

Preharvest seed infection by *Aspergillus flavus* group fungi and subsequent aflatoxin contamination in groundnuts in relation to soil types*

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Abstract

Preharvest seed infection by *Aspergillus flavus* and aflatoxin contamination in selected groundnut genotypes (four *A. flavus*-resistant and four *A. flavus*-susceptible) were examined in different soil types at several locations in India in 1985–1990. Undamaged mature pods were sampled at harvest and seed examined for *A. flavus* infection and aflatoxin content in two or more trials at ICRISAT Center on light sandy soils and red sandy loam soils (Alfisols), and on Vertisols, at Anantapur on light sandy soils, and at Dharwad and Parbhani on Vertisols. Rainy season trials (1985–1989) were all rainfed. Post-rainy season trials were irrigated; late-season drought stress (90 days after sowing (DAS) until harvest at 125 DAS) was imposed in the 1987/88 and 1989/90 seasons. *A. flavus* infection and aflatoxin contamination levels were much lower in seed of all genotypes from Vertisols than in seed from Alfisols across locations and seasons. Vertisols also had significantly lower populations of *A. flavus* than Alfisols. There were no marked differences between light sandy soils and red sandy loam soils (Alfisols) in respect of seed infection by *A. flavus* and aflatoxin contamination. Significant interactions between genotypes and soil types were evident, especially in the *A. flavus*-susceptible genotypes. Irrespective of soil types, *A. flavus*-resistant genotypes showed lower levels of seed infection by *A. flavus* and other fungi than did *A. flavus*-susceptible genotypes. The significance of the low preharvest aflatoxin risk in groundnuts grown on Vertisols is highlighted.

Introduction

Invasion of groundnut (*Arachis hypogaea* L.) pods and seeds by the aflatoxin-producing fungi *Aspergillus flavus* Link ex Fr. and *A. parasiticus* Speare, and subsequent contamination with aflatoxins, is a serious problem in most groundnut-producing countries (Dickens, 1977). In the wetter groundnut-producing areas, which usually have long rainy seasons, aflatoxin contamination

is mainly a postharvest problem. In the major groundnut-growing areas of the semi-arid tropics (SAT) the problem is largely of preharvest origin (Blaney, 1985; Manzo and Misari, 1989). Drought stress during late stages of pod development, a common occurrence in the SAT, predisposes seed to invasion by the aflatoxigenic fungi and consequently to aflatoxin contamination (Davidson et al., 1983; Sanders et al., 1985). Groundnuts are grown on a wide range of soils in the rainfed areas of the SAT, but very little attention has been given to possible lin-

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kages between soil type and aflatoxin contamination risk (Graham, 1982). The present studies were undertaken in the period 1985–1990 to examine preharvest seed infection by *A. flavus* and aflatoxin contamination in selected groundnut genotypes in three soil types at several locations in India.

Materials and methods

Genotypes

Eight groundnut genotypes, four with resistance to seed infection by *A. flavus* (Ah 7223, J 11, PI 337394F and UF 71513) and four susceptible (TMV 2, JL 24, EC 76446(292) and NCAc 17090) (Mehan et al., 1987) were used in all trials. The genotypes Ah 7223, J 11, TMV 2 and JL 24 are spanish (*A. hypogaea* var. *vulgaris*) types and PI 337394F, UF 71513, EC 76446(292) and NCAc 17090 are valencia (*A. hypogaea* var. *fastigiata*) types. They mature in 106–110 days in the rainy season and in 120–125 days in the post-rainy season at ICRISAT Center.

Locations

The trials were carried out in drought-prone locations in the Indian States of Andhra Pradesh (ICRISAT Center farm at Patancheru, and Anantapur), Karnataka (Dharwad), and Maharashtra (Parbhani). Trials at Dharwad and Parbhani locations were conducted in Vertisols, at ICRISAT Center in light sandy soils, red sandy loam soils and Vertisols, and at Anantapur in light sandy soils. Different fields were used at each location each season unless otherwise specified. Crop rotations followed at these locations were: millet-groundnut (groundnut in rainy season and millet in post-rainy season) at ICRISAT Center, sorghum-groundnut at Dharwad, and groundnut-groundnut (rainfed only, continuous groundnut cultivation in rainy season) at Parbhani and Anantapur. At ICRISAT Center, the light sandy (sandy loam) fields had 80% sand, 6% silt and 14% clay with an available water-holding capacity (AWHC) of 90–100 mm, while the red sandy loam soil (sandy clay loam) fields had 73% sand, 8% silt and 18%

clay with AWHC of 90–110 mm. Vertisols (silty clay loam) had 36% sand, 14% silt and 50% clay, with a high AWHC of 180–200 mm. At Anantapur, the light sandy soil fields had AWHC of about 50 mm. Vertisols at Dharwad and Parbhani had a AWHC of 150–160 mm. The pH of Alfisols (light sandy and red sandy loam soils) ranged from 6.8 to 7.3 and of Vertisols from 8.3–8.5. Normal cultural practices were followed and card was taken to harvest each genotype at optimum maturity and to sample only undamaged mature pods. No fungicides or insecticides were used.

Data on rainfall, and maximum and minimum temperatures during the crop seasons were obtained from ICRISAT, Anantapur, Dharwad and Parbhani Meteorological Stations.

Rainy-season trials (1985–1989)

All rainy-season trials were rainfed, sowing dates being normal (June–July) for the locations. In the 1985 and 1986 rainy seasons, research was done only at ICRISAT Center, trials being conducted on light sandy soil fields, on red sandy loam soil fields (Alfisols), and on Vertisol fields.

In the 1987 and 1988 rainy seasons, trials were carried out on light sandy soils, red sandy loam soils, and Vertisols at ICRISAT Center, on light sandy soils at Anantapur, and on Vertisols at Dharwad and Parbhani. The trials were repeated in the 1989 rainy season at all locations, except Dharwad.

All trials were carried out in randomized block design with four replications. Groundnuts were grown in 9-m-long plots of 10 rows 30 cm apart with seeds sown singly at 10-cm spacing along the rows.

Post-rainy season trials

The trials were conducted at ICRISAT Center in the 1987/88 post-rainy season and at ICRISAT Center and Parbhani in the 1989/90 post-rainy season; on red sandy loam soils and Vertisols at ICRISAT Center, and on Vertisols at Parbhani. All trials were carried out in randomized block design with four replications. The post-rainy season crops were grown on raised ridges. Plots were 9 m long and 7.5 m wide. Seeds were sown

singly at 10-cm spacing along 75-cm-wide ridges. All plots were furrow-irrigated to field capacity (at 10-day intervals) until 90 days after sowing (DAS). Drought stress was then imposed from 90 DAS until harvest (125 DAS) by withholding irrigation.

Collection and preparation of pod samples

Genotypes were harvested at maturity. At harvest, 35–40 plants were selected at random from each plot, and about 500 mature undamaged pods were collected from them.

At ICRISAT Center, the pods were immediately shelled, and seeds from each plot were examined for infection by *A. flavus* group fungi and other fungi and for aflatoxin contamination.

At the other locations, the pods were sundried in windrows for 2 days and then transported within a day to ICRISAT Center where they were shelled and seed samples taken for fungal and aflatoxin analyses.

Seed testing for fungal infection

Two hundred seeds from each plot were examined for infection by *A. flavus* and other fungi using standard techniques (Mehan et al., 1986). No distinction was made between the colonies of *A. flavus* and *A. parasiticus* Speare, both being referred to as *A. flavus* group fungi in this paper.

Seed testing for aflatoxin contamination

Two 50-g samples of seed from each plot were tested for aflatoxin content by the method of Pons et al. (1966).

Estimation of soil populations of A. flavus group fungi

Soil populations of *A. flavus* group fungi were monitored in selected trials at ICRISAT Center at different stages of crop development. In the 1987 and 1989 rainy seasons, they were monitored at sowing, 60 DAS, and 105 DAS. In the 1987/88 and 1989/90 post-rainy season trials, they were monitored at sowing, 60 DAS, 90 DAS, and 105 DAS. In the 1989/90 post-rainy season, soil populations of *A. flavus* group fungi

were also monitored in 4 additional groundnut fields each in Alfisols and Vertisols. At each sampling time, soil samples were collected from five randomly selected spots at 0–10 cm depth from between plants (field soil), individual samples were pooled for each plot. All soil samples were taken to the laboratory in polyethylene bags within 2 h of collection. After thorough mixing, from each composite sample, three subsamples (4 g each) were taken for tests. The dilution plate technique was used to obtain soil populations of *A. flavus* group fungi. Each subsample was put into 100 mL of sterile, distilled water in 250-mL flasks. One mL of the selected soil suspension (10^1 or 10^2 dilution) was poured onto malt salt agar medium (Griffin and Garren, 1976) in 9-cm diameter petri plates, three plates per sample. The plates were then incubated at 25°C in the dark. Colonies of *A. flavus* group fungi growing onto the medium in each plate were counted 6–7 days after incubation and averages calculated for each sample. Each colony was considered to have originated from a single fungal propagule.

Statistical analysis

The mean seed infection levels and aflatoxin contents were estimated with standard errors using analyses of variance performed separately on data from each season over Alfisols (red sandy loam and light sandy loam soils), and over Vertisols. Genotype \times soil type interactions were computed separately for *A. flavus*-resistant and -susceptible genotypes. Analyses of variance were also carried out for seed infection by *A. flavus*, and for aflatoxin B₁ content, over the soil types separately for *A. flavus*-resistant and -susceptible genotypes. Analyses of variance were also done for soil populations of *A. flavus* across sampling times.

Results

Natural seed infection by *A. flavus* and aflatoxin levels of test genotypes grown in different soils at ICRISAT Center for the 1985 and 1986 rainy seasons are given in Table 1. Significant differences occurred between soils for seed infection

Table 1. Seed infection by *Aspergillus flavus* group fungi and aflatoxin contamination in groundnut genotypes grown in different soils at ICRISAT Center, 1985 and 1986 rainy seasons

Genotype	Percentage of seed infected by <i>A. flavus</i> group fungi, and aflatoxin contamination					
	1985			1986		
	Alfisols		Vertisols	Alfisols		Vertisols
	Red sandy loam soil	Light sandy soil		Red sandy loam soil	Light sandy soil	
Ah 7223	1.9 ^a (2.8) ^b	1.4 (3.0)	0.1 (0.0)	0.9 (2.5)	1.1 (6.1)	0.0 (0.0)
J 11	2.0 (1.6)	1.1 (2.5)	0.1 (0.0)	1.2 (1.0)	1.2 (7.6)	0.0 (0.0)
UF 71513	2.0 (2.2)	1.4 (4.5)	0.2 (0.0)	1.1 (5.7)	1.6 (8.7)	0.0 (0.0)
PI 337394F	2.1 (4.6)	1.6 (8.9)	0.2 (0.0)	1.6 (7.4)	2.1 (11.1)	0.0 (0.0)
SE		±0.18 ^c (±0.49)	±0.07 ^d		±0.16 ^c (±2.61)	
TMV 2	5.0 (25.7)	4.5 (34.8)	2.0 (0.5)	6.1 (26.7)	7.2 (60.0)	0.6 (0.0)
JL 24	— ^e	—	—	12.2 (80.5)	18.5 (89.0)	1.4 (0.0)
NCAc 17090	17.2 (12.7)	17.7 (20.7)	2.7 (0.0)	27.0 (81.8)	20.9 (76.0)	2.0 (0.0)
EC 76446 (292)	15.5 (20.2)	17.1 (40.8)	3.5 (0.0)	23.4 (236.3)	21.3 (139.0)	2.1 (0.0)
SE		±0.85 ^c (±4.93)	±0.45 ^d (±0.29)		±1.78 ^c (±32.30)	±0.16 ^d

^a Seed infected by *A. flavus* (%).

^b Aflatoxin B₁ content (µg kg⁻¹).

^c SEs apply to non-zero mean values. SEs are for comparing both red sandy loam and light sandy soils as well as genotypes.

^d SEs apply to non-zero mean values. SEs are for comparing genotypes in Vertisols.

^e Not tested.

and aflatoxin levels at time of harvest; levels being much lower in Vertisols than in Alfisols. However, the two groups of Alfisols light sandy soils and red sandy loam soils did not differ significantly in these respects. No significant differences were observed between genotypes in the *A. flavus*-resistant group for infection and aflatoxin levels, but there were highly significant differences between genotypes in the *A. flavus*-susceptible group in these respects in both years. Significant interactions also occurred between soil types and genotypes, particularly in the susceptible group.

Significant differences between soils were also noted for *A. flavus* infection and aflatoxin con-

tamination of seed in the 1987 rainy season trials conducted at ICRISAT Center and three other locations, viz. Anantapur, Dharwad and Parbhani (Table 2). Levels of seed infection and aflatoxin B₁ contamination were lower in Vertisols than in Alfisols at all locations. Significant differences also occurred between Alfisols; levels of seed infection and aflatoxin contamination were higher in most susceptible genotypes in light sandy soils than in red sandy loam soils. Significant interactions were observed between soil types and genotypes in the *A. flavus*-susceptible group of genotypes.

In the 1988 rainy season trials, the levels of infection in the susceptible genotypes were too

Table 2. Seed infection by *Aspergillus flavus* group fungi and aflatoxin contamination in groundnut genotypes grown in different soils at various locations, rainy season 1987

Genotype	Percentage of seed infected by <i>A. flavus</i> group fungi, and aflatoxin contamination					
	Alfisols			Vertisols		
	ICRISAT Center		Anantapur	ICRISAT Center	Parbhani	Dharwad
	Light sandy soil	Red sandy loam soil	Light sandy soil			
Ah 7223	0.9 ^a (0.0) ^b	0.9 (0.5)	0.5 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)
J 11	1.0 (0.5)	1.0 (0.0)	0.7 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
UF 71513	1.0 (0.0)	0.9 (0.5)	0.7 (1.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
PI 337394F	1.2 (0.0)	1.4 (0.0)	0.6 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
SE	±0.11 ^c (±0.23)			±0.04 ^d		
TMV 2	4.7 (1.0)	4.9 (2.9)	3.4 (0.5)	0.4 (0.0)	0.1 (0.0)	0.4 (1.0)
JL 24	11.9 (2.9)	12.9 (10.5)	9.2 (0.0)	1.1 (0.0)	0.4 (0.0)	1.0 (0.5)
NCAc 17090	17.2 (2.5)	14.6 (8.4)	9.9 (1.0)	1.2 (0.0)	0.5 (0.8)	1.2 (0.0)
EC 76446 (292)	21.4 (12.2)	17.2 (13.4)	10.6 (4.0)	1.5 (0.0)	0.6 (0.0)	1.1 (0.5)
SE	±1.08 ^c (±1.52)			±0.14 ^d (±0.26)		

^a Seed infected by *A. flavus* (%).

^b Aflatoxin B₁ content ($\mu\text{g kg}^{-1}$).

^c SEs apply to non-zero mean values. SEs are for comparing both light sandy and red sandy loam soils as well as genotypes.

^d SEs apply to non-zero mean values. SEs are for comparing both Vertisols (ICRISAT Center, Parbhani and Dharwad) as well as genotypes.

low (<2%) to provide meaningful comparisons and so no data are given in Table 2 for these trials.

In the 1989 rainy season, significant differences were again noted between soil types for *A. flavus* infection of seeds (Table 3). Levels of infection were significantly higher in seed from Alfisols than in seeds from Vertisols. There were significant interactions between soil types and genotypes, especially for the *A. flavus*-susceptible genotypes, for seed infection by *A. flavus*. Aflatoxin B₁ contamination was observed only in some seed samples of the genotypes NCAc 17090 (10–12 $\mu\text{g kg}^{-1}$) and EC 76446(292) (8–16 μg

kg^{-1}) grown in Alfisols at ICRISAT Center and Anantapur.

The trials were also conducted under imposed late-season drought stress at ICRISAT Center in the 1987/88 post-rainy season and at ICRISAT Center and Parbhani in the 1989/90 post-rainy season. Levels of seed infection by *A. flavus* are presented in Table 4. Significant differences were observed between soil types for *A. flavus* infection levels in both seasons, levels of infection being significantly higher in seed from Alfisols than in seed from Vertisols. Significant genotype \times soil type interactions were evident in the *A. flavus*-susceptible group. Only low levels of

Table 3. Seed infection by *Aspergillus flavus* group fungi in groundnut genotypes grown in different soils at various locations, rainy season 1989

Genotype	Percentage of seed infected by <i>A. flavus</i> group fungi				
	Alfisols			Vertisols	
	ICRISAT Center		Anantapur	ICRISAT Center	Parbhani
	Light sandy soil	Red sandy loam soil	Light sandy soil		
Ah 7223	0.1 ^a	0.1	0.0	0.0	0.0
J 11	0.1	0.0	0.0	0.0	0.0
UF 71513	0.1	0.1	0.2	0.0	0.0
PI 337394F	0.1	0.0	0.2	0.0	0.0
SE		±0.13 ^b			
TMV 2	1.2	1.0	0.7	0.2	0.0
JL 24	1.2	2.1	3.2	0.5	0.2
NCAc 17090	2.7	5.1	3.5	0.2	0.0
EC 76446(292)	3.5	11.2	4.7	0.0	0.5
SE		±0.46 ^b		±0.25 ^c	

^a Seed infected by *A. flavus* (%).

^b SEs apply to non-zero mean values. SEs are for comparing both light sandy and red sandy loam soils as well as genotypes.

^c SEs apply to non-zero mean values. SEs are for comparing both Vertisols (ICRISAT Center and Parbhani) as well as genotypes.

aflatoxin B₁ (2–8 µg kg⁻¹) were detected in seed samples of some susceptible cultivars, viz. EC 76446(292), NCAc 17090, and JL 24 from Alfisols. No aflatoxin contamination was evident in seed of any genotype from the Vertisols.

There were significant differences between soil types for *A. flavus* group fungi populations in the

1987 and 1989 rainy seasons and the 1987/88 and 1989/90 post-rainy seasons (Figs. 1 and 2). Significantly lower populations were recorded in Vertisols than in Alfisols across seasons. Populations of *A. flavus* tended to increase with time in Alfisols, but considerable fluctuations in population were observed.

Table 4. Seed infection by *Aspergillus flavus* group fungi in groundnut genotypes grown in different soils at ICRISAT Center and Parbhani, 1987/88 and 1989/90 postrainy seasons

Genotype	Seed infected by <i>A. flavus</i> group fungi (%)				
	1987/88		1989/90		
	ICRISAT Center		ICRISAT Center		Parbhani
	Alfisol	Vertisol	Alfisol	Vertisol	Vertisol
	Red sandy loam soil		Red sandy loam soil		
Ah 7223	0.0	0.0	1.2	0.2	0.1
J 11	0.5	0.0	0.6	0.1	0.1
UF 71513	0.0	0.2	1.0	0.2	0.2
PI 337394F	0.0	0.0	1.2	0.6	0.2
SE	±0.00 ^a	±0.08 ^a	±0.19 ^a	±0.14 ^b	
TMV 2	4.2	0.2	5.2	1.1	0.2
JL 24	7.5	0.0	9.9	1.7	1.5
NCAc 17090	6.8	0.3	12.5	2.1	1.0
EC 76446(292)	8.8	0.7	13.9	2.1	1.2
SE	±0.91 ^a	±0.13 ^a	±0.66 ^a	±0.23 ^b	

^a SEs apply to non-zero mean values. SEs are for comparing genotypes.

^b SEs apply to non-zero mean values. SEs are for comparing both Vertisols (ICRISAT Center and Parbhani) as well as genotypes.

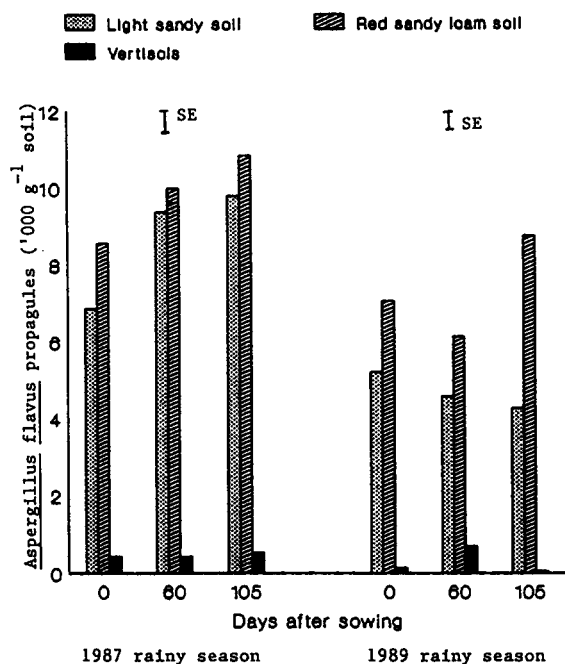


Fig. 1. Soil populations of *Aspergillus flavus* in light sandy soils and red sandy loam soils (Alfisols) and Vertisols during the 1987 and 1989 rainy seasons at ICRISAT Center.

Significant differences for soil populations of *A. flavus* between soil types were also noted when additional Alfisol and Vertisol groundnut

fields were examined in the 1989/90 post-rainy season. Populations of the fungus were much lower in Vertisol fields (218 to 340 propagules g^{-1} soil) than in Alfisol fields (4271 to 7219 propagules g^{-1} soil) (Fig. 3).

There were also significant differences between soil types for seed infection by fungi other than *A. flavus*. *Aspergillus niger* van Tieghem, *Macrophomina phaseolina* (Tassi.) Goid., and *Penicillium* spp. were dominant in seed from Vertisols in all seasons in most locations. *Fusarium* spp., and *A. niger* were commonly isolated from seed from Alfisols in both rainy and post-rainy seasons, and *M. phaseolina* was important particularly in the post-rainy seasons. No *Penicillium* spp. were recorded in seed from soils at Dharwad. *M. phaseolina* was predominant at Parbhani. Genotypes resistant to *A. flavus* had low percentages (0.9–6.2% in Alfisols; 0.9–13.8% in Vertisols) of seed infected by these fungi in all seasons across locations, while susceptible genotypes had substantial infection (5.5–53.2% in Alfisols; 3.5–52.0% in Vertisols). Among the susceptible genotypes, EC 76446(292), NCAc 17090 and JL 24 had significantly high levels of infection by *A. niger* and *Penicillium* spp. Significant interactions occurred between genotypes and soil types, particularly in

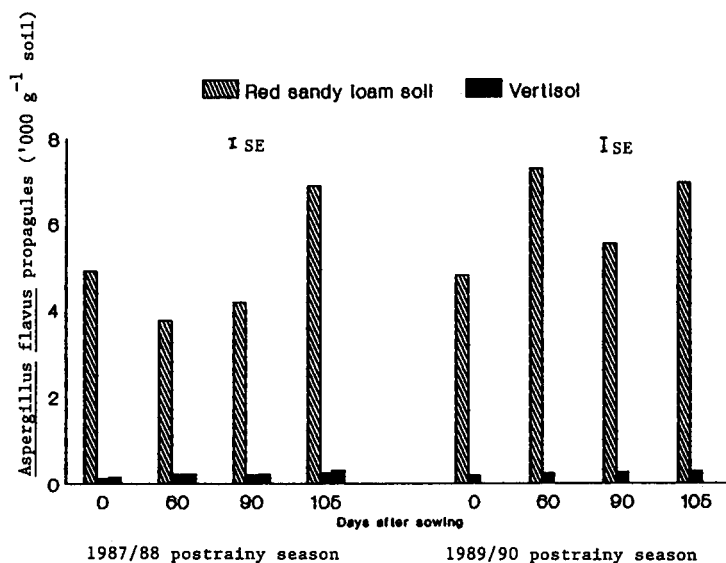


Fig. 2. Soil populations of *Aspergillus flavus* in red sandy loam soils (Alfisols) and Vertisols during the 1987/88 and 1989/90 post-rainy seasons at ICRISAT Center.

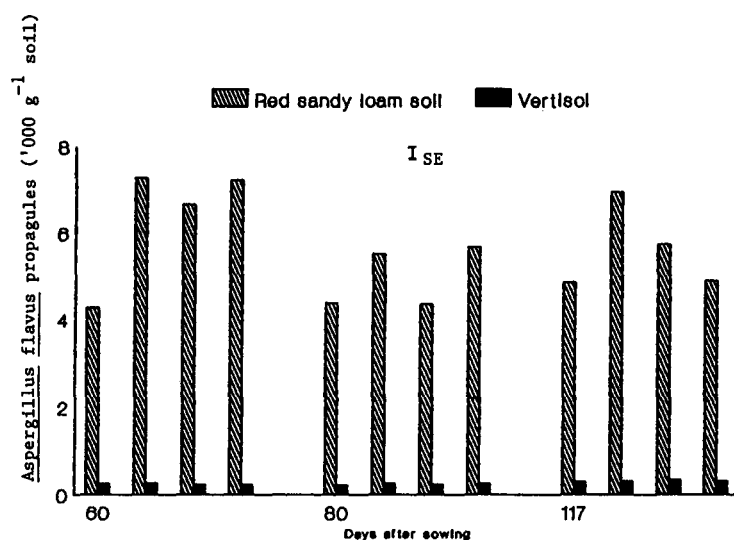


Fig. 3. Soil populations of *Aspergillus flavus* in four red sandy loam soil fields (Alfisols) and four Vertisol fields during the 1989/90 post-rainy season at ICRISAT Center.

the susceptible group genotypes, in respect of overall fungal infection.

Rainfall received by the groundnut crops grown in different soils in the various locations during the rainy seasons of 1985–1989 is shown in Table 5. There was considerable variation in rainfall between locations and seasons. In most situations, conditions were conducive to seed infection by the aflatoxin-producing fungi and for aflatoxin contamination as moderate to severe drought stress occurred during pod maturation.

Discussion

The present investigations have clearly shown that *A. flavus* infection and aflatoxin levels were much lower in seed of all genotypes from Vertisols than in seed from Alfisols (light sandy and red sandy loam soils) across locations in all seasons. Graham (1982) reported similar observations from limited trials in Queensland, Australia. It is pertinent to raise the important question whether these differences in infection and aflatoxin contamination were due to soil types or other environmental factors. Differences between the soil types in such factors as aeration, water-holding capacity, and pH can be important, and these reflect soil type as well as

weather effects. This could primarily be related to water-holding capacities of the soils; Vertisols have high water-holding capacities (150–180 mm) and groundnuts grown on these soils may be less prone to severe drought stress favorable for *A. flavus* infection and consequent aflatoxin contamination of groundnuts than those grown on Alfisols that have lower water-holding capacities (90–100 mm). Indeed, only low levels of seed infection by *A. flavus* and aflatoxin contamination occurred in Vertisols even when rainfall was very scanty during pod development and maturation stages of crop development in the 1986, 1987 and 1989 rainy seasons (Table 5).

Late-season drought stress is known to favor *A. flavus* infection and aflatoxin contamination (Pettit et al., 1971; Sanders et al., 1981). Low levels of *A. flavus* infection in Vertisols were also confirmed in trials over the post-rainy seasons, and it is important that the low levels were maintained under imposed late-season drought stress. Alfisols appear to favor rapid proliferation of *A. flavus* and seed infection, particularly under dry conditions late in the growing season. This is evident from the much higher soil populations of the fungus found in Alfisols than in Vertisols, fluctuations in the populations being influenced by rainfall patterns. Soil populations of *A. flavus* were low in several groundnut fields

Table 5. Rainfall received by groundnut crops grown in different soils at various locations, rainy seasons 1985–1989

Year	Soil type/ location	Sowing date	Total rainfall received (mm)	Rain (in mm) received by the crops at different stages of crop maturity			
				Days after sowing			
				1–30	31–60	61–90	91–110
1985	Alfisol ^a						
	ICRISAT Center	24.6.85	403.3	121.7	101.2	93.0	87.4
	Vertisol						
	ICRISAT Center	26.6.85	401.5	115.9	97.2	91.0	97.4
1986	Alfisol						
	ICRISAT Center	17.6.86	461.9	69.6	312.3	76.3	3.7
	Vertisol						
	ICRISAT Center	18.6.86	461.6	99.7	281.9	76.3	3.7
1987	Alfisol						
	ICRISAT Center	17.6.87	454.9	249.0	69.2	95.5	41.2
	Anantapur ^b	1.7.87	280.1	9.8	90.1	120.4	59.8
	Vertisol						
	ICRISAT Center	17.6.87	454.9	249.0	69.2	95.9	41.2
	Dharwad	9.7.87	362.0	45.6	47.3	174.1	95.0
	Parbhani	26.7.87	491.6	330.0	34.0	123.6	4.0
1988	Alfisol						
	ICRISAT Center	17.6.88	886.4	198.8	234.3	312.9	140.4
		20.6.88	818.2	175.7	283.7	243.5	115.3
	Anantapur	13.7.88	656.5	97.5	420.3	138.8	0.0
	Vertisol						
	ICRISAT Center	20.6.88	816.1	175.3	285.4	247.1	108.3
1989	Alfisol						
	ICRISAT Center	30.6.89	838.0	415.7	91.7	286.0	44.6
	Anantapur	10.7.89	569.7	191.2	133.9	208.1	36.5
	Vertisol						
	ICRISAT Center	1.7.89	838.0	415.7	91.7	288.4	42.2
	Parbhani	20.7.89	894.1	491.5	335.2	67.4	0.0

^a At ICRISAT Center Alfisol included a light sandy soil field and a sandy loam soil field each season; date of sowing was same for these soil types

^b At Anantapur Alfisol included only red sandy loam soil fields.

in Vertisols at ICRISAT Center. Similar observations were recorded at Parbhani in the 1989/90 post-rainy season. Variations in mycoflora of different soils may also account for differential populations of *A. flavus* in these soils. *M. phaseolina* and *A. niger* appeared to be dominant in Vertisols where they may compete with or be antagonistic to *A. flavus*. *A. flavus* has an important competitive advantage in times of drought stress when the activity of many other soil fungi is at a minimum. This ability of survival at low moisture availability, and favorable soil aeration may be responsible for the dominance of *A. flavus* in Alfisols.

Genotypic differences for *A. flavus* infection and aflatoxin contamination of seed were conspicuous in all trials across locations. These results provide additional confirmation of the resistance to *A. flavus* infection of seeds in certain groundnut genotypes (Mehan et al., 1987) and of the stability of this resistance.

The moderate to severe preharvest droughts and favorable postharvest drying conditions in the trials suggest that most of the seed infection by *A. flavus* in the test genotypes originated before harvest.

The results of the present investigations clearly indicate lower risk of preharvest *A. flavus* infec-

tion and aflatoxin contamination in groundnuts grown in Vertisols than in Alfisols.

It will be useful to assess preharvest aflatoxin contamination risks in black soils (Vertisols) in different agroecological zones in various groundnut-growing countries of the SAT where considerable production is on such soils (Virmani and Singh, 1986). The results will be of value in making surveys of aflatoxin contamination of groundnuts in Vertisols to assess risks, as it will help identify areas with low- or no aflatoxin risk.

It would be interesting to assess the aflatoxin risks in such soil types varying in pH (from acidic to alkaline). It would also be useful to examine the effects of different moisture levels on soil populations of the *A. flavus* group fungi in Vertisols.

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