J. Phytopathology **150**, 606–610 (2002)

ISSN 0931-1785

Cátedra de Química Orgánica, Universidad Nacional de Córdoba, Argentina

Effect of Planting Date on *Fusarium* spp. and *Diaporthe/Phomopsis* Complex Incidence and its Relationship with Soya Bean Seed Quality

J. M. Meriles[1], L. M. Giorda[2] and D. M. Maestri[1]

Authors' addresses: [1]Instituto Multidisciplinario de Biología Vegetal (IMBIV, CONICET – UNC), Cátedra de Química Orgánica, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Av. Vélez Sarsfield 1600 - Ciudad Universitaria - Córdoba 5016, Argentina; [2]Estación Experimental Agropecuaria (EEA - INTA, Manfredi), Manfredi 5988, Argentina (correspondence to D. M. Maestri. E-mail: dmaestri@gtwing.efn.uncor.edu)

Received March 25, 2002; accepted August 22, 2002

Keywords: *Diaporthe/Phomopsis* complex, *Fusarium* spp., soyabean, Argentina

Abstract

Fifteen soya bean genotypes from maturity groups IV, V and VI were planted on three dates at Manfredi Experimental Station – INTA, Córdoba Province, Argentina. Seeds were harvested at maturity and evaluated for seed infection by *Fusarium* spp. and *Diaporthe/Phomopsis* complex, and for physical and chemical parameters. There was a significant negative correlation between planting date (PD) and fungal incidence ($P = 0.05$). A higher percentage of fungal incidence at earlier PD was consistent with lower seed weight and volume, higher oil content and no change in protein content. The highest values of fungal incidence were associated with increased oleic acid and decreased linoleic and linolenic acid contents. These results suggest that planting late maturity cultivars or delaying the planting of early and mid-season cultivars may reduce seed infection by *Fusarium* spp. and *Diaporthe/Phomopsis* complex.

Introduction

The *Diaporthe/Phomopsis* complex is recognized as the major cause of lower yield and reduced seed quality in soya bean (Abney and Ploper, 1988; Sinclair and Backman, 1989; Fábrega et al., 2000). It includes seed decay, caused primarily by *Phomopsis longicolla* Hobbs; pod and stem blight, caused by *Diaporthe phaseolorum* (Cke. & Ell.) Sacc. var *sojae* (Lehman) Wehm.; and 'northern stem canker', caused by *D. phaseolorum* (Cke & Ell.) Sacc. var *caulivora* L. Athow R.M. Caldwell, and 'southern stem canker', caused by *D. phaseolorum* (Cke. & Ell.) Sacc. var *meridionalis* F.A. Fernandez. All are seedborne in soya bean, *P. longicolla* and *D. phaseolorum* var. *sojae* being the most frequently recovered in Argentina (Vallone and Giorda, 1997).

Various *Fusarium* spp. have also been reported to be seedborne in soya bean (Sinclair and Backman, 1989; McGee, 1992; Sinclair, 1995), but their importance in reducing soya bean seed quality may have been underestimated. However, mycotoxins produced by these fungi may directly or indirectly affect the chemical quality of soya bean seed (Wilson, 1995), and fungal damage may have significant deleterious effect on chemical and physical properties of soya bean.

Proper choice of soya bean planting date and cultivar maturity group can reduce seed infection. Early planting may result in early maturity dates, which may enhance seed infection with *Phomopsis* spp. (Kmetz et al., 1978). Although management practices may influence seed germination and seed infection, there is little information on their effect on seed composition.

Due to favourable environmental conditions in the central fringe of the Argentinean soya bean growing area for the development of *Fusarium* spp. and *Diaporthe/Phomopsis* seed infection, a high incidence of these pathogens has occurred in recent years (Vallone and Giorda, 1997).

We have determined the effect of different planting dates on *Fusarium* spp. and *Diaporthe/Phomopsis* complex incidence and its relationship to some chemical and physical parameters of seeds of 15 soya bean cultivars from maturity groups IV, V and VI.

Materials and Methods

Plant material and experimental design

The experiment was conducted at Manfredi Experimental Station – INTA, Córdoba Province, Argentina. The experimental design included three planting dates (PD): 18 November and 9 December 1998 and 5 January 1999. Fifteen soya bean cultivars were planted in a randomized block design with three replicates. The cultivars were: Asgrow 4100 RG, DM 49, Nmitchell 44, Promax 450, TJ 2044 and TJ 2046 from group IV; Asgrow 5818 RG, Conesa, CX 500, Eureka 51, Promax

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530, Spring 53 and Asgrow 5901 RG from group V; FH 6686 RR and HM 3-60 RR from group VI. The cultivars were separately harvested and stored at room temperature until processed.

Bioassay for seed-borne fungi

The procedure used was a modification of that described by Kmetz et al. (1974). For each PD/cultivar/replicate combination, a 100-seed sample was randomly chosen and placed in 10-cm plastic culture plates containing potato dextrose agar with four seeds per plate. Seeds were incubated under 12 h light and dark at room temperature. Seed-borne fungi were identified from their morphological characteristics at 14 days after planting.

Fungal incidence was determined using the blotter test according to International Seed Testing Association rules.

Physical analyses

Similarly, for each PD/cultivar/replicate combination two samples of 100 seeds each were randomly chosen and used to determine seed weight and volume according to Hepperly and Sinclair (1978).

Chemical analyses

Protein and oil contents Protein and oil contents were determined according to the methods of the Association of Official Analytical Chemists (AOAC, 1990).

Extraction of oil and fatty acid analysis Seed samples were milled and extracted with *n*-hexane in a Soxhlet apparatus (Figmay SA, Argentina) for 12 h. The extracted oils were dried over anhydrous sodium sulphate followed by removal of the solvent by vacuum distillation at 45°C. The crude oils were subjected to alkaline saponification (1N KOH in methanol). Unsaponifiable matter was extracted with *n*-hexane. The fatty acid methyl esters of total lipids were obtained using 1N H_2SO_4 in methanol and analysed by gas chromatography (GC) according to Maestri et al. (1998).

Iodine and peroxide values of seed oils Iodine values (Iv) were calculated from fatty acid percentages (Maestri et al., 1998) by using the formula

$$\text{Ivs} = (\%\text{oleic} \times 0.899) + (\%\text{linoleic} \times 1.814) + (\%\text{linolenic} \times 2.737)$$

Peroxide values (Pv) were determined according to the thiocyanate method (Osawa and Namiki, 1981).

Statistical analysis

Statistical differences between PD for each cultivar were estimated by ANOVA at the 5% level ($P = 0.05$) of significance, for all parameters evaluated. Whenever ANOVA indicated a significant difference, a pairwise comparison of mean by least significant difference (LSD) was carried out. Correlation analysis was performed employing Pearson's test. Correlation coefficients were calculated on cultivar values for all PD.

Results

Fungal incidence

The fungi most frequently recovered were *Fusarium* spp., *P. longicolla* and *D. phaseolorum* var *sojae*. *Fusarium semitectum* Berk & Ravenele was the *Fusarium* species most commonly found. Significant differences among PD were observed in all cultivars for *Fusarium* spp. and *Diaporthe/Phomopsis* complex incidence, with the exception of cvs Conesa, Spring 53 (MG V, Table 2), FH 6686 RR and HM 3-60 RR (MG VI, Table 3). The mean percentage of fungal incidence from seeds of MG IV cultivars (Table 1) fell into the following ranges: 28.6–39.3% (first PD), 10.7–27.0% (second PD), 1.0–12.3% (third PD); for MG V cultivars (Table 2): 5.3–43.7% (first PD), 2.3–40.3% (second PD), 2.5–17.3% (third PD); and for MG VI cultivars (Table 3): 3.3–4.3% (first PD), 5.5% (second PD), and 2.0–3.0% (third PD). In all cultivars from MG IV and V, the highest percentages of *Fusarium* spp. and *Diaporthe/Phomopsis* complex incidence were observed at the first PD and it decreased towards the third PD. The correlation coefficient between fungal incidence and PD was $r = -0.59$, so there was a trend towards lower percentages of infected seeds as the PD was delayed.

Physical parameters

Cultivars from MG IV had the lowest values of seed weight and volume at the first PD and the greatest at the third PD (Table 1). The reverse relationship was observed for MG VI cultivars (Table 3). In MG V (Table 2), cultivar responses were inconsistent across PD. In general, seed weight and volume had the highest values at second PD. Fungal incidence correlated negatively with seed weight ($r = -0.27$), but no significant correlation was observed with seed volume.

Protein content

Seed protein content showed little variation among PD. With the exception of cvs A 4100 RG (MG IV), A 5818 RG, CX 500, Eureka 51 and Spring 53 (MG V), no significant differences were observed with PD. There was no significant correlation between protein content and fungal incidence.

Oil content

With the exception of cvs A 4100 RG, Nmitchell 44, Promax 450 (GM IV), A 5818 RG, Conesa and CX 500 (GM V), there were significant differences in oil contents with PDs. The highest seed oil contents were obtained at the first PD (Tables 1–3). Oil content was positively correlated with fungal incidence ($r = 0.54$).

Fatty acid composition and physicochemical characteristics of seed oils

Saturated fatty acids (palmitic and stearic) showed little variation with PD (Tables 1–3). There was a

Table 1
Fungal incidence (%), physical parameters (based on 100 seeds), oil and protein contents (g/kg, dry matter), fatty acid composition (% of total fatty acids), iodine values and peroxide values (meq/kg) of seed oils from soya bean cultivars of maturity group IV at three planting dates (PD)

		Cultivars					
	PD	A 4100 RG	DM 49	Nmitchell 44	Promax 450	TJ 2044	TJ 2046
Fungal incidence	1	31.3^{a} ± 8.0	39.0^{a} ± 2.0	29.3^{a} ± 0.6	39.3^{a} ± 12.5	37.3^{a} ± 2.5	28.6^{a} ± 2.5
	2	27.0^{a} ± 5.3	27.0^{ab} ± 6.1	10.7^{b} ± 5.8	26.7^{a} ± 4.1	21.7^{b} ± 5.7	19.7^{a} ± 7.2
	3	12.3^{b} ± 2.5	10.5^{c} ± 1.5	1.0^{c} ± 0.1	1.5^{b} ± 0.7	6.0^{c} ± 4.0	3.3^{b} ± 2.0
Seed weight (g)	1	11.2^{a} ± 0.9	13.3^{a} ± 0.6	12.5^{a} ± 0.7	14.5^{a} ± 0.8	11.6^{a} ± 0.1	14.4^{a} ± 0.7
	2	13.1^{ab} ± 1.6	12.9^{a} ± 0.4	17.0^{b} ± 1.6	16.3^{a} ± 0.8	13.2^{b} ± 0.8	18.7^{b} ± 2.5
	3	15.5^{b} ± 0.5	18.2^{b} ± 1.0	17.4^{b} ± 0.5	19.3^{b} ± 0.6	15.1^{b} ± 0.4	19.1^{b} ± 0.5
	1	10.0^{a} ± 0.8	12.0^{a} ± 0.1	12.0^{a} ± 0.1	13.3^{a} ± 0.4	10.3^{b} ± 0.4	12.3 ± 0.4
Seed volume (ml)	2	11.7^{ab} ± 1.8	11.7^{a} ± 0.4	14.7^{b} ± 0.9	14.0^{a} ± 0.1	11.7^{b} ± 0.9	13.7 ± 3.8
	3	13.3^{b} ± 0.4	15.2^{b} ± 0.8	14.8^{b} ± 0.4	16.3^{b} ± 0.4	8.7^{a} ± 0.4	14.2 ± 3.0
	1	186.1 ± 21.9	207.9^{a} ± 7.9	183.3 ± 5.9	194.3 ± 22.8	199.4^{a} ± 4.8	215.3^{a} ± 2.6
Oil	2	191.4 ± 21.1	174.6^{b} ± 6.0	178.8 ± 5.9	191.3 ± 3.0	176.6^{b} ± 5.6	186.2^{b} ± 4.6
	3	163.5 ± 24.5	172.5^{b} ± 20.0	176.7 ± 8.9	196.5 ± 5.4	181.2^{b} ± 4.2	177.3^{b} ± 17.1
	1	295.5^{a} ± 25.7	352.0 ± 13.9	364.0 ± 17.7	369.0 ± 9.4	366.1 ± 12.1	328.2 ± 15.4
Protein	2	343.9^{b} ± 7.4	381.7 ± 7.1	372.3 ± 15.6	378.0 ± 11.5	387.9 ± 21.8	336.1 ± 16.9
	3	338.2^{b} ± 10.7	361.9 ± 22.8	361.6 ± 6.2	350.1 ± 14.2	376.0 ± 4.9	362.7 ± 23.8
	1	12.3 ± 0.7	12.6 ± 0.3	12.6 ± 0.4	12.4 ± 1.6	12.4 ± 2.0	12.2^{a} ± 0.2
Palmitic	2	11.3 ± 0.7	11.6 ± 0.5	11.9 ± 0.4	10.9 ± 0.7	11.8 ± 1.7	11.2^{b} ± 0.5
	3	11.5 ± 0.9	11.7 ± 0.5	12.5 ± 0.6	11.6 ± 2.1	11.6 ± 1.1	11.7^{ab} ± 0.4
	1	5.4^{a} ± 0.6	4.3^{a} ± 0.3	4.9^{a} ± 0.3	5.3 ± 0.6	5.7^{a} ± 0.3	4.5 ± 0.9
Stearic	2	5.0^{ab} ± 0.1	3.9^{b} ± 0.1	4.1^{ab} ± 0.3	4.5 ± 0.4	4.8^{ab} ± 0.3	3.9 ± 0.3
	3	4.2^{b} ± 0.2	3.5^{c} ± 0.1	3.6^{b} ± 0.5	4.4 ± 1.0	4.2^{b} ± 0.6	3.7 ± 0.5
	1	26.0 ± 1.6	25.7^{a} ± 0.5	21.9 ± 1.1	27.4 ± 0.6	26.1 ± 1.3	26.9^{a} ± 1.0
Oleic	2	26.6 ± 0.5	29.9^{b} ± 0.4	21.3 ± 1.3	27.8 ± 0.4	26.7 ± 1.2	25.4^{a} ± 1.1
	3	24.2 ± 0.3	25.7^{a} ± 2.3	24.6 ± 2.9	27.6 ± 0.1	25.2 ± 2.0	23.0^{b} ± 0.1
	1	50.1 ± 1.5	51.6 ± 0.6	53.4 ± 0.9	49.6 ± 1.9	50.1 ± 1.3	50.3^{a} ± 2.3
Linoleic	2	50.6 ± 1.1	48.5 ± 0.4	55.5 ± 0.7	51.0 ± 0.9	50.1 ± 0.5	53.3^{ab} ± 0.6
	3	50.9 ± 2.4	51.6 ± 2.1	53.9 ± 3.6	51.4 ± 0.1	52.1 ± 1.7	54.3^{b} ± 0.5
	1	6.2 ± 0.8	6.4^{ab} ± 0.4	7.1 ± 0.1	5.3 ± 0.9	5.7 ± 0.6	6.1 ± 0.6
Linolenic	2	6.5 ± 0.2	6.2^{a} ± 0.1	7.2 ± 0.5	5.7 ± 0.6	6.5 ± 0.9	6.2 ± 0.9
	3	7.1 ± 0.9	7.8^{b} ± 0.9	6.9 ± 0.5	5.9 ± 0.9	6.9 ± 1.2	7.2 ± 0.4
	1	131.2 ± 3.3	134.1^{ab} ± 2.2	136.1 ± 0.9	129.2 ± 5.4	130.1 ± 4.1	132.0^{a} ± 1.8
Iodine value	2	133.4 ± 1.9	131.7^{a} ± 0.6	139.4 ± 1.4	133.2 ± 2.9	132.8 ± 3.3	136.6^{ab} ± 2.5
	3	135.4 ± 3.7	137.9^{b} ± 3.1	137.2 ± 3.9	134.1 ± 8.3	136.1 ± 4.3	138.9^{b} ± 0.2
	1	4.0 ± 0.7	8.3 ± 1.7	6.0 ± 1.8	5.3 ± 1.0	6.9 ± 1.9	4.5 ± 1.1
Peroxide value	2	3.0 ± 1.2	6.1 ± 1.1	5.0 ± 0.4	5.8 ± 1.4	6.0 ± 2.1	4.9 ± 0.8
	3	3.8 ± 0.8	5.1 ± 0.7	5.0 ± 1.0	3.6 ± 0.1	4.5 ± 1.4	3.1 ± 0.2

Mean values ± SD ($n = 3$). Mean values in columns for each planting date/cultivar combination followed by the same letter do not differ significantly at $P = 0.05$.

significant positive correlation between fungal incidence and the percentage of stearic acid ($r = 0.55$). Among the unsaturated fatty acids, oleic acid had the lowest values at the third PD, especially in cultivars from MG V and VI, mainly. On the contrary, linoleic and linolenic acid percentages tended to increase towards the third PD (Tables 1–3). Examination of the relation of fungal incidence to unsaturated fatty acid composition revealed a significant positive correlation between fungal incidence and oleic acid ($r = 0.61$), whereas it was negative with each of two polyunsaturated fatty acids: linoleic ($r = -0.51$) and linolenic ($r = -0.63$). Some cultivars varied considerably with PD in the Iv of their oils; in general, the smallest Iv were found at the first PD. When all cultivars were compared across all PD, a significant negative correlation existed between Iv ($r = -0.59$) and fungal incidence by *Fusarium* spp. and *Diaporthe/Phomopsis* complex. With a few exceptions, Pv had the highest values at first PD and they decreased towards third PD. As a consequence, a significant positive correlation between Pv and fungal incidence was observed with $r = 0.70$.

Discussion

Soya bean seed composition varied with PD and this variation was closely associated with fungal incidence. The highest percentages of *Fusarium* spp. and *Diaporthe/Phomopsis* complex incidence were registered in cultivars from MG IV, with the major incidence at first PD. Accordingly, these cultivars sowed at the first PD produced seeds with the lowest weight and volume values.

In association with high levels of fungal incidence, results showed an increase in oil concentration of seeds. However, seed protein content was not as closely correlated to seed infection as oil content. It seems that no apparent gain in protein content was detected in some cultivars by delaying the PD. These results partially agree with those of Wilson et al. (1995) who

Table 2
Fungal incidence (%), physical parameters (based on 100 seeds), oil and protein contents (g/kg, dry matter), fatty acid composition (% of total fatty acids), iodine values and peroxide values (meq/kg) of seed oils from soya bean cultivars of maturity group V at three planting dates (PD)

		Cultivars						
	PD	A 5818 RG	A 5901 RG	Conesa	CX 500	Eureka 51	Promax 530	Spring 53
Fungal incidence	1	14.7^{b} ± 0.6	43.7^{a} ± 5.5	5.3 ± 0.6	28.0^{a} ± 4.6	40.3^{a} ± 12.7	25.0^{a} ± 5.0	16.0 ± 8.2
	2	3.3^{b} ± 1.5	40.3^{a} ± 5.0	2.3 ± 0.6	9.7^{b} ± 1.1	17.6^{ab} ± 9.3	3.3^{b} ± 2.1	6.3 ± 5.1
	3	2.5^{b} ± 0.7	17.3^{b} ± 4.0	4.3 ± 3.2	9.3^{b} ± 1.1	5.0^{b} ± 1.7	2.5^{b} ± 0.7	3.0 ± 1.7
Seed weight (g)	1	14.3 ± 0.1	12.7^{a} ± 0.1	16.4^{a} ± 0.7	18.3^{a} ± 1.2	16.7^{a} ± 0.3	15.5 ± 0.6	13.6^{a} ± 0.6
	2	17.1 ± 0.3	13.7^{a} ± 0.8	17.7^{b} ± 0.5	21.7^{b} ± 1.6	20.3^{b} ± 0.2	15.5 ± 0.5	14.9^{b} ± 0.1
	3	15.6 ± 2.6	17.4^{b} ± 0.1	17.4^{a} ± 0.1	16.4^{a} ± 0.1	16.0^{a} ± 0.3	14.5 ± 0.4	13.8^{a} ± 0.1
Seed volume (ml)	1	12.3^{a} ± 0.4	11.3^{a} ± 0.9	13.7 ± 0.9	15.3^{a} ± 1.3	15.0^{a} ± 0.1	12.5 ± 0.4	11.5 ± 0.4
	2	14.4^{b} ± 0.4	12.2^{a} ± 0.6	14.8 ± 0.2	18.2^{b} ± 1.1	16.6^{b} ± 0.4	12.8 ± 0.8	12.0 ± 0.1
	3	11.7^{a} ± 0.4	15.0^{b} ± 0.1	13.5 ± 0.4	14.3^{a} ± 0.5	13.5^{a} ± 0.4	12.3 ± 0.2	11.7 ± 0.4
Oil	1	190.5 ± 10.4	225.5^{a} ± 3.3	191.2 ± 13.5	210.7 ± 5.8	231.5^{b} ± 19.0	165.7^{b} ± 9.6	220.3^{a} ± 26.2
	2	202.6 ± 11.2	201.7^{ab} ± 15.3	188.5 ± 6.1	202.0 ± 7.0	187.4^{ab} ± 8.0	140.4^{b} ± 3.9	160.3^{b} ± 6.0
	3	183.3 ± 9.5	196.5^{b} ± 8.3	195.2 ± 11.0	186.6 ± 19.0	174.5^{b} ± 20.6	140.8^{b} ± 4.1	165.1^{b} ± 21.1
Protein	1	309.6^{a} ± 12.2	343.2 ± 11.0	334.2 ± 10.4	323.1^{a} ± 12.1	338.9^{a} ± 13.2	328.1 ± 28.2	331.7^{ab} ± 28.0
	2	354.2^{b} ± 22.6	358.6 ± 10.6	355.8 ± 19.7	354.7^{b} ± 4.8	369.1^{b} ± 9.6	318.4 ± 25.8	369.3^{a} ± 17.0
	3	335.2^{b} ± 12.9	338.6 ± 8.8	342.3 ± 2.1	322.7^{b} ± 0.9	347.0^{ab} ± 7.7	327.7 ± 10.9	309.8^{b} ± 1.0
Palmitic	1	11.7 ± 1.8	12.0 ± 0.6	12.4 ± 1.5	10.9 ± 0.2	11.4 ± 0.7	11.6 ± 1.0	11.3 ± 0.2
	2	12.3 ± 0.2	10.7 ± 0.8	12.8 ± 1.5	10.7 ± 0.4	11.0 ± 0.4	12.0 ± 0.3	11.4 ± 0.2
	3	12.2 ± 0.5	11.6 ± 0.6	14.5 ± 0.6	11.3 ± 0.6	11.9 ± 0.3	12.2 ± 0.6	11.8 ± 0.9
Stearic	1	4.0 ± 0.4	4.4 ± 0.4	3.6 ± 0.3	4.4 ± 0.1	4.3^{a} ± 0.3	3.6 ± 0.4	3.7 ± 0.2
	2	3.9 ± 0.1	4.2 ± 0.2	3.8 ± 0.3	4.6 ± 0.1	4.2^{ab} ± 0.1	3.7 ± 0.1	3.4 ± 0.1
	3	4.5 ± 0.6	3.7 ± 0.4	3.8 ± 0.2	4.5 ± 0.3	3.8^{b} ± 0.2	3.5 ± 0.1	3.9 ± 0.8
Oleic	1	19.8^{b} ± 0.6	24.6 ± 0.8	19.1 ± 1.5	22.9^{a} ± 0.4	23.8^{a} ± 0.3	20.6^{a} ± 1.0	20.4 ± 1.2
	2	19.5^{a} ± 0.2	25.4 ± 2.1	18.0 ± 1.0	24.5^{a} ± 1.0	23.6^{a} ± 0.6	21.1^{a} ± 0.3	21.6 ± 0.3
	3	18.2^{b} ± 0.3	22.8 ± 1.6	17.1 ± 0.6	20.2^{b} ± 0.6	18.8^{b} ± 0.2	17.6^{b} ± 0.4	19.9 ± 1.6
Linoleic	1	55.7 ± 0.7	52.6 ± 1.2	56.5 ± 0.8	55.3^{a} ± 0.6	53.1^{a} ± 0.5	56.6^{a} ± 0.6	57.4^{a} ± 0.5
	2	55.1 ± 0.2	52.7 ± 1.5	55.5 ± 0.1	52.6^{b} ± 0.3	53.8^{a} ± 0.6	54.9^{b} ± 0.1	54.8^{b} ± 0.4
	3	55.2 ± 0.8	54.3 ± 1.9	55.4 ± 0.6	55.4^{a} ± 0.4	56.6^{b} ± 0.2	57.0^{a} ± 0.3	55.8^{a} ± 1.1
Linolenic	1	8.4 ± 0.9	6.4 ± 0.5	8.3^{a} ± 0.5	7.0^{a} ± 0.1	7.1^{a} ± 0.7	7.6 ± 1.4	7.7 ± 1.4
	2	9.1 ± 0.4	6.9 ± 0.6	9.9^{b} ± 0.3	7.5^{a} ± 0.4	7.3^{a} ± 0.3	8.4 ± 0.1	8.7 ± 0.5
	3	9.9 ± 0.2	7.6 ± 0.9	9.3^{ab} ± 0.5	8.7^{b} ± 0.3	8.8^{b} ± 0.2	9.8 ± 0.8	8.5 ± 0.5
Iodine value	1	141.9 ± 3.5	135.0 ± 2.7	142.4 ± 2.2	140.2^{ab} ± 1.5	137.3^{a} ± 2.6	142.0 ± 3.7	143.4 ± 3.1
	2	142.5 ± 0.6	137.4 ± 1.8	143.9 ± 1.4	138.1^{a} ± 0.7	138.9^{a} ± 1.5	141.4 ± 0.4	142.8 ± 0.2
	3	143.6 ± 1.9	139.7 ± 3.9	141.2 ± 1.0	142.4^{b} ± 0.8	143.7^{b} ± 0.4	146.0 ± 1.8	142.5 ± 1.9
Peroxide value	1	4.4 ± 1.2	8.6^{a} ± 3.1	8.3^{a} ± 0.5	8.6^{a} ± 0.3	13.1^{a} ± 1.6	6.0 ± 0.7	9.0 ± 5.1
	2	3.6 ± 0.8	4.3^{ab} ± 0.9	5.7^{b} ± 0.2	5.9^{ab} ± 0.8	5.1^{b} ± 1.0	4.7 ± 0.3	6.4 ± 2.4
	3	3.7 ± 0.5	3.2^{b} ± 0.7	5.2^{b} ± 0.4	4.5^{b} ± 1.7	3.7^{b} ± 0.8	4.2 ± 1.2	4.3 ± 0.4

Mean values ± SD ($n = 3$). Mean values in columns for each planting date/cultivar combination followed by the same letter do not differ significantly at $P = 0.05$.

have postulated that fungus-damaged soya beans may exhibit higher protein concentrations and either no change or increased oil concentrations.

The effect of seed infection on fatty acid composition of oils is less clear and differences among cultivars within the same MG are difficult to interpret. In fungal damaged soya beans, total tocopherol levels may decline under conditions that favour lipid oxidation (List, 1980; Wilson, 1995). Thus, severe oxidation may result in higher oleic and lower linoleic and linolenic acid concentrations (List, 1980). Consequently, the lower Iv observed at higher percentages of fungal incidence (specially MG IV cultivars at earlier PD), may be due to lipid oxidation. The highest Pv and poor flavours found in oils from highly infected seeds shed light on this matter. Furthermore, these oils had a darker colour than those from seeds with lower fungal incidence.

The late-maturing cultivars (FH 6686 RR and HM 3-60 RR), regardless of PD, produced seeds with a lower fungal incidence than MG IV and V cultivars. These two cultivars from MG VI reached harvest maturity later in the growing season, for all three PD, when environmental conditions were less favourable for *Fusarium* spp. and *Diaporthe/Phomopsis* complex seed infection. As a result, cvs FH 6686 RR and HM 3-60 RR escaped severe seed infection by these pathogens. On the other hand, the lower percentages of fungal incidence observed in cv. Conesa (GM V) at three PDs might reflect at least some degree of resistance to the pathogens evaluated.

Although it is difficult to separate the influence of environmental, cultural and genetic factors on seed quality, the results of this and related studies (Tekrony et al., 1984; Hershman et al., 1987; Jordan et al., 1988; Rupe, 1989; Wrather et al., 1996) suggest that planting late-maturing cultivars or delaying the planting of early- and mid-season cultivars may reduce seed infection by *Fusarium* spp. and *Diaporthe/Phomopsis* complex. However, further research is needed to

Table 3
Fungal incidence (%), physical parameters (based on 100 seeds), oil and protein contents (g/kg, dry matter), fatty acid composition (% of total fatty acids), iodine values and peroxide values (meq/kg) of seed oils from soya bean cultivars of maturity group VI at three planting dates (PD)

	PD	Cultivars	
		FH 6686 RR	HM 3-60 RR
Fungal incidence	1	4.3 ± 2.5	3.3 ± 2.3
	2	5.5 ± 0.7	5.5 ± 3.5
	3	3.0 ± 1.0	2.0 ± 1.0
Seed weight (g)	1	16.0^{a} ± 0.6	12.7^{c} ± 0.1
	2	13.4^{b} ± 0.3	12.6^{c} ± 0.4
	3	13.2^{b} ± 0.2	10.1^{b} ± 0.2
Seed volume (ml)	1	13.8^{a} ± 0.6	11.0^{c} ± 0.1
	2	11.5^{b} ± 0.4	10.5^{b} ± 0.4
	3	11.2^{b} ± 0.2	9.3^{b} ± 0.4
Oil	1	196.1^{a} ± 6.3	156.6^{a} ± 17.1
	2	147.7^{b} ± 5.6	133.9^{b} ± 12.3
	3	124.9^{b} ± 20.1	130.9^{b} ± 5.1
Protein	1	354.2 ± 6.9	324.2 ± 13.3
	2	355.4 ± 12.1	342.2 ± 25.4
	3	341.9 ± 28.2	344.2 ± 11.3
Palmitic	1	13.5 ± 0.6	12.0 ± 1.2
	2	13.5 ± 1.8	11.5 ± 1.1
	3	13.0 ± 0.6	13.7 ± 1.1
Stearic	1	3.5 ± 0.4	3.4 ± 0.2
	2	3.3 ± 0.2	3.5 ± 0.2
	3	3.3 ± 0.2	3.6 ± 0.4
Oleic	1	23.4^{a} ± 2.1	17.4^{a} ± 0.5
	2	20.2^{ab} ± 0.6	15.9^{b} ± 0.3
	3	20.0^{b} ± 0.6	14.8^{c} ± 0.4
Linoleic	1	51.9 ± 2.7	58.1 ± 0.3
	2	54.0 ± 1.6	58.3 ± 0.5
	3	54.3 ± 0.7	57.9 ± 1.3
Linolenic	1	7.7^{a} ± 0.3	8.4^{a} ± 0.9
	2	9.0^{b} ± 0.1	10.0^{b} ± 0.4
	3	9.4^{b} ± 0.6	10.0^{b} ± 0.2
Iodine value	1	136.2 ± 2.8	144.0 ± 2.1
	2	140.8 ± 2.9	147.9 ± 0.6
	3	142.3 ± 2.2	145.6 ± 2.6
Peroxide value	1	5.9 ± 0.6	5.6 ± 0.7
	2	7.6 ± 1.5	7.0 ± 2.3
	3	7.1 ± 1.8	5.5 ± 0.9

Mean values ± SD ($n = 3$). Mean values in columns for each planting date/cultivar combination followed by the same letter do not differ significantly at $P = 0.05$.

evaluate maturity group effects on fungal seed infection and more cultivars within MG VI must be included.

Acknowledgements

These studies were cooperative investigations between Cátedra de Química Orgánica (FCEF y N - UNC) and EEA-INTA Manfredi, Córdoba. This research was supported by grants from CONICET and SECyT-UNC.

References

Abney, T. S., L. D. Ploper (1988): Seed diseases. In: Wyllie, T. D. and D. H. Scott (eds). Soya bean Diseases of the North Central Region. pp. 3–6. The American Phytopathological Society, St. Paul, MN, USA.

AOAC (1990): Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edn. Arlington, USA.

Fábrega, A. R., A. L. Lamarque, L. M. Giorda, C. A. Guzmán, D. M. Maestri (2000): Effect of *Diaporthe phaseolorum* var. *sojae* infection on seed quality of soya bean genotypes. Fitopatol. Bras. **25**, 624–627.

Hepperly, P. R., J. B. Sinclair (1978): Quality losses in *Phomopsis*-infected soya bean seeds. Phytopathology **68**, 1684–1687.

Hershman, D. E., J. W. Hendrix, R. E. Stuckey, P. R. Bachi, J. H. Grove (1987): Effect of soya bean cultivars and planting date on development of soya bean sudden death syndrome. Phytopathology **77**, 689–694.

Jordan, E. G., J. B. Manandhar, P. N. Thapliyal, J. B. Sinclair (1988): Soya bean seed quality of 16 cultivars and four maturity groups in Illinois. Plant Dis. **72**, 64–67.

Kmetz, K. T., C. W. Ellett, A. F. Schmitthenner (1974): Isolation of seedborne *Diaporthe phaseolorum* and *Phomopsis* from immature soya bean plants. Plant Dis. Repr. **58**, 978–982.

Kmetz, K. T., A. F. Schmitthenner, C. W. Ellett (1978): Soya bean seed decay: prevalence of infection and symptom expression caused by *Phomopsis* sp., *Diaporthe phaseolorum* var. *sojae*, and *D. phaseolorum* var. *caulivora*. Phytopathology **68**, 836–840.

List, G. R. (1980): Handbook of soya bean Oil Processing and Utilization. American soya bean Association/American Oil Chemists' Society, Champaign, Illinois, USA.

Maestri, D. M., D. O. Labuckas, J. M. Meriles, A. L. Lamarque, J. A. Zygadlo, C. A. Guzmán (1998): Seed composition of soya bean cultivars evaluated in different environmental regions. J. Sci. Food Agric. **77**, 494–498.

McGee, D. C. (1992): soya bean Diseases. A Reference Source for Seed Technologists. The American Phytopathological Society. St Paul, Minnesota, USA.

Osawa, T., M. Namiki (1981): A novel type of antioxidant isolated from leaf wax of eucalyptus leaves. Agric. Biol. Chem. **45**, 735–739.

Rupe, J. C. (1989): Epidemiology of sudden death syndrome of soya beans. In: Pascale, A. J. (ed.), Proceedings of the IV World soya bean Research Conference, pp. 2085–2090. Buenos Aires, Argentina.

Sinclair, J. B. (1995): Reevaluation of grading standards and discounts for fungus-damaged soya bean seeds. J. Amer. Oil Chem. Soc. **72**, 1415–1419.

Sinclair, J. B., P. A. Backman (1989): *Phomopsis* seed decay. In: Sinclair J. B. and Backman P. A. (eds), Compendium of soya bean Diseases, pp. 13–20. The American Phytopathological Society, St. Paul, MN, USA.

Tekrony, D. M., D. B. Egli, J. Balles, L. Tomes, R. E. Stuckey (1984): Effect of date of harvest maturity on soya bean seed quality and *Phomopsis* sp. seed infection. Crop Sci. **24**, 189–193.

Vallone, S., L. M. Giorda (1997): Enfermedades. In: Giorda, L. M. and H. E. J. Baigorri (eds). El Cultivo de la Soja en la Argentina. Instituto Nacional de Tecnología Agropecuaria, pp. 213–244.

Wilson, R. F. (1995): Dealing with the problems of fungal damaged in soya bean and other oilseeds. J. Amer. Oil Chem. Soc. **72**, 1413–1414.

Wilson, R. F., W. P. Novitzky, G. P. Fenner (1995): Effect of fungal damage on seed composition and quality of soya beans. J. Amer. Oil Chem. Soc. **72**, 1425–1429.

Wrather, J. A., S. R. Kendig, W. J. Wiebold, R. D. Riggs (1996): Cultivar and planting date effects on soya bean stand, yield, and *Phomopsis* sp. seed infection. Plant Dis. **80**, 622–624.