

Downy mildew (*Plasmopara halstedii*): importance and geographical distribution on sunflower in Morocco

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Summary. Downy mildew, caused by *Plasmopara halstedii* (Farl.) Berl. and de Toni, is a very serious disease of sunflower. Studies on the evolution of sunflower downy mildew conducted in 1996 and in 1997 showed that this disease was spreading to new sunflower-growing areas. In 1996, among 146 fields inspected, 77 (53%) were found to be infested with downy mildew. The Gharb region had the highest proportion of fields affected (60%), followed by Saïs (50%) and Loukous (41%). In 1997, 33% of the fields surveyed were infested. Again, the Gharb was the most frequently infected region with 39%, followed by Saïs (32%) and Loukous (17%), the last a region where downy mildew affects fewer fields. The incidence of mildew in sunflower plants in most of the regions averaged about 3% in 1996, and exceeded the values for 1997, when it was 5%. The disease is most often randomly distributed in the field. The surveys conducted with a sample of a hundred farmers showed that the lack of rotation and the utilisation of chemically untreated seeds of sensitive varieties favoured the disease.

Key words: sunflower, downy mildew, Morocco.

Introduction

In Morocco, the sunflower (*Helianthus annuus* L.) is the target of some potentially destructive diseases: gray rot caused by *Botrytis cinerea*, white rots from *Sclerotinia sclerotiorum* and downy mildew, which affects productivity and represents the principal obstacle to the more extensive cultivation of this crop (Achbani and Tourvieille, 1993b). Downy mildew, caused by *Plasmopara halstedii* (Farl.) Berl. and de Toni, is the most serious dis-

ease of sunflower (Achbani and Tourvieille, 1993c). Its spectacular spread constitutes a considerable problem to sunflower cropping if resolute and strong measures are not taken (Achbani and Tourvieille, 1993a).

Downy mildew was first reported in Morocco in the Gharb region in 1971 (Anonymous, 1981). However, until 1990, attacks on sunflower remained modest (Gosset, 1995). In 1990, Achbani and Tourvieille found the disease in the Safi area (Khemis zemamra) but only in two plants (Achbani and Tourvieille, 1993a). The manifestation of the disease in sporadic and restricted attacks did not worry farmers at the time (Gosset, 1995). The survey of 1991 confirmed the existence of mildew in a limited part of Saïs (Aïn jemâa) with an incidence

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on the plant that did not exceed 9% (Mouzeyar *et al.*, 1993). However, by the following year the disease had spread to all areas of Saïs without exception, as well as to the Aïn Maaskar area in northern Morocco (Larache) (Achbani and Tourvieille, 1993a). Damage was significant in Saïs, where the average incidence now exceeded 20% of plants (Achbani and Tourvieille, 1993a) and reached 78% of plants in some fields (Mouzeyar *et al.*, 1993). In Larache, Achbani and Tourvieille (1993c) reported an incidence of 4% of infected plants.

The survey carried out by Arouay (1993) revealed the existence of the disease in new locations: Aït Mimoun (Khémisset); Arbaoua (Loukous); Mnasra, Sidi Hachmi Bahraoui, Douar Ouled Hamdane, Souk Larbaa (Gharb); Karia Ba Mohamed (Taounate). Akrim (1994) also found mildew in some new areas: Aïn Orma, Dkhissa, Agouray, Volubilis, El Hajeb (Meknès); Jorf El Melha (Sidi Kacem); Moulay Bouselham (Kénitra); Sfassif (Khémisset); Ouazzane. The disease incidence varied from 1 to 40% of plants affected (Serrhini *et al.*, 1994). Since its appearance in Meknès in 1991, systematic surveys and investigations have been carried out in order to follow the evolution of the disease and its spread through the entire sunflower-producing area of Morocco.

The aim of this work was to determine the geographical distribution, the importance and the manner of spread of downy mildew in the principal sunflower areas in Morocco during two crop years, 1995-96 and 1996-97.

Materials and methods

Site selection and inspection

In order to ascertain the current status of downy mildew in Morocco, a survey was carried out in sunflower-producing areas during April, May, June and July of 2 crop years (1996 and 1997). The choice of sites was facilitated by local agricultural services (Direction Provinciale d'Agriculture, DPA, and Centres des Travaux, CT) and farmers. The survey examined the presence or absence of the disease in each locality and area inspected. Further information was gathered from farmers in interviews and concerned soil nature, topography, symptoms observed, type of rotation, variety grown, seed origin and the treatments carried out.

Incidence and manner of spread

During inspections, 6 to 17 field-grown sunflowers, chosen at random on each site, were examined to evaluate the incidence and severity of infection.

The data thus obtained made it possible to calculate the proportion of fields with mildew (field incidence), and also, within fields, the proportion of sunflower plants with mildew symptoms (plant incidence). To assess this second parameter, several sites of 100 plants each were delimited on the two diagonal axes of fields. The plant incidence of a field was the average incidence of its sites.

In each field, the manner of spread of the disease was also determined: Sporadic, or plant-to-plant, or both.

Results and discussion

The two surveys reported here revealed the presence of downy mildew at locations where it had already been noted in preceding surveys (1991-1995) such as Aïn Jemaa, Aïn Orma, Aïn Karma, Agouray, Oued Rommane and My Driss (Meknès); Boufekrane (El Hajeb); Mnasra, My Bouselham, Jorf and Melh (Kénitra); Larbaa Souk; Me rissa, Lalla Mimouna (Larache) (Table 1). It also unfortunately spread to new areas each year of the survey: in 1996 to Ras Jerry (Saïs); Had Kourt and Ouezzane (Gharb); Ksar Lkbir, Arbaoua and Aoumra (Loukous), and in 1997 to Sidi Yahia, Allal Tazi, Sidi Mohamed Lahmer and Kariat Ben Aouda (Gharb). At the same time, however, some areas previously found to harbour mildew now seemed to be free of it: in 1996, Kariat Ba Mohamed and Had Aït Mimoun (Arouay, 1993; Akrim, 1994); in 1997, Arbaoua (Arouay, 1993), Agouray and Jorf El Melha (Akrim, 1994). This renewed absence of downy mildew could be attributed to climatic conditions unfavourable for infection development. Moreover, some locations have hitherto received spared attacks: Sebt Jahjough (El Hajeb), Tihli, Khnichat and Zekouta (Sidi Kacem) and others (Table 1).

These results have enabled us to bring up to date the map showing areas where downy mildew occurs (Fig. 1).

The incidence of fields with downy mildew presence in the areas surveyed in 1996 and 1997 is presented in Table 2. In 1996, downy mildew was present in all the areas inspected. Of 146

Table 1. Distribution of downy mildew (*P. halstedii*) in sunflower-producing areas in Morocco during the two crop years 1996 and 1997.

Region	With infection		Without infection	
	1996	1997	1996	1997
Saïs	A. Jemaa, A. Orma A. Kerma, M. Driss Agouray, Boufekrane R. Kerry	A. Jemaa, A. Orma, O. Rommane, M. driss, Boufekrane	- ^a	Agouray, S. Jahjouh, R. Jerry
Gharb	Mnasra, S. lahmar, H. Kourt, M. Bouselham, J. El melh, Ouezzane	Mnasra, S. Lahmer, S.Yahya., A. Tazi, S. Larba, Kariat Ben Aouda	-	Tihli, Khnichat, H. Kourt J. El melh, Zekouta, Ouezzane
Loukous	Arbaoua, Aoumra	M'rissa, Lalla Mimouna.	-	Arbaoua

^a -, not recorded.

fields inspected, 77 presented the disease (53%). The area of Gharb had the highest proportion of fields with mildew presence (60%), followed by Saïs (50%) and Loukous (41%). In Gharb, the highest field incidence was recorded at Ouezzane with 73% of fields infected and the lowest incidence was at Souk Larbaa (40%) (Table 2). The incidence of mildewed plants averaged over all 3 regions did not exceed 4% (Table 4). The highest incidence of mildewed plants was in one field in Ouezzane where it reached 20%. In Saïs, the field incidence recorded at the different survey locations showed no large variations and varied between 40 and 62%, with an average of 50% (Table 3).

The average incidence of plants with mildew in Saïs was 4.4% and varied from 1% at Ain Karma to 11% at Ain El orma. At this last location the highest incidence was noted (30% of mildewed plants), followed by Ain Jemaa (13.4%) and My Driss (12.4%). The Loukous area had the lowest levels of downy mildew infection, which occurred on 41% of all fields, with less than 1% of all plants being infected (maximum 3% at Ksar Lkbir).

The 1997 survey inspected 121 fields of which only 40 (33%) had a mildew presence. These fields were located in the principal sunflower-producing regions of the country, Saïs, Gharb and Loukous. Comparison between these regions (Table 3) showed that in 1997 the incidence of fields with mildew was significant in Gharb, where it aver-

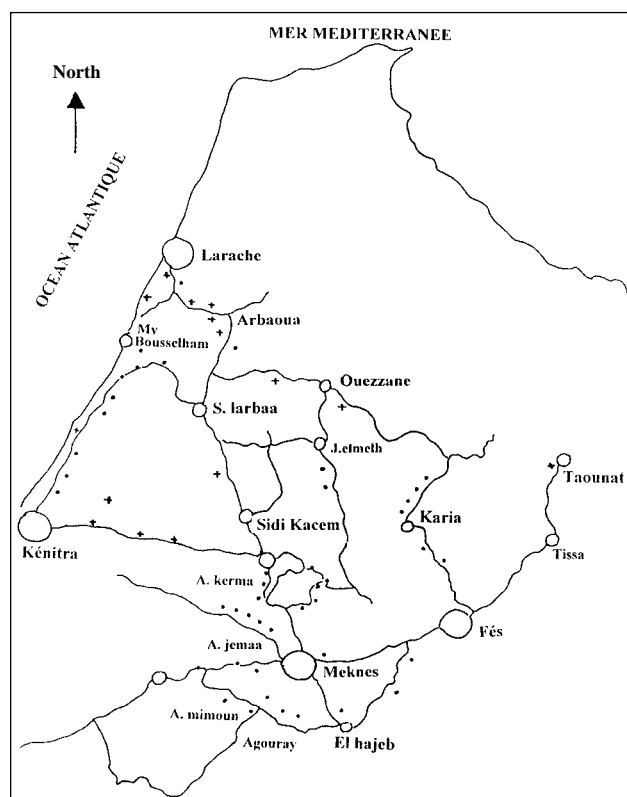


Fig. 4. Map of Morocco (north, centre) showing main sunflower production areas and mildew incidence in the crop years 1996 and 1997 (scale : 1cm = 10km).

• Locations with reported mildew before 1996.
+ New locations invaded by mildew in 1996 and 1997.

Table 2. Field incidence and manner of spread of downy mildew (*P. halstedii*) in the locations surveyed.

Area	Locality	No. of fields infected and % ^a		Manner of spread ^b	
		1995-1996	1996-1997	1995-1996	1996-1997
Saïis	Aïn Jemaa	4/9 (44.44)	7/17 (41.17)	F	S
	Aïn Orma	6/11 (54.5)	3/9 (33.33)	SF	SF
	Aïn Karma	3/6 (50)	-	S	-
	Oued Rommane	-	1/6 (16.66)	-	S
	My Driss	5/8 (62.5)	1/6 (16.66)	F	S
	Ras Jerry	4/10 (40)	-	F	-
	Boufekrane	5/11 (45.5)	2/6 (33.33)	S	SF
	Agouray	5/9 (55.6)	-	FS	-
Gharb	Jorf el melha	2/4 (50)	-	S	S
	Ouezzane	8/11 (72.7)	-	F	-
	Souk Larbaa	4/10 (40)	4/9 (44.44)	S	S
	Mnasra	10/15 (69.3)	5/8 (62.5)	S	S
	Had Kourt	5/10 (50)	-	FS	-
	My Bouselham	7/10 (70)	-	S	-
	Sidi M. Lahmer	-	6/9 (66.66)	-	FS
	Sidi Yahya	-	1/14 (7.14)	-	S
	Allal Tazi	-	5/11 (45.45)	-	FS
	Kariat B. Aouda	-	2/8 (25)	-	S/FS
Loukous	M'rissa	-	2/12 (16.66)	-	S
	Ksar Lkbir	4/8 (50)	-	S	-
	Arbaoua	3/9 (33.33)	-	S	-
	Aouamra	2/5 (40)	-	S	-
	Lalla Mimouna	-	1/6 (16.66)	-	F

^a In brackets number of fields infected/total number of field inspected expressed as percentage.

^b F, plant-to-plant spread; S, sporadic distribution; SF, both types.

Table 3. Average incidence (%) of fields with presence of downy mildew (*P. halstedii*) recorded in various sunflower producing areas during the crop year 1996 and 1997.

Region	1995-1996	1996-1997
Saïis	50.00	31.80
Gharb	60.00	39.00
Loukous	41.00	16.70

Table 4. Incidence of plants with downy mildew (*P. halstedii*) in various of sunflower-producing areas during the crop years 1996 and 1997.

Region	1995-1996	1996-1997
Saïis	4.40	5.70
Gharb	3.40	5.80
Loukous	1.00	5.00

aged 38.98%, followed by Saïis with 31.80%. The field incidence remained very low in Loukous at 16.67%. In Saïis, developed downy mildew remains a matter for concern however because of high field incidences of 41.17% at Aïn Jemaa and 33.33% at Aïn Orma and Boufekrane (Table 2). At My Driss and Oued Rommane, on the other hand, the field incidence was only 16.66%. In Gharb, the highest field incidence was observed at Sidi Mohamed Lahmer and in the Mnasra area: 66.66% and 62.5% respectively (Table 2). In addition, this disease was present in 44.44% of inspected fields at Souk Larbaa and in 45.45% of fields at Allal Tazi. At Kariat Ben Aouda, 25% of fields were affected, at Sidi Yahya only 7.14%. In Loukous, downy mildew was present on 16.66% of all fields at M'rissa and Lalla Mimouna (Table 2), but the incidence of mildewed plants never exceeded 3%. The three region-wide incidences of mildewed plants were

all between 5 and 6% while the incidence of mildewed plants in individual fields varied from a few traces to 10% except for 5 fields: 2 at Aïn Jemaa, where 20% of sunflowers were mildewed, one field in Boufekrane with a 14% mildew rate, and two in the Sidi Mohamed Lahmar area (Gharb) where the rates were 20 and 24%.

In the two crop years of the survey, three possible manners of spread of the disease were noted; a sporadic distribution of individual plants, (the most common), a plant-to-plant spread from a centre of infection outward (at Aïn Orma/Saïs, 1997), and a combination of the first two (3 cases out of 7 in 1996)

Conclusions

Until 1990, attacks of mildew were modest and very sporadic (Gosset, 1995). Two years later, the disease took a worrying upswing in all the areas of Saïs and even in the Aïn Maaskar area (Larache) in northern Morocco (Achbani and Tourvieille, 1993a); with time it spread to other areas as well. The present survey showed that the field incidence of downy mildew in all areas inspected regressed in 1997 to 38%, from about 53% in 1996; the average incidence of plants with mildew, on the other hand, underwent a slight increase (from 1 to 4.4% in 1996 to 5.7% in 1997). The survey also showed that the disease was present both at locations found to be affected before and in new areas (Sidi Yahya, Allal Tazi, Sidi Mohamed Lahmer and Kariat Ben Aouda). The highest field incidences were recorded in Gharb (60% in 95-96 and 39% in 96-97). On the whole, these incidences did not show great variations from year to year or from area to area (except in Loukous in 1997), which testified to the importance of infected soil in ensuring the survival of the mildew fungus. On the other hand, the incidence of mildewed plants in 1997, about 5%, was much higher in all areas than in 1996, particularly in Loukous, where it went up from 1 to 5% in this short period. In the crop year 1995-96 more rain fell (580 mm in Saïs, 867 mm in Gharb); than in 1996-97 (563 mm in Saïs, 705 mm in Gharb); this explains both, the significant rate of downy mildew infection in 95-96 and the difference in infection between Gharb and Saïs.

Field work carried out by close to a hundred

farmers enable us to suggest some factors that account for the presence and spread of downy mildew in Morocco. They can be summed up in two great categories: varieties planted and seed treatment. At present, most farmers use the sunflower varieties "Oro9" and "Record", which are susceptible to downy mildew. Farmers buy these varieties through the Work Centres from a Moroccan company marketing agricultural products (CO.MA.PR.A). In 1997 this company treated sunflower seeds with 300g/100kg Pomarsol (80% Thirame) (Erraji, personal communication). In spite of this treatment, downy mildew is observed, which suggests the fungicide is ineffective against this fungus. Moreover, some farmers use either stored seed from the previous sowing or uncontrolled seed from the souk. In the Gharb area, some farmers buy imported varieties in spite of the high cost. Fields sown with hybrids such as Hogar, Riosol, Euroflore, Florasol and Arbung have a fair genetic resistance to downy mildew. On fields sown with the downy-mildew susceptible cultivar Perodovik (3 cases in Gharb), the incidence of mildewed plants ranged between 8 and 24%. There was also a rotation effect: in the areas surveyed, farmers practice a rotation of cereals with sunflower, which gives only a one-year interval between sunflower crops. Such a situation allows mildew inoculum to accumulate gradually in the soil. The coastal area of Gharb is an exception to even this type of short rotation because here farmers are obliged to plant a sunflower crop every year on the same fields, on account of excessive rains and the resulting floods. This absence of rotation and high soil humidity means that soil inoculum increases from year to year and seriously affects yield and production quality. Climate is also a factor.

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