Screening for Resistance to Sorghum Shoot Bug and Spider Mites

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Introduction

Sorghum is cultivated under diverse agroecosystems, and its production is influenced by various abiotic factors such as extended periods of high temperatures, low humidity, and low and erratic rainfall, and these factors result in drought stress (Garrity et al. 1982; Rosenow et al. 1983; Holtzer et al. 1988). In addition, the stability of sorghum production is threatened by several insect pests. The corn planthopper, popularly known as shoot bug in India, and spider mites assume greater importance under drought stress because of increased insect establishment and rapid population build-up, thus causing considerable loss in grain and forage yields. Continuous cropping, reduced genetic variability in high-yielding varieties and hybrids, changes in cultural practices as well as reduction in the natural enemy complex, all lead to the increased severity of these pests.

Shoot Bug (*Peregrinus maidis*)

The shoot bug or corn planthopper is cosmopolitan in distribution. Its outbreaks have become frequent in many sorghum-growing states in India in the postrainy and rainy seasons. Adults and nymphs usually congregate in groups in the leaf whorls, inner leaf sheaths, panicles, and exposed roots (Chelliah and Basheer 1965), and are often found in association with ants. They suck the plant sap, resulting in reduced plant vigor, stunting, and yellowing of leaves. Severe infestations, combined with excessive oviposition in the midribs, result in gradual withering of leaves downwards from the top, or girdling by twisting of top leaves and inhibition of panicle formation (Singh and Rana 1992). However, infestation at later stages prevents either normal panicle exertion (Agarwal et al. 1978), or poor development of panicles (Rawat and Saxena 1967). It is also a vector of several viruses: maize mosaic, maize stripe, freckled yellow, and male-sterile stunt.

In general, it has been observed that two peaks of macropterous (winged) adults coincide with migratory periods at the beginning and at the end of the crop season. Brachypterous (wingless) adults appear from the 6th week onwards, with a slow growth

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in population, and decrease towards the end of the crop season. Nymphs appear by the 5th week after seedling emergence, reaching peak abundance between 8-10 weeks after plant emergence, and decline thereafter (Fernandez-Badillo and Clavijo 1989). High nymphal population determines the development of macropterous adults, and low populations result in brachypterous forms (Fernandez-Badillo and Clavijo 1990a,b).

The females prefer to lay eggs on the upper surface of the midrib of older and mature leaves at 30 days after emergence (DAE). The females of macropterous and brachypterous forms lay 18-98 and 5-64 eggs, respectively (Rawat and Saxena 1967), which hatch in 5-8 days. The nymphal stage comprises 5 instars, and development is completed in 2 days. The total life cycle ranges from 18 to 31 days, with an average of 24.5 days (Chelliah and Basheer 1965); 14-53 and 19-71 days for macropterous males and females; and 17-41 and 22-62 days for brachypterous males and females, respectively (Rawat and Saxena 1967).

Resistance-screening techniques

Techniques to screen for resistance to corn planthopper have been described by Chandra Shekar (1991) and Chandra Shekar et al. (1993a,b). The following approach can be adopted to screen for resistance to corn planthopper under field and laboratory conditions.

- Selection of hot-spot locations and adjustment of planting time so that the most susceptible stage of crop growth coincides with peak population density of the shoot bug.
- Mass-rearing of the insect on a susceptible cultivar, e.g., CSH 1, for laboratory testing and field infestation.
- Plant interlards of a susceptible cultivar (CSH 1) for screening under field conditions.
- Simulation of drought stress.

Rearing of insects, for mass multiplication and for use in laboratory and field experiments, can be carried out on the susceptible cultivar grown in pots in the greenhouse, by confining the plants with gravid females (macropterous or brachypterous) in a mylar tube.

Laboratory conditions. Plant samples of test genotypes grown in pot culture can be used at susceptible growth stages (30, 45, and 60 DAE). Excise the plant at the base and keep it in a conical flask (100 mL) filled with water, place the plants in a circular pattern in a cage at random from the center of a circular plastic trough (30-cm diameter). Release approximately 3 000 macropterous or brachypterous adult females; or 2nd-instar nymphs can be released into the plastic trough to allow free access to all the test genotypes. The number of shoot bugs are then recorded on each plant at frequent intervals (2, 6, 24, and 48 h after release) to determine the role of visual, olfactory, and gustatory stimuli in host-plant selection. Similarly, the extent of oviposition can be recorded by splitting the midribs and counting under a binocular microscope (x 50) the number of eggs laid.

Field conditions. To record insect numbers/extent of oviposition, select five plants in each replication in each genotype randomly at three growth stages (30, 45, and 60 DAE). Enclose the samples with a polythene envelope and cut the plants at the base to prevent the escape of insects during sampling. A cotton swab soaked in chloroform can be used to

immobilize the insects for counting. In addition, remove the leaves from each sample carefully, split the midribs, and count the number of eggs under a binocular microscope (x 50). Plant damage symptoms can be recorded at three crop growth stages (Chandra Shekar 1991):

45 DAE = Yellowing of leaves with stunted growth.

60 DAE = Girdling of topmost leaves without panicle development.

75 DAE = Poor panicle exertion or/development of panicle.

The extent of plant damage can be expressed as follows:

$$\text{Plant damage (\%)} = \frac{\text{Damaged plants}}{\text{Total plants}} \times 100.$$

Sources of resistance

Sources of resistance to corn planthopper have been identified. These include: Kafir Suma, Dwarf Hegari, I 753, H 109, GIB, 3677B, BP 53 (Agarwal et al. 1978), MSH 65, SPH 388, SPV nos. 475, 678, 736, 741, 756, 775, 819, 858, and CSV 10 (Rajasekhar 1989), IS 18657, IS 18677, and PJ 8K(Y) (Singh and Rana 1992), and IS 18676 and IS 19349 (Chandra Shekar et al. 1993a,b).

Mechanisms of resistance

Among the mechanisms of resistance, predominance of antixenosis for adult/nymphal colonization and oviposition (Singh and Rana 1992; Chandra Shekar et al. 1993a) and tolerance have been reported (B U Singh, unpublished).

Spider Mites (*Oligonychus indicus* and *O. pratensis*)

The spider mites are important pests of sorghum. They are usually confined along the midrib on the undersurface of the basal functional leaves. The infested area of the leaves becomes pale yellow initially, and later turns reddish or tan on the dorsal surface. As the mite population increases on the basal leaves, dense webbing is seen on the undersurface of the infested leaves. Mite densities are positively correlated with leaf area and plant maturity. Mite feeding damage is significantly lower on the late-maturing lines, demonstrating that sorghum susceptibility to mite feeding increases as the plants reach anthesis and caryopsis (Archer et al. 1986a,b).

Rahman and Sapra (1940) and Rai et al. (1989) reported that the developmental periods for egg incubation, larvae, and proto- and deuto-nymphs was 4.7, 2.2, 1.2, and 1.6 days, respectively, for females; and 1.94, 0.91, and 1.4 days for larvae, proto- and deuto-nymphs, respectively, for males. In general, the males of *O. pratensis* develop faster than the females (Tan and Ward 1977). The females reared on infested leaves produce significantly more female progeny than on uninfested leaves, suggesting that the offspring sex ratios change in response to deteriorating food sources (Stiefel et al. 1992).

On the other hand, rearing of *O. pratensis* on intact sorghum leaves at growth stages 1 to 6 have a longer life span (25.7 days) and ovipositional period (11.6 days) than on leaf disks at growth stages 6 to 8 (19.1 and 8.9 days, respectively) (Foster et al. 1977a) [Definition of plant growth stages are based on Vanderlip (1972): 1 = three leaves with fully developed sheath; 2 = five fully developed leaf sheaths; 3 =growing point differentiation; 4 = final leaf visible in whorl; 5 = boot stage; 6 = half-bloom; 7 = soft-dough; 8 = hard-dough; and 9 = physiological maturity]. However, fewer eggs (4.3) were oviposited daily by females at growth stages 1 to 6 than at 6 to 8 (Foster et al. 1977a).

Resistance-screening techniques

Techniques to screen for resistance to spider mites have been described by Dabrowski (1972), Foster et al. (1977a,b) and Sreedhar (1995). Screening under field conditions is relatively difficult because many factors affect the mite population abundance and the plant's reaction to infestation (Owens et al. 1976). The following methodology may be followed for screening under field and laboratory conditions.

- Selection of hot-spot locations and manipulation of sowing time.
- Mass-rearing of mites on a susceptible cultivar e.g., CSH 1.
- Planting border rows and interlards of a susceptible control (CSH 1).
- Simulation of drought stress.

Laboratory conditions. Screening for mite resistance under laboratory conditions can be carried out under free-choice (FC) and no-choice (NC) conditions using leaf disks and intact leaves (IL). In the FC test, the leaf disks (1.5 cm diameter) are taken from the mid-section of the larger middle leaf and arranged equidistantly in a circle on a moistened filter paper at random. A moistened sponge sheet is kept in a round plastic trough (30-cm diameter) leaving a central space. Approximately 5 000 spider mite adult females are released from the infested leaves into a petri dish (3.5-cm diameter) kept in the center of the leaf disks. The preferential response is based on orientation and colonization due to olfactory, visual, and gustatory stimuli. Similarly, oviposition can be measured by egg counts recorded at periodic intervals of 24, 48, and 72 h after adult female release.

In the IL technique, test samples of the plant are cut from the base and kept in a conical flask (100 mL), arranged randomly 15 cm apart in a cage encircling a plastic trough (30-cm diameter), and infested dry susceptible sorghum plants containing adults are kept in an empty glass jar (7.5 x 15 cm).

In the NC test, 10 gravid females are confined on leaf disks or intact leaves with tangle foot (a sticky material). The levels of preferential response is estimated by recording the mite numbers, or oviposition at 24, 48, and 72 h after infestation. In the NC test, antixenosis for feeding can also be measured.

Field conditions. Mite movement mostly depends on the direction of wind or migration, so there is considerable variation in mite abundance in research plots. Mite infestations increase rapidly and are most damaging to the crop at the reproductive stage associated with hot and dry climatic conditions. Thus, artificial infestation is the most

effective way to obtain dependable and uniform infestation. Field-collected miles can be used to infest research plots when the plants are in their late-vegetative growth stage and therefore most vulnerable to mites. Mite-infested leaves may also be collected from plants. A single sorghum leaf infested with mites can be placed across plants within a row. Mites spread rapidly between the plants (Archer 1989).

Damage evaluation

Leaf damage rating/mite counts. Leaf damage ratings estimate the total leaf area showing chlorotic stippling or death caused by mite feeding. Death of an entire leaf from mite feeding usually does not occur until the whole plant damage approaches 50%. The condition of the plant also influences the extent of damage:

- Moderately drought-stressed plants are better mite hosts than irrigated ones.
- Plant maturity may help plants escape maximum mite pressure.
- The leaf area available to the mites can influence how many mites are required to cause a given amount of damage.

Mite counts are taken at weekly intervals on 10 randomly selected plants per genotype following the procedure used by Jeppson (1951). In this system, only the number of adult female mites are recorded (Foster et al. 1977b).

In another measure of mite infestation, each leaf (from 10 randomly selected plants in each genotype) can be evaluated for susceptibility to mites (1 = no mites; 2 = few individuals above midrib only; 3 = colonies along the midrib; 4 = mites spreading away from midrib; and 5 = entire leaf covered with mites) (Foster et al. 1977b). Data presented using this technique are expressed as mean leaf ratings per plant of each test genotype.

An additional rating system can also be used to denote the damage to each test entry based on the leaf area damaged (Foster et al. 1977b) as a measure of leaf necrosis (1 = 10-20%, 2 = 21-30%, 3 = 31-40%, 4 = 41-50%, 5 = 51-60%, 6 = 61-70%, 7 = 71-80%, 8 = 81-90%, and 9 = > 91%). In order to obtain more precision, foliar damage can also be measured in comparison with uninfested leaf area with a leaf area meter.

Grain and forage yield, and 100-grain mass. Record grain and forage yield and 100-grain mass in genotypes maintained under infested and uninfested conditions. Harvest the panicles at maturity and record the panicle grain mass and 100-grain mass. Express the loss of grain/forage yield, or 100-grain mass in the infested plants, in comparison with uninfested plants of the same genotype. But note that the loss in grain and forage yields and 100-grain mass mostly depends on the time of mite infestation.

Sources of resistance

KS 30, SC 599-6, and BTx 618 are resistant to *O. pratensis* (Foster et al. 1977a). More mites have been recorded on late-maturing M 100, and fewest on early-maturing genotypes (60 M and CK 60) (Archer et al. 1986a). In respect of *O. indicus,* low foliar damage has been observed on 2219A x SB 901, 2077A x SB 905, and 168 (Kulkarni et al. 1978), CSH 5, CSH 6, SPH 890, CSV 5, and IS 3687; and SPV nos.106, 135, 192, 220, 222, 224, and 365 (Singh et al. 1981).

Mechanisms of resistance

Among the mechanisms of resistance, tolerance is a major component of resistance to *O. pratensis* (Foster et al. 1977a). Singh et al. (1981) reported antixenosis as a component of resistance to *O. indicus.* Sreedhar (1995) evaluated different components of resistance to mites and found (a) high degree of antixenosis for adult colonization in CSV 8R, CSV 14R, and IS 2146; (b) oviposition nonpreference in CSV 8R, SPV 913, and RS 29; (c) antibiosis in SPV 913, CSV 8R, ICSV 705. Sel 3, and Swati; and (d) tolerance to foliar injury in Sel 3 and ICSV 705, grain yield in IS 2146, IS 2312, IS 5613, and ICSV 705, and 100-grain mass in IS 5613, Sel 3, and SPV 913.

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Plant Resistance to Insects in Sorghum

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Abstract

Sorghum is one of the most important cereals in the semi-arid tropics. Nearly 150 insect species have been reported to damage the crop worldwide, causing an estimated loss of over US$ 1 000 million annually. Of these, shoot fly, stem borers, greenbug, sugarcane aphid, shoot bug, spider mites, armyworms, midge, head bug, and head caterpillars are the major pests. Plant resistance to insects is one of the most important components of pest management in sorghum. Thus, the 18 specialist scientists who have contributed the 25 papers included in this book, that is based on a training course for researchers involved in the development of insect-resistant cultivars for integrated pest management in sustainable agriculture, describe and discuss the theoretical and practical aspects of resistance-screening techniques, mechanisms and inheritance of resistance, breeding for resistance, statistical designs, and strategies for integrated pest management. Information has also been provided about the international sorghum insect resistance testing program and the role of networks in collaborative research and technology exchange.

Résumé

La résistance variétale aux insectes nuisibles chez le sorgho. Le sorgho est une des plus importantes cultures céréalières dans les zones tropicales semi-arides. Près de 150 insectes nuisibles seraient responsables pour les dégâts à cette culture à travers le monde, occasionnant des pertes annuelles de l'ordre de 1 000 millions de dollars. Les insectes les plus nuisibles sont la mouche des pousses, les foreurs des tiges, le puceron vert, le puceron jaune du mil, la cicadelle du maïs, les araignées rouges, les chenilles légionnaires, la cécidomyie du sorgho, les punaises et les chenilles des panicules. La résistance variétale aux insectes constitue l'une des composantes les plus importantes de la lutte contre les insectes nuisibles chez le sorgho. Cet ouvrage, comportant 21 articles présentés par les chercheurs spécialistes, est basé sur un cours de formation destiné aux chercheurs travaillant à la mise au point de cultivars résistants aux insectes dans le cadre de la lutte intégrée contre les ravageurs pour l'agriculture durable. Les auteurs décrivent et examinent les aspects théoriques et pratiques des techniques de criblage pour la résistance, les mécanismes et l'hérédité de la résistance, la sélection pour la résistance, les dispositifs statistiques, ainsi que les stratégies pour la lutte intégrée contre les ravageurs. L'ouvrage fournit également des informations sur le programme international d'essai de la résistance du sorgho aux insectes nuisibles ainsi que sur le rôle des réseaux dans la recherche collaborative et dans l'échange de la technologie.

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