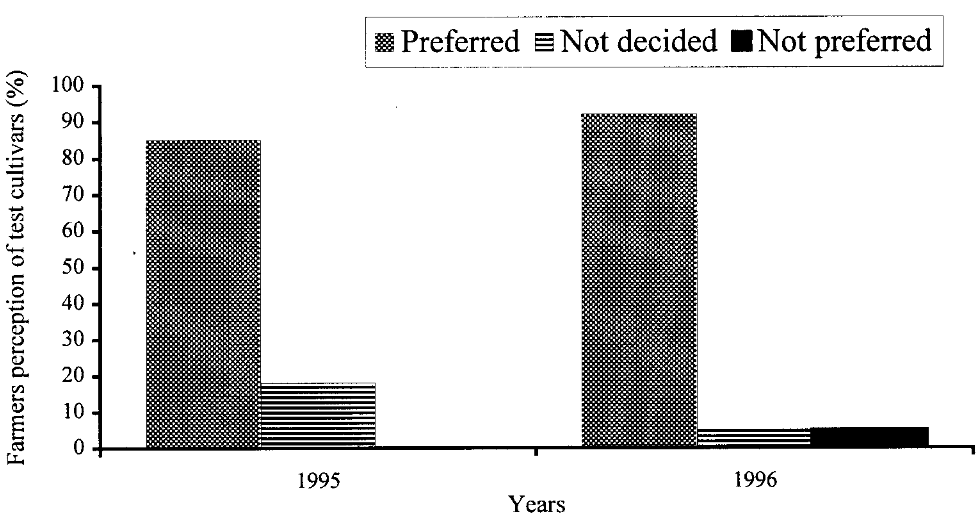

Figure 2. Farmers' perception of preference for test cultivars.

with fungicide control, yields and economic returns are higher than for chemical control of a susceptible cultivar (Gorbet *et al.*, 1990). This also clearly demonstrates that the resource-poor farmer, who cannot afford fungicide protection, can grow these moderately resistant cultivars to achieve higher yields without using fungicide.

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