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A survey on pest insects of fiber and grain sorghum in northern Italy

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Abstract

In the Po valley plain grain sorghum (*Sorghum bicolor*) has been introduced in the last decades for cattle feed production. More recently fiber sorghum has been tested to be used for electric power production. Since little is known about the sorghum insect pest community in northern Italy, a research was carried out in a study area located in the central western area of the Po valley. Grain sorghum plots and fields were studied between 2008 and 2011. No insect pest of economic importance was recorded in grain sorghum cultivations. Population density of the aphid *Rhopalosiphim maidis* was very low, as well as the one of the European Corn Borer (ECB, *Ostrinia nubilalis*, Lepidoptera Crambidae). *Lygus rugulipennis* (Hemiptera Miridae) tended to colonize grain sorghum after panicle development, but densities were not a matter of concern. In fiber sorghum plots ECB populations did not result noxious, while *R. maidis* density was higher than the one on grain sorghum, but infestations did not significantly affect the development of the stalks, being localized only on panicles during their first stage of development. The production of cyanogenetic compounds by young sorghum plants is likely to be an effective protection against ECB first generation larvae, while earlier harvest time of both grain and fiber sorghum compared with maize later harvest time prevents significant damages caused by ECB second generation larvae. Sorghum requires less water than maize. Such a condition, joint to the weak susceptibility to insect pests, could favour a further increase of sorghum cultivations in northern Italy.

Keywords: sorghum, insects, Northern Italy

Introduction

Sorghum (*Sorghum bicolor* L) is a drought resistant crop (Habyarimana et al,1992) and finds suitable conditions in both temperate and tropical zones. More than 41,000 accessions have been selected in over 115 Countries (Dahlberg et al, 2011) where it is grown both as a food for millions of people (Pontieri et al, 2012) and as a source of fodder.

Sorghum cultivation is affected by adverse factors that change according to different latitudes and weather conditions, first of all temperature, that tends to limit the diffusion of this crop to cold areas (Osuna-Ortega, 2003). Other limiting factors are pests (birds, insects, bacteria, fungi) that in some areas can cause severe yield loss (ICRISAT, 1982, 1985). However the presence of several toxic or repellent compounds (tannins, cyanogenetic glycosides) in sorghum usually provides a natural chemical defence against birds, insects, bacteria and fungi attacks (Hanna et al, 1999; Wanuska, 2000). Those chemicals anyway are not equally produced by all the selected sorghum varieties and not all sorghum enemies are susceptible to them in the same way. Sorghum is not therefore an insect pest free crop (Tillman, 2006).

Crop losses caused by insects are worldwide a matter of concern; more than 150 insect and mite species are globally known as potential pests (Teetes and Pendleton, 2000; Velasco et al, 2007) and 43 are considered to be serious (Nwanze et al, 1995). The approach to pest control mainly based on insecticides, as it happened in the past (Sukhani and Jotwani, 1980), has eventually evolved into an integrated management model including methods such as the selection of resistant genotypes (Andrews et al, 1993; Chandrashekar and Satyanarayana, 2006), intercropping of non palatable or repellent plants (Ampong-Nyarko et al, 1994; Khan et al, 2000) and regulation of pest insects by natural enemies (Kring et al, 1985).

It is known that data on sorghum insect pests in central Italy are available (Del Bene, 1986,1987), but, except for the record of the exotic moth *Pseudolaetia unipuncta* (Manetti, 2006), there is a lack of knowledge about potential sorghum pest insects in northern Italy. Therefore a survey on potential insect pests of sorghum in an agricultural agroecosystem of the Po valley (the main Italian agricultural district) was planned. In the study area grain sorghum has been cultivated since the '90s, while fiber sorghum has been introduced in the agro industrial chain to replace sugar beet, whose cultivation was abandoned as a result of the European Community policies. Nowadays fiber sorghum is grown to produce bio-

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mass to be burnt for the production of electric power or to be converted into biogas (Demirbas et al, 2009).

Materials and Methods

Study area

The survey was carried out between 2008 and 2011 in the sorghum fields of some farms located in the province of Pavia (central western Po Plain, Figure 1). The main cultivations in this agroecosystem are cereals (maize, wheat, barley, sorghum) and horticultural crops, which are usually rotated. The research analyzed both grain sorghum and fiber sorghum insect pests. While grain sorghum cultivation is widespread in the study area, fiber sorghum one has an experimental character; therefore this crop was grown in a few small fields, working as trial plots.

Grain sorghum: field observations

Grain sorghum insects were studied in 2008 and 2009. As a first step of the work, nine farmers from the study area involved in grain sorghum cultivation were interviewed about damages, if any, caused by insects. In addition, two harvest operators were also involved in the collection of information.

Four grain sorghum fields were studied both in 2008 and in 2009. The first round of surveys was carried out at the beginning of July, the second one during the last decade of July and the last one before crop harvest, which usually occurs in the last decade of August.

In smaller fields (up to 5 hectares) stalks and panicles were examined inside 10 transects; greenflies and bug samples were taken, fixed and brought to the lab for identification, carried out by a stereo microscope. Each transect was made of 10 plants on a row, one close to the other, and rows were selected in different field sectors (margins or core).

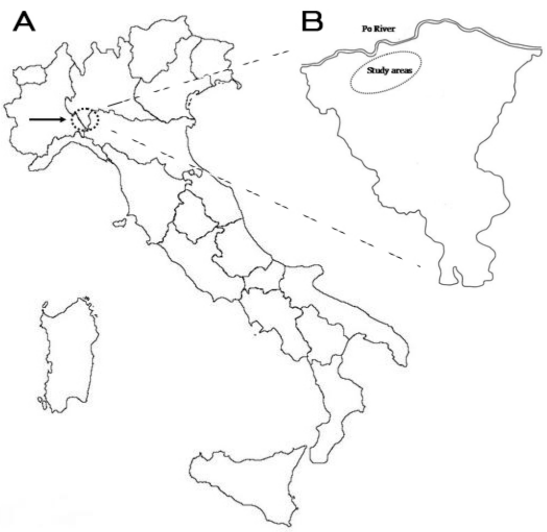

Figure 1 - Location of study areas.

In larger fields (wider than 5 hectares) 600 plants (30 transects - 20 plants each) were controlled.

The list of sites where grain sorghum was studied in 2008 and in 2009 respectively includes i) Bastida Pancarana: 45°05'26"N-9°04'59"E | 45°05'57"N-9°04'45E; ii) Bressana Bottarone: 45°05'24"N -9°07'38"E | 45°04'44"N-9°05'57E; iii) Castelletto di Branduzzo: 45°04'38"N-9°05'04"E | 45°04'32"N-9°04'52"E; iv) Silvano Pietra: 45°03'38"N-8°57'16"E | 45°03'48"N-8°57'04"E.

Grain sorghum: plot

In 2008 two grain sorghum hybrid accessions - Cargo (red grain) and Brigga (white grain) - were sown on the 28th April. For each accession, four randomized plots (2.6 x 4.2 m) were planned in Bastida Pancarana (45°05'22"N-9°04'59"E). Plots were established on silt and slightly alkaline soil (silt 61%, clay 21.8%, sand 17.2%; pH = 7.53). Plants were spaced 9 x 40 cm; each plot included 10 rows made of 450 plants. Plots were sown next to a maize field (40.5 ha) to provide suitable conditions for a potential infestation by the European corn borer (*Ostrinia nubilalis* Hübner, Lepidoptera Crambidae) - a polyphagous pest which finds in maize its most favourite habitat. A sample of 20 plants belonging to rows n° 2 and n° 5 was randomly chosen in each plot and regularly checked (160 plants accession^{-1}) throughout the crop life cycle to record signs of damage by borers and other potential pests.

Checks were carried out on the 1st July and 20th July, in search for possible borers larvae; on the 20th August (close to the usual sorghum harvest time) and on the 1st October (just before harvesting) for an assessment of the final damage by insects.

In the study area, sorghum harvest usually occurs starting from the last week of August, but this time the crop was intentionally retained in the field beyond its usual life cycle in order to analyze it better.

In 2011, a supplemental survey was dedicated to monitor the abundance trend of *Lygus rugulipennis* (Hemiptera Miridae) a pest which can be noxious to a wide range of crops (Blando and Mineo, 2005; Holopainen and Varis, 1991; Limonta et al, 2004; Pansa et al, 2012). Starting from the first decade of July, after panicles had developed, three fields were weekly checked and 10 samples of five panicles each (50 panicles field^{-1}), located along a median transect (margins and core of the field), were analyzed. The top of sorghum plant including its panicle was beaten against the frame to make bugs fall into the net.

Fiber sorghum

Fiber sorgum insects were studied in 2009 and in 2010 in experimental plots located in Corana (45°03'45"N-8°57'09"E) on a sandy soil (silt 38%, clay 7%, sand 55%). Plots were carried out by the company involved in the research on the feasibility of the agro energy chain which will have to support a biomass power plant fed by sorghum.

In 2009 six plots of rough rectangular shape (size 0.25 ha each one) were sown. For each accession two nearby plots were organized, one of which supplied with water. Irrigated plots were supplied with 30 mm water. Three sorghum hybrids (*S. bicolor* x *S. bicolor*) were tested: i) Biomass 133 (BM133); ii) Goliath; iii) Biomass 144 (BM144).

In 2009 (on 17th July and 6th August) 20 plants, from a median transect parallel to the major side of the field, were checked. Plants were gently bent to the ground and accurately examined, from top to bottom. Then the highest part of the plant, including the panicle, was cut by means of shears and the top flag-leaf sheath, if still placed for panicle protection, was removed in order to expose possible hidden insects.

Aphid density (winged and wingless morphs) was estimated according to five abundance classes: i) absence; ii) 1 specimen; iii) 2-10 specimens; iv) 11-100 specimens; v) > 100 specimens.

At the same time, possible aphid natural enemies were surveyed and classified as follows: i) ladybirds (Coleoptera Coccinellidae): larvae, pupae, adults; ii) *Orius* sp. (Hemiptera Anthocoridae): neanids, nymphs, adults; iii) hoverflies (Diptera Syrphidae): larvae and pupae; iv) green lacewings (Neuroptera Chrysopidae): larvae, adults; v) other predators: (Nabidae, Staphilinidae).

Signs of borer activity were recorded in the form of tunnels excavated inside the stalks, sawdust falling from them and holes recorded on leaves surface. Borer eggs and larvae were sampled and brought to the lab for rearing.

The method used for estimating the rate of egg parasitization is referred to the only surveyed borer (*O. nubilalis*). It happens that after eggs have been attacked by *Trichogramma brassicae* Bezdenko (Hymenoptera Trichogrammatidae), they turn from the original white to solid black in a few days. The eggs that can escape ophagous attacks, preserve their white colour, except for a black central spot which tends to appear as soon as the larvae cephalic capsule has come to a complete development. In the lab egg masses, either parasitized or not ,were kept into Petri dishes and reared to observe their destiny by stereoscopic observation. The number of eggs included in each egg mass was counted and the parasitization rate was calculated.

In 2010, the research on experimental sorghum plots in Corana (45°03'34"N-8°56'24"E) continued with the study of three sorghum hybrids: i) Biomass 133; ii) Pioneer 811; iii) Trudan HL.

Biomass 133 and Pioneer 811 are fiber sorghum hybrids (*S. bicolor* x *S. bicolor*), while Trudan HL is a smaller *S. bicolor* x *S. sudanense* hybrid. This time no watering was planned.

Every plot was surveyed four times every 10 days from 18th July to 26th August. In order to test the hypothesis that aphid natural enemies could be differently distributed within the plots, the sampling method slightly changed. The number of plants to be checked was doubled; forty plants from a median transect parallel to the major side of the field were controlled: 10 from both plot margins and 20 from the plot core. The methods for detection of potential sorghum pest insects were the same as above.

Statistic analysis

The relationship between categorical variables was assessed by means of contingency tables, showing the relationship between those variables. The Chi-square statistic reflects the strength of the relationship.

Results

Grain sorghum (2008-2009) - field observations

No farmers nor harvest operators involved in the grain sorghum cultivation mentioned any records of significant damage by sorghum insect pests, except for the sporadic observation of borer signs on plants just before the harvest.

Field observations revealed that signs of damage (holes on leaves) seen on grain sorghum were caused by *O. nubilalis* the only borer which had emerged from reared larvae.

In the study area ECBs usually develop two generations. The first flight peak occurs across the last decade of May and the beginning of June, due to the emergence of adults coming from the overwintering generation. From the beginning of July, the flight starts again as a result of the appearance of adults coming from the following generation (Camerini, 1992).

The maximum intensity of males flight is recorded during the second half of August. In response to particularly favourable weather conditions, a partial third generation can occur.

In 2008, the frequency of signs of damage by ECBs first generation larvae was on average 1%, ranging from 0.5% to 1.5%. In 2009, grain sorghum plants showing signs of borer feeding were on average 0.7%, ranging from 0.4 to 1.1%.

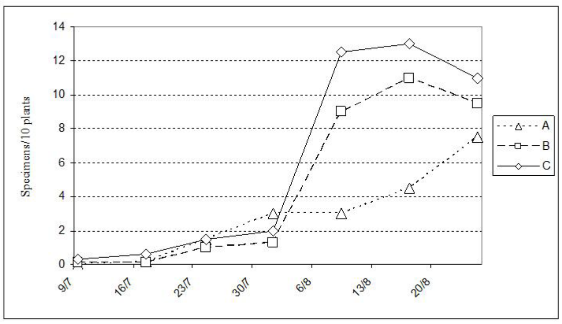

Figure 2 - Density trend of *Lygus rugulipennis* during 2011 summer (number specimens 10 plants^{-1}).

Aphid colonies were not a matter of concern either. In 2008, aphid density on grain sorghum was almost under the detection limit of the applied method; it was possible to collect only a few samples (n = 6) belonging to *Rhopalosiphum maidis* Passerini (Homoptera Aphididae). In 2009, seven samples could be collected and the results confirmed that a single species could be found: *R. maidis*.

The only species of bug that could be regularly detected on growing panicles exposed to light was *L. rugulipennis*, whose trend density on grain sorghum is displayed by Figure 2.

The trend resulting from samples in studied fields was very similar: density was very low until the end of July and then it suddenly slightly arose - maximum abundance fewer than 2 specimen a plant. Those values were also recorded during 2008 and 2009 summers, when the final density of the bug was recorded just before crop harvest.

Grain sorghum (2008) - plots

At the beginning of July 2008, in grain sorghum plots in Bastida Pancarana, 5.6% (Brigga) and 6.2% (Cargo) of plants showed signs of borer damage. In maize plots next to sorghum plots the proportion of plants on which signs of damage could be observed ranged from 14% to 21%. In spite of the fact that signs of borer occurrence were detectable on grain sorghum, on 20th July no larva was found, while at the same time mature ECB larvae could be easily found in the surrounding corn fields.

As a result of the following survey (20th August 2008), ECB density was 0.01 larvae/plant on Cargo and 0.02 larvae plant^{-1} on Brigga. Larvae (n = 10) mainly tunnelled the leaf sheath without entering stalk tissues.

Such a distribution pattern was confirmed by samples (n = 21) that were collected just before final plot mowing. The final density of ECB larvae was significantly lower than the one (2.3 larvae plant^{-1}) recorded in the maize field closer to the sorghum plots (see Table 1).

It was also possible to collect some samples (n = 18) of ECB egg masses from the grain sorghum plots at the end of the first decade of September. The rate of parasitization by *Trichogramma brassicae* was 83.2%. In maize cultivation next to sorghum plots the percentage of eggs attacked by *T. brassicae* was 94%.

Table 1 - Results of final survey on damage by ECB larvae in experimental grain sorghum plots (n = 160 plants cultivar^{-1}) October 2008.

	Brigga	Cargo
Damaged plants (%)	13,8	18,1
Plants hosting larvae (%)	5	8,1
Uninjured plants (%)	86,2	81,9
Number of larvae plant^{-1}	0,05	0,08
Egg masses plant^{-1}	0,07	0,06

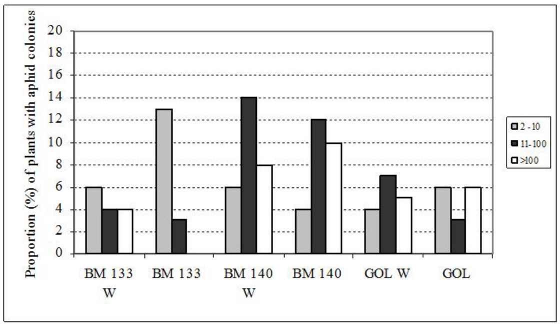

Figure 3 - Proportion (%) of plants hosting *R. maidis* colonies (2-10, 11-100, and >100 aphids colony^{-1} - year 2009; W: watered plot).

Fiber sorghum (2009-2010)

In fiber sorghum plots the same aphid species that colonizes grain sorghum was found (*R. maidis*) both in 2009 (samples: n = 123) and in 2010 (n = 208). No other species were surveyed. Aphid colonies were solely found under the leaf sheath protecting panicle at the top of plants before they were exposed to sunlight, as a result of plant growth. After panicle had been exposed to sunlight, aphid colonies rapidly extinguished. Frequency distribution of aphid colonies recorded during 2009 is shown by Figure 3.

In 2009, frequency distribution of aphid abundance classes (Figure 3) in not significantly different in watered or in dry plots of each tested hybrid (χ^2 test; $p > 0.05$). On the contrary, a significant difference occurs when data from accessions (watered+dry) are compared (n = 115; df = 2; χ^2 =18.3; $p < 0.01$) because of the higher frequency of aphid colonies (10-100 and >100 aphids) recorded in BM 140 samples.

The aphid predators community (n = 109) mainly consisted of Coccinellids (50.5%) and *Orius* sp. (34,9%). Green lacewings (Neuroptera, 4.6%), Syrphidae (3.7%) and other predators (6.3%) were of minor importance.

The frequency distribution of predators tends to depend on prey abundance. The proportion of aphid colonies controlled by predators tends to increase as the abundance of aphids grows; when aphid density is in the range 2-10 specimens, 51% of infested plants host at least one predator, while the percentage rises to 63% and 91% when the aphid abundance is of, respectively, 11-100 and > 100 specimens. Such an increase is statistically significant (n = 117; df = 2; χ^2 =11.2; $p < 0.01$)

Ladybirds population (n = 55) includes three species: *Harmonia axyridis* Pallas (38.3%), *Propylaea 14 punctata* L (38.3%), and *Hippodamia variegata* Goeze (23.4%). *H. axyridis* is an exotic species that has rapidly colonized northern Italy since 2006 (Burgio et al, 2008).

The search for ECB egg masses and larvae in the experimental plots did not produce any results.

During 2010 frequency distribution of aphid abun-

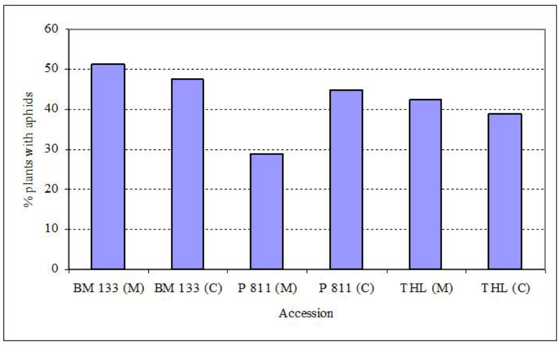

Figure 4 - Proportion (%) of plants hosting *R. maidis* colonies (2-10, 11-100, and >100 aphids colony^{-1} - year 2010; M: margins; C: core).

dance classes was not significantly different ($p > 0.05$) in tested accessions both at the core and the margins of plots. If a comparison between frequency distribution of plants hosting aphids is made for each cultivar, only THL data are of statistic significance ($n = 65$; $df = 2$; $\chi^2 = 9.8$; $p < 0.01$) due to the higher density of colonies, that is >100 specimens in margin samples (Figure 4).

In 2010, the predator community ($n = 169$) was dominated by *Orius* sp. (46.7%) which prevailed on Coccinellids (39.1%). Sirphids (8.9%), Chrysopidae (1.8%) and other predators (1.8%) were also recorded. *Propylaea 14 punctata* (55%) was the dominant species within ladybirds population.

The main predators (*Orius* sp. and ladybirds) showed a different distribution pattern within the field: Orius sp. were more frequently recordable in the core of the field, while ladybirds tended to be more abundant in the margins (Figure 5). The different distribution is statistically significant ($\chi^2 = 6{,}96$; $df = 2$; $n = 169$; $p < 0{,}05$).

The density dependant relationship between aphids and predators confirms a tendency already observed during 2009 summer; the percentage of plants infested by aphids tends to raise as the extent of aphid infestation grows. This pattern is significant both for margin ($\chi^2 = 17.4$; $df = 2$; $n = 118$; $p < 0{,}01$) and core samples ($\chi^2 = 6{,}6$; $df = 2$; $n = 91$; $p < 0{,}05$)

At the end of August 2010, a few days before harvest, some ECB egg masses ($n = 11$) were found; 78.8% of them was parasitized by *T. brassicae*. Larvae density was 0.1 plant^{-1}.

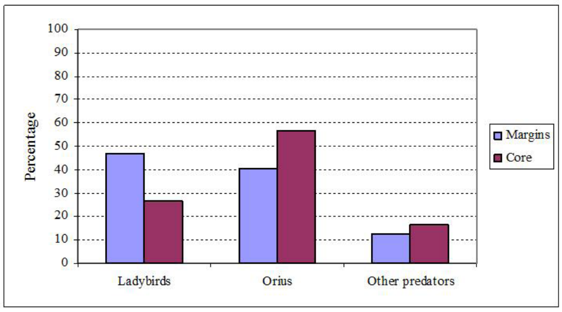

Figure 5 - Frequency distribution (%) of ladybirds and Orius sp. within the plot (margins and core).

Discussion

In southern Italy sorghum can suffer from damages caused by the dipteran *Atherigona soccata* Rondani (Diptera Muscidae) (Del Bene, 1987) and the bug *Nysius graminicolus* Kolenati (Heteroptera Lygaeidae). In the study area both species are uncommon and do not seem to be actually a threat. The exotic *Pseudoaletia unipuncta* Haworth (Lepidoptera Noctuidae) recently introduced in northern Italy can be harmful to sorghum (Manetti, 2006), but damage coming from this species was not observed. *L. rugulipennis* was regularly recorded on grain sorghum, but its density was far to be a matter of concern.

Aphid density on grain sorghum was negligible. The only species that was found (*R. maidis*) was shared with maize and fiber sorghum. No other aphid species were detected; the aphid community of maize had a wide spectrum (Camerini, unpublished data), including *Rhopalosiphum padi* L, *Sitobion avenae* (Fabricius) and *Sipha maidis* (Passerini).

On fiber sorghum *R. maidis* populations were much more abundant than the ones feeding upon grain sorghum. Anyway, they exclusively colonized the microhabitat created by the leaf sheath protecting the panicle. Grain sorghum invests a lot of its resources in promoting the growth of panicle biomass, which represents the final crop. In fiber sorghum panicle biomass is of little importance and almost the whole biomass resulting from plant growth consists of carbon molecules (cellulose) from stalks. For this reason attacks by aphids have a minor importance in the economy of fiber sorghum cultivation. Aphid colonies rapidly become extinct after the panicle has fully developed and is no longer protected by the leaf sheath. In addition, aphid colonies are controlled by a rich natural enemies community.

Maize is the elective host of ECB; when corn is widespread in the agricultural landscape, it can work as a source of infestations for other crops. This is the case of the study area. Anyway, results from the research show that although signs of feeding activity by borers (ECB larvae of the first generation) can be recorded, ECB mature larvae can rarely be found alive inside sorghum stalks. This evidence supports the hypothesis that sorghum, thanks to the production of cyanogenetic molecules, can work as an ecological trap for borers: adults can lay eggs on the plants, but as soon as young larvae start feeding on leaves and stalks, they tend to cease because of toxic compounds ingestion (Guthrie et al, 1988).

The cyanogenetic molecule that has been identified as the main defence for sorghum is dhurrine (Woodhead and Bernays, 1978). Cyanogenetic compounds concentration tends to change according to the life cycle of the plant. Sorghum tends to be toxic to phytophagous insects when young, but it becomes suitable for feeding as plants mature (Haskins et al, 1987).

In the study area records of ECB on grain and fiber sorghum seem to be in accordance with the gradual decrease of protection against pests coming from antibiotic defence.

It was possible to collect only ECB larvae of second generation both from grain and fiber sorghum, and any resulting damage was low mainly because of the poor synchronization between ECB and sorghum life cycle. Oviposition peak by ECB usually occurs in the second half of August; while maize starts to dry in this period, so ECB females tend to leave corn cultivations and colonize other crops, but such a dispersion occurs when both grain and fiber sorghum are going to be harvested. Larvae are rare and they usually do not attack the panicle of grain sorghum; the result is some negligible damage. Larvae density in grain sorghum at the end of August 2009 was 100 times less than the one in corn fields: 0.01-0.02 larvae plant^{-1} vs a density ranging from 1.95 to 2.63. Both life cycle and harvest timing are similar for fiber sorghum and grain sorghum, therefore, given ECB life cycle, ECB will not be a problem for fiber sorghum, either.

Up to now maize and grain sorghum have been traditionally used as a source of fodder, but they are now also produced as a source of biomass to generate electric power. In Europe the ongoing trend is to provide incentives to support those technologies, like the EU is doing. As a result, the area involved in the cultivation of both corn and sorghum could increase, but maize cultivators have to face the growing costs of the watering needed to ensure good crop yields. In addition, in the Po floodplain corn can be damaged by important pests (*Ostrinia nubilalis*, *Diabrotica virgifera*). In such a condition, a drought resistant crop, such as sorghum, could be an interesting alternative crop in northern Italy also thanks to its actual low susceptibility to pest insects.

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