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SOME ASPECTS OF PEST MANAGEMENT AND HOST PLANT RESISTANCE IN PEARL MILLET IN THE SAHEL

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Abstract—Among several species of insect pests that attack the millet crop, the earhead caterpillar, *Raghuva albipunctella* de Joannis and *Acigona ignefusalis* Hmps., are considered the major pests. The constraints against the successful implementation of an integrated pest management programme of these insects are examined. The relative importance and significance of host plant resistance in such a programme is compared against other modalities.

The use of insecticides is negated by lack of cash value returns, water supply, trained personnel and poor delivery system. Cultural practices, such as the synchronisation of early planting, destruction of harvest residues and end-of-season ploughing, have the potential for reducing carry-over populations. However, the difficulties in their implementation range from farmer education and efficiency to changes in traditional practices and introduction of new labour intensive practices after harvest. While it appears that natural enemies are taking a gradual toll on *R. albipunctella*, they appear inefficient in controlling *A. ignefusalis*. A range of plant characters have been identified: tillering in certain varieties as a form of tolerance to borers; maturity cycles that result in escape (pseudo-resistance) from *Raghuva* infestation, hairiness in relation to preference for oviposition and head compactness in deterring larval penetration into millet heads. Most of these characters are common in landrace types. The real problem appears to be one of incorporating and utilising the identified resistance into germplasm sources which possess other desirable agronomic characters that the farmer requires. This implies multi-disciplinary effort which is the basis for integrated pest management. In most of Africa, and in the Sahel in particular, this basis is remotely present.

Key Words: Pearl millet, Sahel, *Raghuva albipunctella, Acigona ignefusalis*, resistant varieties, control strategies, crop management, integrated pest management

Résumé—De nombreuses espèces d'insectes s'attaquent aux cultures de mil. La mineuse de l'épi, *Raghuva albipunctella* Joannis, et le foreur des tiges *Acigona ignefusalis* Hmps, sont considérés comme les deux plus importants. nous faisons état des principales contraintes rencontrées lors de l'établissement d'un programme de lutte intégrée contre ces insectes. Nous comparons le potentiel et l'importance de la résistance de la plante hôte aux autres composantes d'un tel programme.

L'utilisation d'insecticides n'est pas réalisable actuellement compte tenu de la très faible rentabilité de cette pratique, des problèmes d'approvisionnement en eau, du niveau de formation des utilisateurs et des carences du système de livraison. Les pratiques culturales de lutte telle la synchronisation de semis hâtifs, l'enlèvement des résidus de récoltes et le labour de fin de campagne permettraient de réduire les populations diapausantes. Cependant, les problèmes rencontrés sont les suivants: formation des paysans, problèmes rencontrés sont les suivants: formation des paysans, problèmes rencontrés sont les suivants: formation des paysans, problèmes rencontrés lors de l'adoption de techniques nouvelles et introduction après la récolte de nouvelles opérations requérant beaucoup de travail. Les ennemis naturels sont de plus en plus efficaces contre *Raghuva albipunctella*, mais non dans le cas de *Acigona ignefusalis*. Plusieurs caractères de résistance ont été identifiés: le tallage de certaines variétés augmenterait la tolérance aux foreurs; certains cycles de maturation permettraient d'échapper (pseudorésistance) aux attaques de *Raghuva*; la pilosité des plantes pourrait servir en fonction des sites préférés pour la ponte; les chandelles compactes entraveraient la pénétration des larves dnas l'épi. La plupart de ces caractères sont présents dans les variétés locales non améliorées. *Il reste maintenant à les incorporer dans un matériel génétique* agronomiquement supérieur que les paysans accepteront de cultiver. Ce travail ne peut être réalisé que dans le cadre d'un effort de recherche pluridisciplinaire; ce qui est fondamental en lutte intégrée. Dans la plupart des pays d'Afrique, ceux du Sahel plus particulièrement, cette possibilité devient peu à peu réalité.

INTRODUCTION

Cereals constitute over 90% of the total agricultural production of the Sahel and both sorghum and millet are the major cereal crops that provide the nutritive energy requirements of the population (CILSS, 1978). The yields of millet are pitifully low on farmers' fields (200–400 kg/ha) in a region where rainfall ranges from 250 to 600 mm per annum. However, yields on research stations can be as high as five times those reported on farmers' fields with little or no pest control. This indicates that much can be done with improved crop management practices.

In recent years, there has been increased concern over Third World food production, and there are indications of an actual decline in total production in

Africa (FAO, 1983). The recognition that insect pests, diseases and weeds are a major constraint to the realisation of self-sufficiency in food production in the Sahel resulted in the USAID-financed Integrated Pest Management Project which encompasses 8 Sahelian countries. By definition, integrated pest control is a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods, cultural practices, host plant resistance, chemical insecticides, biological control and legislation, in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury (Brader, 1979).

The term Integrated Pest Management (IPM) is 'la mode du jour'. But the way it is used clearly indicates that in many instances its real implication is not understood. Apart from the perennial constraints of low and erratic rainfall, poor soil fertility, insect pests and diseases that are associated with acute shortages in food production in Africa, the number of qualified indigenous research, development and extension workers actually involved in these activities is not only low, but may actually be decreasing (Davies, 1982). With little or no information on pest population dynamics, economic injury levels and threshold limits or estimates of crop losses, IPM measures cannot be developed.

Integrated pest management is itself a component of the overall crop management and production system and requires true inter-disciplinary effort. In the developed world, this effort is fueled by strong economic and commercial forces and the availability of personnel; whereas in the developing world, and in particular, the Sahel, the basis hardly exists for such an approach. This paper briefly examines the present status of IPM in the Sahel. It weighs host plant resistance against other components and shows that given the present status of agricultural research in the Sahel, host plant resistance is perhaps the research area that needs to be emphasized.

INSECT PESTS OF MILLET

The insect pests of millet have been the object of several studies (Risbec, 1950; Bowden, 1956, 1976; Appert, 1957, 1964; Harris, 1962). Over 100 species belonging to several major insect orders have been identified, but the principal species belong to the Lepidoptera, Diptera, Coleoptera and Orthoptera. These include seedling pests, leaf feeders, stem-borers, pollen beetles, head caterpillars and head bugs. Fortunately, of the numerous lists produced cataloguing species as pests or potential pests, the actual number which fall within the category of major pests of economic importance is perhaps less than a half dozen. The earhead caterpillar, *Raghuva albipunctella* de Joannis, Noctuidae and the millet stem-borer, *Acigona ignefusalis* Hmps., Pyralidae are widely distributed in the Sahel and are considered the major pests of millet. However, the fact remains that while it is widely accepted that these two species cause severe losses, there are no reliable data on actual losses in the Sahel.

Several species of the Acrididae, especially *Oedaleus nigeriensis* Uv. and *O. senegalensis* Krauss, sometimes bring about severe crop losses. Chrysomelid beetles, especially *Lema planifrons* Ws., and armyworms, *Spodoptera* spp., may reduce crop stand during the seedling stage. Species of meloid beetles, namely: *Psalydolytha flavicornis* Mkl., *P. theresa* Pic., *P. vestita* Duf., and *Cylindotharax westermani* Mkl., have lately been reported to cause severe losses in the northern areas. The meloid, *Decapotoma affinis* Billb., and the pentatomid, *Dysdercus volkeri* Schmidt, affect grain formation in early maturing varieties.

CHEMICAL CONTROL

The classical implementation of IPM in Africa on a large scale was reported in Egypt. This arose from the recognition of the limitations of the use of insecticides as the ultimate control of pests attacking cotton, maize, rice and sugar-cane in the densely populated Nile Valley (Brader, 1979). This recognition arose from problems involving insecticide resistance, high costs of chemical pest control and environmental pollution.

The main difficulty in using insecticides against the millet stem-borer is one of timing applications to coincide with the hatching of *Acigona* larvae. Systemic insecticides may be of value in controlling this species, but such insecticides must be of low mammalian toxicity. The situation with *Raghuva* is more promising. Application can be timed to control this pest at the egg or early larval stages when they are easily accessible on the developing millet head. However, even with the so-called environmentally safer chemicals, the current yield levels in West African peasant agriculture and the greater importance attached to cash crops, chemical insecticides even though subsidised by governments are rarely used on food crops. In the Sahel, the problem is compounded by such factors as availability of water, technology of application, lack of trained personnel, and poor to non-existent extension services.

BIOLOGICAL CONTROL

The biological control of stem-borers and the earhead caterpillar have not received adequate attention in the Sahel. The situation with *Raghuva* is yet to be understood. This pest was little known before the drought years of 1970–1974 in the Sahel. It became devastating in subsequent years and reached its peak with severe crop losses in 1976–1980. In 1981 the number of parasitised larvae was reported higher than in previous years and this pattern continued in 1982 and 1983. If this pest is a native of the region and its pest status is affected by ecological changes in the environment, perhaps with time, *Raghuva* will relegate itself below economic importance.

Although Harris (1962) listed 14 primary parasites, one predator and four diseases that attack different stages of borers, including *A. ignefusalis* at Samaru, Nigeria, the overall rate of parasitism was low and only increased during the end of the growing season when borer damage was well advanced. Other reports on parasitic species of *Acigona* have also come from Upper Volta (Nwanze, 1981) and Niger (Guevremont, 1983); but the overall rate of parasitism was low. The inefficiency of parasites and predators in controlling *Acigona* is also seen in the borers of other cereals namely, sorghum and maize. The case in maize is perhaps explained in that it is an introduced grass, but sorghum and millet are indigenous to Africa; West Africa is in fact the centre of origin of both crops and therefore it may well be that these grasses are the native original hosts of the borers: millet for *A. ignefusalis* and sorghum for *B. fusca*. Similarly, one would expect that there must have existed in the wild, undisturbed ecosystems a parallel evolution of equilibrium in the relationship between the borers and their natural enemies which kept the borers below primary pest status. Is it possible to suggest therefore that the extensive cultivation of these cereals did offset the balance and the natural enemies trailed behind in the ensuing ecological race?

CULTURAL CONTROL

Among the various alternatives to chemical insecticides the use of insect resistant varieties in combination with good cultural practices is perhaps the most effective, convenient, economical and environmentally acceptable method of insect control. In the Sahel, the first step in ensuring a crop in any particular year is to plant at the earliest possible time. Planting date is determined by rainfall and the Sahelian farmer will plant with the first major rains. Early planted millet suffers less stem-borer damage than the late crop. On the other hand, early planted photoperiod non-sensitive varieties are more likely to suffer losses from *Raghuva* infestation. Such varieties may however also escape infestation by their earliness to maturity. Thus, the question of synchronising planting time in order to maximise success must ensure that large areas are sown in good time. The primary requirement of this cultural practice is not necessarily linked with the objective of pest control, but that of reducing the dependence of the farmer on hand cultivation and to speed up the use of animal-drawn equipment.

Raghuva survives the dry season as diapausing larvae in the soil with the majority at depths of 10–20 cm (Vercambre, 1978). Ploughing after harvest will expose larvae to both desication and predation by birds and rodents. It will also provide a rugged surface and reduce the effect of wind erosion on the soil. However, this is a labour intensive practice at a time that is least favourable to the farmer.

The removal of crop residue after harvest reduces crop damage caused by the infestation of the first generation of *A. ignefusalis*. But the extension of such a practice is difficult since millet and sorghum stems are used for construction of fences and roofs, bedding for animal and fuel for cooking. It also has an added agronomic disadvantage in exposing the soil to wind erosion. However, diapausing populations of stem-borer in millet can be reduced by exposing the stems to the full effect of heat during the long dry season. Adesiyun and Ajayi (1980) have also shown that partial burning of sorghum stalks after harvest can reduce *B. fusca* larvae within stalks by 95%. The practice of stacking stems in the shade of trees is thus a disadvantage to effective control.

The difficulties involved in the implementation of cultural practices namely, adherence to age-old traditions, labour intensive, conflict of interest in the use of crop residues and soil conservation factors and lack of farmer education and extension services, reflect the general problem of the need to improve the efficiency of the peasant farmer in Africa.

HOST PLANT RESISTANCE

The limitations in the implementation of cultural practices directed at reducing pest damage can be overcome with time. But parasites are apparently inefficient in controlling stem-borers, and insecticides have their problems. The use of resistant varieties is thus of relevance in the control of millet pests. The principle of host plant resistance in control and management programmes takes into account the natural ability of plants in wild ecosystems to resist attack by pests. A resistant variety does not need to be immune. In fact, an immune variety is a non-host. Host plant resistance implies the ability to reduce populations of insect pests or to tolerate pest populations by regrowth or recovery from injury (Horber, 1980). Tolerance therefore, is an important agronomic plant characteristic which implies a biological relationship between insects and plants that is quite different from resistance in the strict sense (Beck, 1965).

Borer attack causes tillering in grasses, an aspect of a general adaptive tolerance of native grasses to their own stem-borers. Local millet varieties exhibit a high tillering ability and tillering as an aspect of varietal tolerance at low borer infestations may result in an overall increase in head production. This situation was reported by Harris (1962) where increases in yield per stand were obtained from bored stands as against stands in insecticide controlled plots, presumably a function of either extra tiller production or selection of potentially higher yielding stems for attack by borers. Other studies have shown an increase in millet head production and grain yield with an increase in internode damage (ICRISAT, 1982).

Differences have been observed in the initial choice or preference for infestation of millet by *Acigona* and levels of infestation were observed to shift with plant age and the growth stage of different varieties (ICRISAT, 1982). Such changes may be due to differences in both the biophysical and chemical constituents between varieties at different physiological growth stages and have a role to play in affecting pest populations.

Vercambre (1978) indicated that certain varieties of millet appeared resistant to *Raghuva*. It is now known that *Raghuva* infestation is highly correlated with crop maturity cycle and very early or late varieties may escape infestation (ICRISAT, 1983). Plant escape (pseudo-resistance) is an adaptive crop characteristic which may have evolved in parallel with an insect species or an adverse environment and has been identified in several millet landraces. While emphasis in host plant resistance centres on the development of genetically inheritable resistant genes, early maturing varieties have a role to play in IPM programmes. Such a variety can be harvested early, thus evading peak pest populations, shortfalls in rainfall and may better withstand a high-density cropping pattern. It may also induce a pest species into premature diapause thereby reducing numbers of carry-over populations. Earliness also reduces the available niche that is necessary for pest population increase.

Other sets of studies have identified less infested varieties of millet with panicle emergence occurring during the critical period of adult *Raghuva* emergence from the soil (ICRISAT, 1983, 1984). This may be a case of either non-preference for oviposition and/or antibiosis against larval penetration and/or feeding. Non-preference for oviposition may be related to bristle density and variations in their length and orientation. Bristles are known in several crops to affect insect oviposition. In *Raghuva* they may also deter feeding of the early instars. Antibiosis is seen only as a possibility with compact heads in some varieties and this character may deter larval penetration between the rachis and florets, thereby (a) causing death by starvation, (b) inducing premature entry into diapause with reduced chances of survival, and (c) prolonging larval exposure to natural enemies.

The successful use of resistant varieties abound in literature. The factors range from mechanical or physical interference to chemical antibiosis. The key point however is the initial search for resistance. Screening for resistance requires detailed knowledge of the insect biology, ecology, population dynamics and its relationship with the host plant. Such studies are needed for determining methods and timing of artificial infestation or for planting in order to maximise insect numbers and damage levels that are needed for effective and reliable screening techniques in the identification of pest resistant varieties. The first step therefore is providing screening techniques for uniform and optimum infestation and the development of scoring systems for adequate classification to include all modalities of resistance and in particular, to facilitate the identification and use of low levels of resistance and distinguish such phenomena as pseudo-resistance.

Success in locating resistant varieties is enhanced by the availability of a wide and variable germplasm collection and an infrastructure for the multilocational screening of materials. ICRISAT's strong centre and cooperative breeding programmes, supported by a large germplasm unit and the developing network of national and regional programmes are factors which will greatly contribute to the development and use of resistant varieties of millet.

CONCLUSION

The alarming rate of dependence of the Sahelian countries on food imports is becoming more disturbing. The World Bank estimates suggest that, while population has grown 2% a year throughout West Africa, food crop production has stagnated and in several cases decreased. The problem of pest control is really one of overall development and resides in the need to seriously examine some of the straight-forward interpretations of developed country results. Studies continue to show that local land races of millet and sorghum are often difficult to outperform and that these cultivars have evolved a high degree of stability under an extremely harsh environment. A great deal could be done by the introduction of improved agronomic practices even with existing cultivars and known research information and techniques with little pest control (Davies, 1982).

The overall implication of this statement in our breeding programmes, including entomology and the use of resistant varieties is the need to examine results obtained with improved cultivars under high input conditions in contrast to actual farmer conditions. Perhaps we are overemphasising particular plant types, earliness and yield potential against the insurance factor of crop stability and should change our approach and work from the locals upwards. It is possible to transfer within a reasonable length of time heritable desired plant characters using recurrent selection or pedigree approaches coupled with suitable screening techniques. However, it should be remembered that the number of scientists working in the field in developing countries is inadequate and the number of entomologists even fewer. It is useless to encumber these few with work or ideas which are of marginal importance to pest control and ultimately to production (Davies, 1982). The problem we face is one of overall crop management and technology transfer. It is one of development—of national programmes, training of research workers, farmer education, individual motivation and orientation of objectives.

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