MAIN SUBJECT 1

THE INCIDENCE AND EFFECTS OF PESTS, DISEASES AND WEEDS

TOPIC 1A

EFFECTS OF PESTS, DISEASES AND WEEDS ON YIELD AND QUALITY

CHAIRMEN

SYMPOSIUM. Prof. D. G. Schuhmann

WORKSHOP DISCUSSION. H. J. Gould

TOPIC ORGANISER. B. H. Bagnall

SYMPOSIUM PAPERS 1A–S1 to 1A–S4

RESEARCH REPORTS 1A–R1 to 1A–R29

ECONOMIC IMPACT OF CROP LOSSES

C. AHRENS, H. H. CRAMER, M. MOGK and H. PESCHEL

Bayer AG, Agrochemicals Division, West Germany

I. A REVIEW OF LOSS ESTIMATES

The first attempt for a global assessment of losses for 60 of the most important crops was made in 1965 by Cramer (1967, Pflanzenschutz Nachrichten Bayer 20, 1 - 524) who came to the conclusion that approximately 35% of the potential yield or 75 billion $/year were lost due to insect pests, diseases and weeds. These figures were frequently used in later publications and many other authors treating this subject have since published loss figures for certain crops or in particular regions. A review of more recent publications on rice and wheat is given in Table 1.

TABLE 1

Loss figures as indicated by literature

Crop	Region	Estimated Loss	Cause	Source
Rice	Malaysia	40 %	Nephotettix sp	GUAN SOON, L. and KEE GUAN, G. (1969): The Malaysian Agr. J. 47, 1-23
Rice	India	35 %	Insects	WAY, M.J. (1976): Bull.Ent. Soc. of Amer. 22, 125-129
Rice	Philippines	16 - 24 %	Insects	
Rice	Philippines	20 - 30 %	Insects	
Rice	trop. Asia	19 dt = 40 %	Insects	
Rice	trop. Asia	35 - 44 %	Insects	PATHAK, M.D. and DHALIWAL,G.S. (1981): IRRI Res.paper Series 64, 1-15
Rice	Brasilia	23,6-34,6 %	Insects	FERREIRA, E. et al. (1982): Pesq.agropec.bras.,17, 671-675
Wheat	U.K.	2,1 - 2,3 %	Diseases	KING, J.E. (1977): Proc.Brit. Crop.Prot.Conf., 677-687
Wheat	Germany	4,2-7,7 dt/ha	Diseases	OPPITZ, K. and HOESER, K. (1978): Bayr.Lw.Jhb. 55, 1005-1014
Wheat	France	4,9 dt/ha	Diseases	DUPERRAY,Y. (1979): Phytoma, H. 307, 38-40
Wheat	Germany	Infection 12 % early 8 % later 5 % late 5,1 dt/ha	Cercosporella herpotrich.	HANUSS,K. and OESAU,A. (1979): Mitt.Biol.Bundesanst. f. L. u. F. H. 191, 171/72
Wheat var.	U.K.	0,0-5,0 dt/ha	Septoria	WEBSTER,J.RG. and COOK,R.J. (1979): Ann.app.Biol. 92 39-48
Vuka	Germany	40 - 63 %	Puccinia striiform.	
Saturn	"	33 - 45 %	P. striiform. + Mildew	BARTELS,G. (1980): Ges.Pflzn., 32, 77-80
Diplomat	"	16 - 19 %	P. striiform.	
Wheat	U.K.	1,6-3,7 dt/ha= 2,4-6,6 %	Diseases	COOK,R.J. (1980): Plant Path. 29, 21-27
Wheat	Germany	2,2-2,9 dt/ha	Foot rot	SAUR,R. et al. (1980): Mitt. Biol.Bundesanst. f. L.u.F., H. 191, 183
Wheat	Germany	5,2 %	Mildew	BUSCHHAUS,H. and WERNING,L. (1981): Z.f Pfl.krnkh. u. Pfl.schutz 88, 286-292
Wheat	France	3 - 9 dt/ha	Diseases	LESCAR,L. (1981): EPPO Bull 11, 337-346
Wheat	U.K.	5,8-15,1 % depending on cultivar	Diseases	PRIESTLEY,R.H. (1981): Eppo Bull, 11, 357-383

II. CORRELATION BETWEEN YIELD LEVEL AND LOSS

Since 1967 yields of agricultural crops have increased remarkably. The question is how the correlation between loss levels and yield increases has developed over these years. Two of the most important staple foods, rice and wheat, serve as examples for this study.

The second table shows the global production of wheat in 1965 and 1981, and the loss estimate by Cramer in 1965. The hypothetical loss calculations for 1981 are also shown assuming that either

a) the loss percentage has remained unchanged since 1965, or
b) the losses in absolute terms have remained unchanged since 1965.

TABLE 2

Global wheat production and loss estimates for 1965 and 1981 (in million tons)

Year	Production		Loss Estimates of the Potential Yield							
			Insect Pests		Diseases		Weeds		Total	
			abs.	rel. (%)	abs.	rel. (%)	abs.	rel. (%)	abs.	rel. (%)
1965	266		18	5.0	33	9.1	35	9.8	86	23.9
1981	458	a)	30	5.0	55	9.1	59	9.8	144	23.9
		b)	18	3.3	33	6.1	35	6.4	86	15.8

Considering hypothesis a) with constant loss percentages, the potential wheat production in 1981 would have been 602 million tons instead of 458 million tons, i.e. the losses in absolute figures would have increased from 86 to 144 million tons. Hypothesis b) with constant absolute loss figures would imply a potential wheat production of 458 + 86 = 544 million tons, and decreasing percentage figures of 15.8% in 1981 compared to 23.9% in 1965.

For rice, the situation is similar. Perhaps it is for these purely arithmetical interrelations between the evolution of yields and losses that from time to time it is stated that there "is no concomitant decrease in crop losses due to pests despite an intensification in crop protection measures" (Edens, T.C. and Haynes, D.L., 1982. Ann. Rev. Phytopath., 20, 363-395).

III. LOSSES IN RICE THROUGH INSECT PESTS AND IN WHEAT THROUGH DISEASES - COMPUTER ANALYSES OF TRIAL RESULTS

1. Material and methods

The data material presented is based on specially designed computer analyses of trial results. The trials were carried out and evaluated by the Department for Biological Development of Bayer AG over a period of 12 years in all important growing areas. We have selected the subject of losses in rice due to insect pests, and in wheat due to diseases, and have compared the yields in treated plots with those in the untreated control plots. The evaluation also comprises data on infestation pressure and efficacy of the treatments. The aim of the trials was to evaluate new pesticides, not to establish loss figures.

The data contain all trial results including products which showed unsatisfactory results. These were, therefore, excluded from further development. Although for the assessment of loss levels in absolute figures it would be sufficient to select results with an efficacy near 100%, other results can also be interesting as far as the concept of economic thresholds is concerned. This will be discussed later.

2. Losses in rice due to insect pests

The data material comprises 843 trial results from East and South East Asia, the Near East and Columbia. The mean yield in treated plots was 43.4 dt/ha, in untreated control plots 33.1 dt/ha, the difference, or in other words, the mean loss was 10.3 dt/ha. If the yield in treated plots is regarded as the "potential yield", the mean loss due to insect pests would be 23.7% as compared to Cramer's figure (1967) of 26.7%. The infestation pressure was low in 27.3% of the trials, medium in 43.4% and high in 29.2%. As could be expected, losses increase with mounting infestation pressure.

TABLE 3

Correlation between Yield and Infestation Pressure of Insect Pests in Rice (843 trials)

	Yield in dt/ha at Infestation Level			
	Low	Medium	High	Mean
Untreated control	34.7	34.2	25.4	33.1
Treated	42.7	44.6	39.0	43.3
Yield Increase = Loss	8.0	10.4	13.6	10.3

The figures in Table 3 show that the yield in the treated plots at low and medium infestation levels are similar, whereas at a high infestation pressure the yield becomes depressed even in the treated plots. Assuming a mean potential yield of 43.4 dt/ha, the loss in untreated at a high infestation level would be 18 dt/ha. The loss at medium infestation pressure (10.4 dt/ha) coincides with the mean loss figure in all 843 trials (10.35 dt/ha). There is a clear interrelation between yield increase which equals the potential yield loss, and efficacy of treatments.

TABLE 4

Interrelation between Yield Increase (= Loss) and Efficacy of Treatments

Number of Trials	Efficacy %	Yield Increase dt/ha	Maximum Increase dt/ha
22	1 - 20	7.2	21
58	21 - 40	7.3	30
118	41 - 60	8.9	33
237	61 - 80	9.2	39
123	81 - 90	12.2	43
285	91 - 100	12.0	53
Total 843		Mean 10.3	

Although there is no difference between the mean yield increases of the efficacy groups 81 - 90% and 91 - 100% (12.2 dt/ha and 12.0 dt/ha resp.), the difference between the maximum yields of these two efficacy groups are remarkable and indicate high potential yield reserves.

The yield differences between treated and untreated plots demonstrate the necessity of plant protection measures in general. The more detailed analyses of the interrelation between infestation level and efficacy on the one hand, and yield response on the other, may better reflect the situation under practical farming conditions. The frequency distribution of the yield groups from 5 to 95 dt/ha for the treated and untreated trial plots is shown in Fig. 1. The mean yield for all treated plots is 43.4 dt/ha, for untreated 33.1 dt/ha.

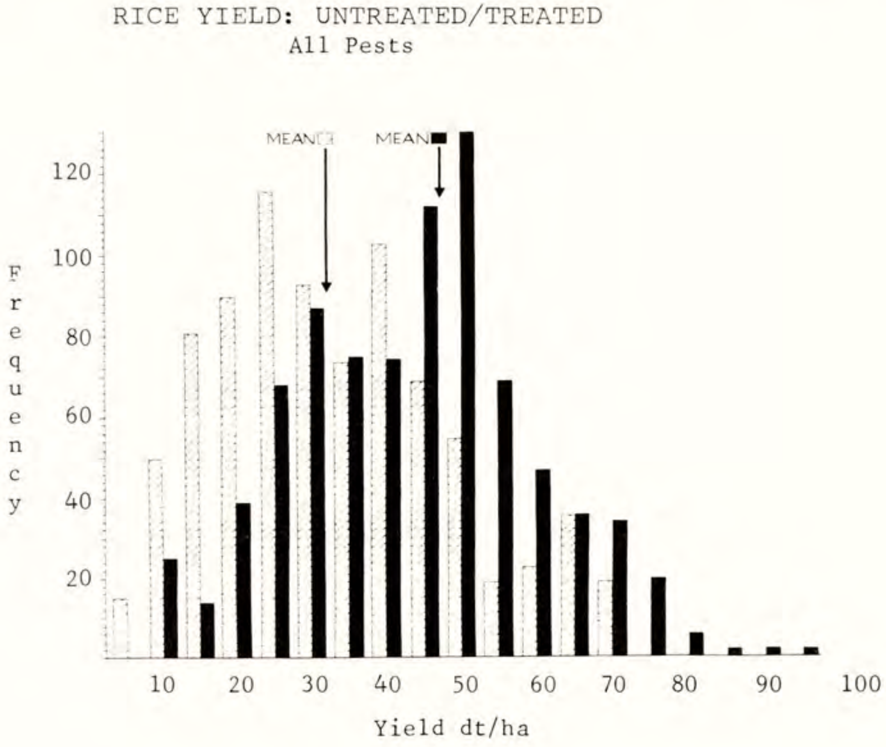


Fig. 1. Frequency of yield groups in treated and untreated plots (modified computer chart).

Again this clearly shows that the lower yields are more frequent in untreated control plots, the groups with higher yields are to be found in the treated plots, and the highest yields are exclusively in the treated plots.

Fig. 2 shows a computer chart of the correlation between infestation level, efficacy of control, and yield response.

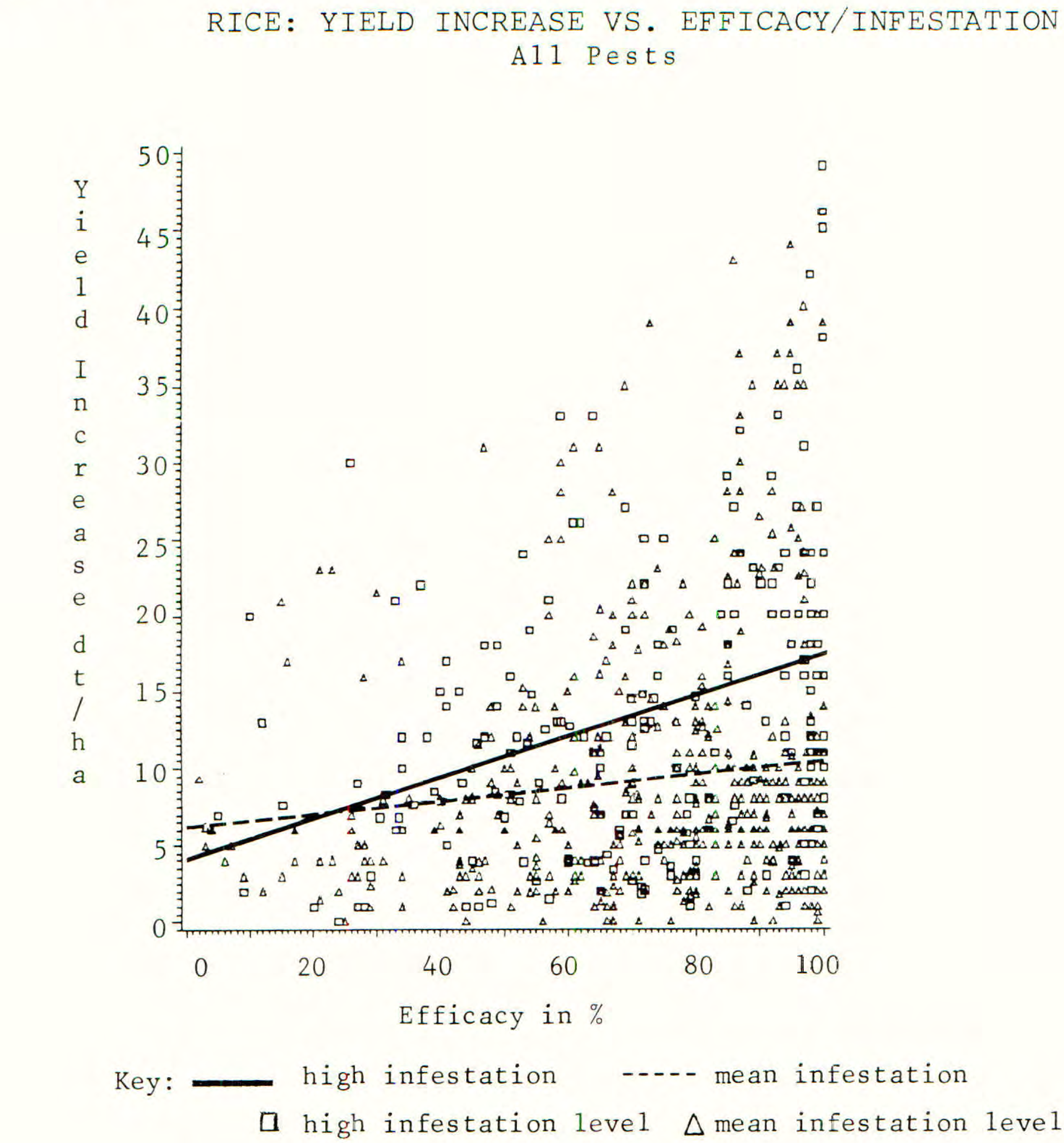


Fig. 2: Computer chart showing yield response and infestation level.

Our data material is suitable for more detailed computer analyses, for example classifying data according to various regions, varieties or specific pests. As an example, results of 324 trials against rice stem borers are presented. Mean yield increase in treated plots was 8.1 dt/ha, with high infestation pressure the yield increase reaches 9.6 dt/ha.

3. Losses in wheat due to diseases

Results from 5851 trials were available for computer analyses. The mean yield in control plots was 52.9 dt/ha, in treated plots 58.3 dt/ha; the loss of 5.4 dt/ha in untreated represents 9.3% of the potential yield of 58.3 dt/ha. Again this figure is near to Cramer's estimate (1967) of 9.1% loss due to diseases.

The data permit a classification of the trials according to the different diseases like mildew, rusts or other pathogens, and the losses they cause. Table 5 shows the loss figures for mildew based on 1914 trial results, in relation to the disease level.

TABLE 5

Loss Figures for Mildew in Wheat

	Yield in dt/ha for disease level Low	Medium	High
Untreated Control	56.1	56.9	48.2
Treated Plots	60.2	61.8	55.4
Yield Increase (= Loss)	4.1	4.9	7.2

Parallel to the results for rice insect pests, the yield is slightly depressed at high disease levels even in treated plots when compared to medium or low infection pressure. An explanation for this is the lack of effectiveness of many of the test products in case of strong disease pressure.

The interrelation between yield increase and efficacy of treatments is shown in Table 6.

TABLE 6

Interrelation between Yield Increases and Product Efficacy (1914 trials)

Efficacy %	Yield Increase dt/ha	Maximum Yield Increase dt/ha
1 - 20	2.98	15.2
21 - 40	4.78	22.0
41 - 60	4.99	23.0
61 - 80	5.25	20.0
81 - 90	5.62	21.0
91 - 100	7.56	50.0

It is very interesting to note that the highest efficacy figures of 91 - 100% obtain a mean yield increase of 7.56 dt/ha taking into consideration the number of 525 trials in this efficacy group over several years. Noteworthy, too, is the considerable yield difference of almost 2 dt/ha between efficacy ratings of 81 - 90% and 91 - 100%.

The frequency distribution of different yield groups ranging from 35 - 115 dt/ha is shown in Figure 3. The yields of treated plots, symbolized by the black columns, are considerably less frequent in the lower yield groups, but exclusively present in the highest yield groups.

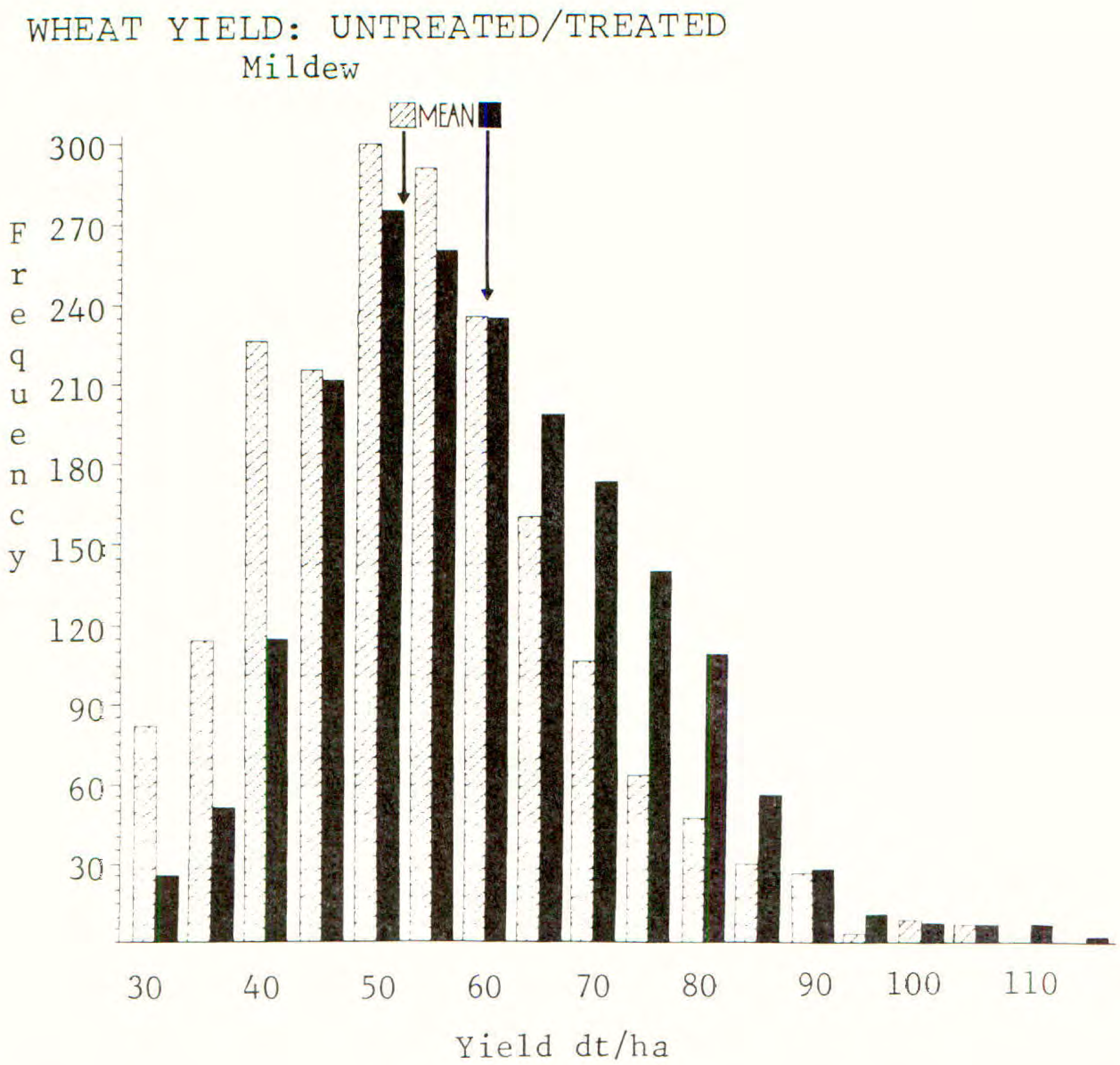


Fig. 3: Frequency of yield groupsin treated and untreated plots (modified computer chart)

IV. DISCUSSION

The yield level in our sample of trials is relatively high, if compared with world averages. The figures (dt/ha), as published in the FAO Production Yearbook 1981, are:

TABLE 7

Yield Comparisons (dt/ha)

Crop	World Average	Developed Market Econ.	Developing Market Econ.	Trials Treated	Trials Control
Rice	28.6	53.3	27.7	43.4	33.1
Wheat	19.1	24.1	15.3	58.3	52.9

The average losses in the untreated controls of our trials amount to 5.4 dt/ha with wheat and 9.3 dt/ha with rice, which is in the same order of magnitude as indicated by recent publications (Table 1).

The loss figures are furthermore in the same percentage range as estimated by Cramer (1967). These figures, however, do not allow the immediate conclusion that the loss percentage may not have considerably changed during the last 16 years, since (1) it is not known to what degree the total acreage grown is at present effectively treated and (2) our sample of trials covers both, effective and less effective treatments. In general, we have the impression that due to the relatively great number of trials under different conditions the data may reflect a true picture of reality. In this case, the increase of the yields per hectare from 1965 to 1981 from 20.7 dt to 28.6 dt with rice and from 12.5 dt to 19.1 dt with wheat would indicate a constant percentage of losses in spite of a remarkable intensification of agriculture. Our data indicate the highest absolute yield figures in trials with a degree of efficacy near 100 and - vice versa - the highest vulnerability to losses in case of high potential yields. This confirms the conclusion of Unterstenhöfer (1950)* who stated the close relationship between intensity of agriculture and the necessity of crop protection. It can, however, also be concluded from the data that under certain circumstances there is also a yield response even with low degrees of efficacy. This can be of interest in respect to the calculation of economic thresholds in the context of Integrated Pest Management.

* Unterstenhöfer, G., 1950: Höfchen-Briefe 3, (4), 6 - 48

1A—S2

CROP LOSSES CAUSED BY INSECT PESTS IN THE DEVELOPING WORLD

W. REED

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Patancheru PO, 502 324, AP, India

ABSTRACT

Information on crop losses caused by insect pests is essential for pest management research but such data are lacking, particularly in the developing world. Many of the available data have been collected from trials on research station farms where conditions are very different from those in farmers' fields. Natural selection has ensured that the farmers of the developing world have inherited crop genotypes and farming systems that reduce the risks imposed by pests and other constraints. The best available estimates indicate that losses to insects average 20% or more, but there is enormous variation in time and space. Recent changes in agricultural practices, including the introduction of irrigation, fertilizer, high yielding cultivars and new farming systems, are being accompanied by changes and increases in pest problems. The need to monitor such changes, and to provide the farmers with pest resistant cultivars and pest management practices to prevent sole reliance on pesticide use, is stressed.

INTRODUCTION

The "developing world" covers an enormous range of agroclimatic conditions, from swamps to deserts and tropics to tundra. With such diversity, most generalisations are of little value but we do know that most farmers in the developing world are well acquainted with risks imposed by droughts, floods, pests and diseases. Most of these farmers are the descendants of ancestors who survived because of their ingenuity in overcoming these risks by selecting seeds, farming systems and other methods that would provide enough food to keep their families alive, even in the bad years. Thus, natural selection has ensured that most farmers are not incompetent. Traditional methods of farming, which limit the risks of losses to the major crop yield reducers, including pests, have been developed over centuries. Integrated pest management was being practiced long before the phrase was invented!

However, we live in a changing world in which new methods of increasing agricultural production and reducing risks are becoming increasingly available. The farmers of the developing world need no longer limit their expectations to growing enough to keep their families alive. With increasing urbanisation providing markets for food in all countries, the farmers can expect to generate a cash income that will enable their families to enjoy some of the amenities that the world now offers to those who can afford to buy. Most farmers are eager to try the new methods of increasing crop production, which are brought to them by the extension services from the commercial, national and international research network.

This is the environment within which entomologists, such as myself, are now working; we are searching for methods that will enable the farmers to reduce their risks and losses to the insect pests. To establish our priorities we need to know the extent of the losses caused by the insect pests, for such data are basic to any pest research programs and so should be readily available. However, we appear to be still at the stage of asking how such data can be obtained. For example in a recent IOBC/Gerdat Colloquium (1982) concerning cotton, rice and maize, which are probably the most important crops of the developing world, the discussion mainly centered upon how crop loss assessment and economic threshold evaluation should be attempted.

At the All India Seminar on Crop Losses Due to Insect Pests held at Hyderabad in 1983, most of the participants stressed the enormous variability, in time and space, that they had encountered when summarising the crop loss assessment data that were available, and the paucity of good data collected systematically. Speaker after speaker showed data with losses to insect pests ranging from very little to 100%. They emphasised that most of the available data were from research station farms where ecological conditions were atypical of those in farmers' fields. They called for increased efforts to (a) develop standard methodologies for collection of crop loss data and (b) to apply these methodologies to an adequate well organised survey of the real world of the farmers' fields.

This is the crop loss assessment situation in the developing country which probably has the greatest number of well qualified and able entomologists of any country in the world. Most developing countries do not have India's wealth of entomological talent. In most countries the few entomologists available spread themselves thinly, attempting to develop immediate answers to pest control problems on the major crops in their area. They seldom have the time or resources even to consider the possibility of organising crop loss assessments on any of their crops on a national scale.

The paucity of crop loss data is not restricted to the developing world. Schwartz and Klassen (1981) while attempting to estimate the losses caused by insect pests in the USA found that data were not available for many crops and pests.

CROP LOSS ASSESSMENT

There is no shortage of publications giving advice on the methodology of crop loss assessment. The best known of these is probably the FAO Manual (Chiarappa, 1971) which, together with more recent supplements, provides a useful guide. However, even the simplest approach to crop loss measurement, that of paired plot comparisons with one of each pair of plots protected by pesticide use, is fraught with difficulties. Economic entomologists appreciate that pesticidesgive the greatest returns when used on close spaced, well fertilized, high yielding cultivars, so any paired plot comparisons tend to be carried out under such conditions. Such comparisons often give massive yield differences and so give very high estimates of pest caused losses. However, in the real world of the developing countries at present, most farmers' crops are still wide spaced, often intercropped and of land race cultivars that have been selected over hundreds, if not thousands, of years for tolerance of pest damage. Few entomologists will consider it worth-while to lay out paired plot comparisons on such fields, but if they did they would often find that pesticide use would give very small yield increases!

Most land race cultivars of several crops in the tropics show remarkable tolerance to many of the pest threats that they have to face. Perhaps we are too ready to assume that insect attack equals yield loss. For example stem borers are considered to be among the major pests of sorghum, but J.H.MacFarlane working in Nigeria (personal communication, 1983) has found no consistent difference in grain yield between plants that had no damage and other plants that had ten internodes, and more, bored by *Busseola fusca*! Similarly, Nwanze (1982) in Niger found that pearl millet plants bored by *Acigona ignefusalis* tended to have greater grain yields than those that were free from damage! In many crops compensation for damage, both within and between plants, can be spectacular. A good example of this is found in pigeonpea, a crop that is attractive to a large number of phytophagous insects. Pigeonpea in southern India can lose all of its flowers and young pods to *Heliothis armigera* but will produce a compensatory flush of flowers at least as great as that which was lost, provided climatic conditions allow (ICRISAT, 1981). Similarly on cotton, several workers including Brown (1965) have shown that removal of early flowers can lead to yield increases.

Although insect damage does not always result in yield loss there is no doubt that insects do cause massive losses of yield on many crops in the tropics. In a survey of pigeonpea in farmers' fields just before harvest over several years in India, S.S.Lateef (Bhatnagar et.al., 1982) found that half of the pods were damaged by insects in southern India, mainly by *Heliothis armigera* (Table 1). Such pod losses just before harvest cannot be compensated for.

TABLE 1

Pigeonpea pod damage by insects in samples from farmers' fields in India, 1975-1981

	North zone	Central zone	South zone
Fields sampled (no.)	359	446	443
Pods damaged by lepidopteran borers (%)	13.2	24.3	36.4
Pods damaged by podfly (%)	20.8	22.3	11.1
Total pods damaged by insect pests (%)	33.8	48.0	49.9

Lateef also found that in spite of such massive losses, less than 10% of the farmers attempted to use any pesticide on this crop. Such a low percentage of farmers using pesticides is certainly not because of a failure by the farmers to appreciate the pest problem, nor because of ignorance, apathy or laziness. For most farmers in developing countries, the problem of finding cash to pay for the pesticides and applicators, and of procuring water for spraying, are often insurmountable obstacles. It was also interesting to note that of the surveyed farmers who used pesticides, most used dust formulations of DDT or HCH. There is little doubt that this is because of the low cost of such chemicals. We are all aware of the objections by entomologists and environmentalists to the use of such persistent chemicals, but most of us would use these if we were farmers in similar straitened circumstances. Pesticide pollution is not of immediate concern to most subsistence farmers in developing countries. We can warn them by quoting the pesticide caused disasters such as those in Texas (Adkisson, 1973) and the Australian Ord Scheme (Anon, 1982), but few people learn from others mistakes! With *Heliothis armigera* eating chickpea and pigeonpea to a value of US $300 million in India in each year, we can expect farmers to grasp at any means that might reduce their losses.

CHANGING PEST PROBLEMS IN THE DEVELOPING WORLD

Generally,pest problems tend to increase closer to the equator. In northern Europe the winters tend to reduce the need for economic entomologists! Similarly in north India the relatively cold winters generally reduce the insect pest problems. On pigeonpea and other crops after each winter there is a race between crop maturity and build up of the populations of insects such as *Heliothis armigera*, with the crops usually winning the race. In southern India temperatures do not fall to levels which prohibit insect multiplication. Here the annual fluctuations of populations of pests appear to be associated with host plant availability which is in turn controlled by soil moisture availability. The increasing use of irrigation in the semi-arid tropics will undoubtedly have a major effect upon the pest populations. There is an obvious danger that pests such as *H. armigera* which were formerly reduced to very low populations in each year, partly because of a shortage of host plants through dry seasons, may increase dramatically if irrigated crops are available. For example in Andhra Pradesh in southern India, irrigated tomatoes, which were virtually unknown a few years ago, are now a regular feature through each dry season. These tomatoes are heavily infested by *H.armigera* and many farmers spray their crops at least weekly to control this pest. Here we have a potentially dangerous situation, where the pest is being afforded a new host plant through the period when its population is normally reduced to a very low level. Much of that population is now subjected to pesticide resistance selection.

In addition to increasing irrigation, there are many other changes occurring in agriculture in the developing world. Breeders are producing high yielding varieties and hybrids which are being readily accepted by many farmers. Fertilizer use is increasing. Farmers are being persuaded to sow monocrops at high plant densities. Such changes are inevitably accompanied by changes in pest problems.

In the Sudan Gezira the introduction of groundnut into the cropping system enabled *H.armigera* to become established as a major pest (Balla, 1982). In India in 1968, only four insects were regarded as major pests of groundnuts (Rai, 1976), but by 1982 at least eight insects were considered to be major pests (Amin, 1983). The designation of major pests is subject to personal opinion, but one of the new major pests was *Spodoptera litura* which had been important as a pest of tobacco but was sporadic on groundnuts. It appeared in epidemic form in 1978 and since then it has been of major importance on groundnut in each season in south-east India, where many farmers have failed to control this insect with intensive pesticide use.

Pimental (1981), referring to the "Green Revolution", pointed out that many of the high yielding cultivars may be more prone to pest caused losses than the old land race cultivars which they are replacing. Davies (1982), warned that the new high yielding, compact headed sorghums may be more susceptible than the older cultivars to several pests. Many crop plant breeders are selecting and testing genotypes under a "pesticide umbrella" on research stations. It is inevitable that plants selected under such conditions will be of little use in farmers' fields unless they are protected by pesticides. At ICRISAT, a pesticide free trial conducted by S.S.Lateef in which he compared chickpeas which had been selected under pesticide protected conditions with others selected in pesticide free conditions, well illustrates the danger (Table 2). The selections made in pesticide protected conditions will outyield the "pesticide free" selections only when protected.

TABLE 2

Comparison of entomologists' and breeders' selections of early maturing chickpeas in pesticide free conditions at ICRISAT Center, 1980-81

Genotype	Selection history	Mean pod damage %[c]	Yield kg/ha
IC-7394-18-12-1P	Ent[a]	14.6	2223
ICC-506	Ent	5.1	2001
IC-738-8-1P	Ent	9.9	1963
IC-73103-10-2-1P	Ent	14.9	1900
ICCC-9	Br[b]	18.0	1876
Annigeri-1 (Check)	-	20.0	1828
ICCC-6	Br	17.8	1726
ICCC-8	Br	14.9	1685
ICCC-1	Br	28.0	1297
S.E.M.		± 1.70	± 46.2

[a]Ent - Selected by entomologists in pesticide free fields in previous seasons.

[b]Br - Selected by breeders in pesticide treated fields in previous seasons.

[c] - Pod damage caused by *Heliothis armigera*.

ICRISAT has a large area (100 ha) of its farm designated as a pesticide free area on which pesticides never have been and, hopefully, never will be used. All the ICRISAT plant breeders' selections are eventually exposed in this pesticide free area to ensure that they are not more susceptible to pests than the cultivars currently used by farmers. This area is also being increasingly used in our host plant resistance selection and breeding work. Unfortunately the ICRISAT pesticide free area appears to be unique for we know of no other research farm that has a similar facility.

FUTURE WORK

The rapidly changing pattern of agriculture in the developing world will ensure that the few reliable estimates of crop loss to insect pests that we have today will soon become obsolete. The most comprehensive estimate of crop losses that we have available is that by Cramer (1967). His estimate, of 12.3% loss worldwide and 17.7% loss in the continents that include most of the developing world, should now be regarded as historical, but we have no more recent estimate. The National Academy of Sciences (USA) in 1978 estimated that post harvest losses in the developing countries averaged between 10 and 20%; much of this loss being caused by insects. Thus, the best available estimates indicate that insects are destroying more than 20% of the developing world's agricultural production. This estimate should at least suffice to convince the world that it must invest in pest control research.

The crop loss assessment data being collected in the developing world at this time are unlikely to provide us with a basis from which we can usefully update Cramer's (1967) estimates. The best that we can hope for is that well planned crop loss assessments will be undertaken on major crops in farmers' fields in some of the developing countries. These surveys should be on a continuing basis so that we can assess the impact of new agricultural practices upon the pest caused losses. As agricultural production in the developing world increases, we may be hard pressed to retain the pest caused losses to the present unacceptable levels.

We have an admirable slogan - Integrated Pest Management - but will we be able to convert this slogan into action in the farmers' fields in the developing world? We have an ideal opportunity, for the farmers are accepting major changes in their agriculture and they are not yet locked into pesticide insurance. There is little doubt that chemical pesticides will be more widely used in the developing world in the near future. We have to supply other elements of pest management, including resistant cultivars before the farmers become convinced that pesticides are the only answer to pest problems.

REFERENCES

Adkisson, P.L. (1973) The principles, strategies and tactics of pest control on cotton. Insects Studies in Population Management, Ecology Society of Australia (Memoirs 1), Canberra, 274-283.

Amin, P.W. (1983) Major field pests of groundnuts in India and associated yield losses. Proceedings, All India Seminar on Crop Losses Due to Insect Pests, January 1983, Hyderabad.

Anon. (1982) History of cotton in the Ord. The Australian Cotton Grower 3(2): 27-30.

Balla, A.N. (1982) Progress in research development for *Heliothis* management in the Sudan. Proceedings of the International Workshop on *Heliothis* Management, 15-20 November 1981, ICRISAT Center, Patancheru, AP, India, 363-368.

Bhatnagar, V.S., Lateef, S.S., Sithanantham, S., Pawar, C.S., Reed, W. (1982) Research on *Heliothis* at ICRISAT. Proceedings of the International Workshop on *Heliothis* Management, 15-20 November 1981, ICRISAT Center, Patancheru, AP, India, 385-396.

Brown, K.J. (1965) Response of three strains of cotton to flower removal. Empire Cotton Growing Review, 42: 279-286.

Cramer, H.H. (1967) Pflanzenschutz und Welternte. Pflanzenschutz - Nachrichten, Bayer 20/1967, 523 pp, L everkusen.

Chiarappa, L. (Ed) (1971) Crop loss assessment methods: FAO manual on the evaluation and prevention of losses by pests, diseases and weeds. Commonwealth Agricultural Bureaux, England.

Davies, J.C. (1982) Pest losses and control of damage on sorghum in developing countries - The realities and myths. Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum, ICRISAT, Patancheru, AP, India, 2-7 November 1981, 215-223.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), (1981) Annual Report, 1979/80. ICRISAT, Patancheru, AP, India, 109-110.

IOBC/Gerdat. (1982) Colloquium on crop loss assessment and economic threshold evaluation in cotton, rice and maize. Entomophaga, 27, Special Issue 1982.

National Academy of Sciences. (1978) Post harvest food losses in developing countries, Board on Science and Technology for International Development, National Academy of Sciences, Washington D.C.

Nwanze, K.F. (1982) Annual Report, 1982, Entomology (Niger and Upper Volta), ICRISAT Centre Sahelien, BP12 404, Niamey, Niger

Pimental, D. (1981) Introduction. CRC Handbook of Pest Management in Agriculture 1, CRC Boca Raton, Florida, 3-11.

Rai, B.K. (1976) Pests of oilseed crops in India and their control. Indian Council of Agricultural Research, 1976, 121 pp, New Delhi.

Schwartz, R.H., Klassen, W. (1981) Estimate of losses caused by insects and mites to agricultural crops. CRC Handbook of Pest Management in Agriculture, 1, CRC, Boca Raton, Florida, 15-77.

CROP LOSSES DUE TO PLANT PATHOGENS

P.S. TENG and W.W. SHANE

Department of Plant Pathology, University of Minnesota, St. Paul, Minnesota 55108, U.S.A.

ABSTRACT

Losses caused by plant pathogens have been and remain important constraints, worldwide, on efforts to increase crop production and productivity. With what appears to have been a decade of small improvements in the yield of major food and fiber crops, interest has renewed on better definition and reduction of losses as a means of increasing crop yields. Crop loss assessment and management requires a multidisciplinary approach because pathogens (fungi, bacteria, viruses, nematodes) not only interact with each other, but with other biotic and abiotic factors to affect yield. This review addresses both historical and current issues associated with the physiological basis of yield loss in plants, the statistical estimation of field disease and losses, and the use of modern technology and systems modeling in the study of losses at different levels of biological organization. The authors also discuss implementation of regional loss assessment programs and the use of loss information for decision-making.

INTRODUCTION

Crop losses caused by plant pathogens remain significant constraints, worldwide, on efforts to increase crop production and productivity. Historically, famines caused by crop failure gave impetus to the development of plant pathology as a science in its own right. Yet, to date, there are few reliable estimates of losses, with the estimate of 35% annual loss due to insects, weeds and diseases still being most cited in the literature (James 1981, Teng & Oshima 1983). Recently, Teng and Oshima (1983) have noted that, if the average figures of 35% preharvest loss due to pests were added to the 20% postharvest loss and 10% consumer wastage in the U.S.A., then in some years, this loss far exceeds the estimated world food deficit in cereal grains. Crop loss statistics tend to be given credence if cited often enough, and it is necessary to question whether, by providing misinformation, we may be harming our plant protection sciences in the longer term. In spite of the scarcity of reliable statistics on crop losses, it is generally accepted that there is recurrent loss in modern agricultural systems.

Crop production is a multifactorial equation, in which the factors may act separately or interactively to constrain yield. Trends in crop productivity (yield/unit area) for many crops worldwide show only marginal changes in the rate of productivity per year, over the last decade. For example, U.S. average wheat yields between 1969 and 1979 increased from 2.14 t/ha (1969) to 2.06 t/ha (1977) to 2.30 t/ha (1979), from U.S.D.A. statistics. Of more concern is the continued difference between what breeders and agronomists consider to be a practical, attainable yield level, and the actual yield obtained by growers. Soybean yield data from Minnesota for 1979 illustrate this:

Waseca Agricultural Experiment Station (Max. Potential) 5.5 t/ha
Waseca Agricultural Experiment Station (Actual) 3.4 t/ha

Waseca County (Farmer Average Actual) 2.5 t/ha
1979 World average 1.7 t/ha

The small increases in crop productivity and the large differences between attainable and actual yields led James and Teng (1979) to emphasize the concept of "production constraints", with crop losses caused by plant pathogens being a major constraint in efforts to increase productivity. This concept is translatable, in practice, into a crop loss profile (Chiarappa, 1981). In Colombia, Pinstrup-Anderson et al (1976) quantified the effect of each constraint in reducing attainable bean yield to actual. Crop loss profiles provide an analytical framework for quantifying losses and for determining the economics of loss management. The concepts of crop loss profile and production constraints are two significant developments since the last International Congress of Plant Protection.

The quantification of crop losses as production constraints requires a strategy. This includes a phase to experimentally determine the relationship between disease and loss, and another phase to apply the experimental results over a region (James 1974, James & Teng 1979). In many crop loss programs, these phases are, respectively, the experimental/modeling phase and the field survey phase.

In any discussion of crop losses, it is necessary to define the type of loss being considered. Zadoks and Schein (1979) presented a loss typology, which recognized that losses may occur at many levels in the food production and consumption system, and that loss occurs in crop quantity and quality. Recently, MacKenzie (1983) has distinguished between yield loss and crop loss, with yield loss being applied to single-pathogen, small populations and crop loss to multiple stress factors and over large populations. The concept of loss is further dependent on definitions and measurements of various yield levels, such as attainable yield, actual yield and economic yield (Zadoks & Schein 1979). In research, yield loss is most often the difference between yield in a disease-free plot and that with a certain level of disease. We must be clear, at the beginning of any crop loss assessment program, on the system boundaries within which we are operating.

In this paper, we will review selected topics in the assessment of crop losses due to plant pathogens, in particular, the methodology for loss assessment and the gathering of regional loss data. Our focus is on the state of present knowledge relative to the last international congress.

METHODOLOGY FOR CROP LOSS ASSESSMENT

Most of the methodology in crop loss assessment has been developed with fungal pathosystems and our discussion in the following sections reflects this.

Physiological Basis of Loss

Pathogens cause physiological disruptions in their host, the magnitude of which may affect biological parameters viewed as crop yield. Disease may have direct effects on crop biomass during the growing season or indirectly influence a final product like grain weight and quality. Gaunt (1980) and his co-workers have given us fresh insights into the dynamic nature of yield responses to different disease intensities in relation to crop development stage. By dividing crop development into stages during which individual yield components may be affected under unconstrained and constrained (diseased) conditions, a basis is established for examining expected final yield responses to disease. This approach has enabled the development of conceptual models for selected pathosystems (Teng & Gaunt 1980), which may then be used to evaluate the biological validity of disease-loss models. It is important that, as crop loss assessment becomes increasingly quantitative, we do not lose sight of the physiological reasons for loss, or develop models that are biologically unacceptable.

Dynamic plant physiological models, which attempt to simulate plant growth and development, have been used by several workers to explain pathogen effects on crop yield (Loomis & Adams 1980). These models address interactions between pathogen and host plant at the process level (e.g. photosynthesis) and may be used to model healthy crops and crops with specified levels of disease.

Disease Measurement

This is one of the most important components of any disease-loss appraisal program because it generates the baseline data on disease development for loss computation. This term is used to include all methods of disease quantification in one of the following categories: disease assessment (direct), indirect methods and remote sensing (James & Teng 1979). While efforts have continued, notably by the Food and Agriculture Organization, United Nations, to standardize disease measurement worldwide, and some progress has been made, there is still little uniformity relative to disease diagnosis methods. The International Collaborative Program on Crop Loss Assessment, F.A.O. (Chiarappa et al. 1975) serves as the umbrella worldwide for efforts in this area. The "James' Keys", a set of standard area diagrams and assessment keys, mostly based on the percentage scale (James, 1971) was reproduced by the American Phytopathological Society, and has stimulated much use of percentages for quantifying diseases caused by fungi, bacteria and viruses. In this regard, two concepts have prevailed in the field measurement of disease - disease incidence (proportion of infected plants) and disease severity (proportion of infected area). Disease intensity may be used on diseases caused by systemic infections, with no clearly defined symptom area. Disease assessment remains the most popular field method for quantifying many diseases (Teng 1983a), and will continue to be so. Its correct use has recently been questioned (Hebert 1982), because many assessment methods utilize the Horsfall-Barratt Scale, which in turn relies on the Weber-Fechner Law governing psycho-visual phenomena. This law suggests that the ability of the human eye to respond to stimuli is logarithmically related to the intensity of the stimuli. Many diseases do not show intensity symptoms, i.e. grades of colors, but rather are a proportion phenomenon. Therefore, other laws may govern eye response to disease. James (1974) noted that in some cases, linear scales could be used with reproducibility between assessors and Teng (1983a) has suggested that there may be no universal rule governing human eye response to the many types of symptoms.

Remote sensing uses equipment to gather data about the attributes of an object from a distance and without contact. In plant pathology, it includes photography and the measurement of spectral reflectance. While progress has been made with the use of satellite imagery to identify crops and quantify crop area, it has not been possible to routinely identify disease or quantify disease severity. Remote sensing is specially applicable to those pathogens causing total plant death, i.e. measurement of disease incidence. There has been recent research into portable, hand-held remote sensing devices which may be used in conjunction with ground assessments (Pederson & Fiechner 1980). These appear promising, both as devices on their own and as further verification of satellite information. A related development is the use of video image analyzing equipment for disease quantification (Lindow & Webb 1983). With improvement, this method shows much promise as an objective, yet practical means for disease measurement.

There have been few studies to evaluate methods of disease measurement on the same pathogen-host system. With tomato leaf mold Smith et al (1969), found that their assessment method most often overestimated the actual diseased area, as determined by a graphical method. Sherwood et al (1983) have further confirmed the variability associated with using the human eye as a sensing device.

Experimental Techniques

The common technique of generating data for characterizing a disease-loss relationship is to conduct experiments in which the treatments represent a wide range of epidemics, and with a disease-free treatment. The methods for producing these epidemics include use of fungicides, cultural practices, multi locations and cultivars (James & Teng 1979, Burleigh 1980). Almost without exception, experiments use designs like the randomized complete block, and factorial, with replication. Recently, plant pathologists have become more aware of the misuse of statistical techniques, especially in comparing quantitative properties such as different disease intensities (Berger & Johnson 1982). With estimation of a disease-loss relationship, the treatments used are generally quantitative, and may be viewed as a response function. Therefore, it would be logical to use response surface methodology to generate data for disease-loss modeling (Teng & Oshima 1983). This methodology emphasizes the number of treatments over number of replications and suggests that with response estimation, the aim is not to prove significance between two treatments but to prove significance of the overall relationship. The approach is particularly relevant to crop loss models, most of which are empirical, regression models. We can expect to see increased research in response surface methods for crop loss experiments.

A long-standing problem in crop loss experiments is defining the reference yield from which loss is calculated. Because reference yields vary in response to many factors, loss is commonly expressed as a proportion term. This leads to the assumption that yield plus loss equals 100%, which MacKenzie and King (1980) noted, is misleading. More recently, attempts in Minnesota at using models to predict yield loss for justifying fungicide sprays led to similar problems of non-linerarity when we found that percent recovery was not the reduction of percent yield loss. Currently, through the auspices of the U.S. Department of Agriculture's National Crop Loss Assessment System (NCLAS), research has been initiated to examine experimental techniques more suited for loss estimation, compared with yield estimation.

The conventional sampling unit in crop loss experiments is a plot, although there has been much effort in using single plants, shoots or tillers as units for assessment. The work by Richardson et al (1975) showed that, while the single tiller method may result in statistically significant regression models based on the F-test, these models generally explain a very small proportion of the variation in loss due to disease. A modification of the Richardson method was tested in Africa by Hau et al (1980) to estimate cassava yield losses due to mosaic virus. These workers corrected for the potential yield of each plant by measuring leaf area, a plant parameter presumably unaffected by virus, and were able to reduce inter-plant variation in yield to produce models with higher accountability of variation. Many workers recognize that a minimum sample size is needed to approximate the dynamics of epidemics occurring in farmers' fields. However, as both Richardson et al (1975) and Hau et al (1980) argue, the single plant/tiller method may result in a disease-loss relationship being developed after just one growing season, while plot methods require several seasons to produce enough representative epidemics.

Reducing the size of the experimental unit may lead to "representational" problems. As Teng and Oshima (1983) noted, the highest level disease-loss model reported is still a plot model, whereas crop losses are generally assessed for a field. We do not know how much error is incurred when applying models developed at a lower level to a higher level. Another problem related to size of experimental unit is that of interplot interference (Vander Plank 1963). The work by James et al (1973) made many "crop lossologists" (Chiarappa 1981) aware of this phenomenon in all experiments with treatments of different disease intensities. Jenkyn et al (1979) demonstrated that certain plot layouts may reduce interference. Work in Minnesota has shown that interference can be modelled by computer simulation and in some cases, corrected (Bowen 1983).

Crop and Yield Loss Modeling

A mathematical model is a convenient and practical way to summarize large data sets and concurrently, integrate scientific hypotheses with empirical data. While the majority of single disease-yield loss models are empirical, linear models, an important development since the 1979 congress is non-linear modeling, as exemplified by use of the Weibull Function (Madden et al 1981). Recently, Teng (1983b) postulated that there were nine possible shapes to represent the relationship between disease and yield or loss, based on published literature. The linear form, most easily modeled using least squares regression by plant pathologists, is most prevalent in crop loss literature.

Conceptually, the empirical models may be either single point (where loss is estimated using one disease variable at a growth stage), multiple point (where loss is estimated from more than one disease variable, commonly at different growth stages) or integral models (where loss is estimated using a summation disease variable such as area under curve). With linear models, multiple point models generally explain more loss variation due to disease than single point models. With non-linear models, no equivalent comparison has yet been reported. A non-linear critical point model may also offer better fit to data than a linear multiple point model for the same disease-loss system (Madden et al 1981).

While nearly all published empirical models have been developed using data generated in small plots or by single plant/tiller methods, recently, the problems of scale in modeling has received some attention (Teng & Oshima 1983). Work at Purdue University has led to the development of large-scale crop yield models for predicting yield and loss at the county level (Don Holt, personal communication). Australian workers have used a macro-physiological growth model for estimating potato yield over large areas (Sands et al 1979). Although the idea of coupling disease simulation models to crop physiological models is well known, relatively little progress has been made.

Yield loss models for single diseases, when used to estimate crop losses in growers' fields, cannot account for interaction between diseases, other stresses and the environment. The result is that, when yield losses are totaled, they often overestimate crop loss (MacKenzie 1983). There has been insufficient research into developing multiple pest-loss models using experimental data. King's (1982) work on weed-insect-late blight interaction models for loss estimation confirmed the huge amount of resources required. Other workers have made use of sample-surveys to provide data for modeling, using multivariate methods for analysis like principal components analysis (Stynes 1975, Wiese 1980).

One of the weakest areas in modeling methodology for crop losses is validation. There are few examples of validated disease-loss models in the literature. Most research has been done up to the point when a model is defined, and it is then published for general use. Teng (1981) has pointed out that the use of invalid models will do much harm to pathologists in the long run, and that an equivalent effort should be spent on validation as on model development.

REGIONAL CROP LOSS DATA

Collection Methods

Crop loss data may be collected by both direct (survey, remote sensing) and indirect (expert opinion, non-crop loss assessment activities, mail surveys) methods (Van der Graaf 1981). James (1974) and James and Teng (1979) were of the opinion that only direct methods could generate objective loss data for use in decision-making. These authors suggested that a program in which disease-loss relationships were experimentally determined and then used in conjunction with survey data, was the only reliable means of regional crop loss assessment. Indirect loss data may be used as validation of direct data (Teng 1983b). We feel that a major effort is needed to compare the utility of direct versus indirect loss data.

Survey methodology is still relatively under researched, although there is increased appreciation of this in many countries. Standard statistical methods for sample selection, e.g. simple random and multistage, predominate in disease-loss surveys (James & Teng 1979). A new trend in survey method is the use of portable, microcomputers for field recording of data, leading to a rapid conversion of data into management information (Teng 1983a). This has made workers examine more critically the quality of the data being collected, and the efficiency of the collection process. For example, in Minnesota we have done comparative studies on different methods of field data recording vis-a-vis information utility and cost of information.

Within-field sampling methods to determine mean disease have received some recent attention, both in field studies (Rouse et al 1981) and with computer simulation (Lin et al 1979). The distribution of diseased units in a field determines sampling method and many statistical functions have been suggested to describe diseases that occur randomly, aggregatively or regularly in a field, e.g. Poisson, Negative Binomial (Teng 1983a). We can expect to see more results on this aspect of survey methodology being reported in the next five years.

Available Regional Loss Information

There are still few examples of ongoing programs to collect regional disease and loss information at the state, national or international level. The survey programs for cereals in the United Kingdom (King 1977) have generated much useful information. These programs assume that losses caused by one pathogen are independent of other pathogens, because of the single disease-loss models available. For example, King (1977) reported that losses caused by diseases in England and Wales were:

		1976	1977
Barley	Mildew	8.7	3.6
	Net Blotch	0.2	0.3
	Leaf rust	0.3	0.4
Wheat	Mildew	1.8	1.4
	Septoria	0.1	0.1
	Yellow rust	0.01	trace
	Eyespot	0.2	0.8

The above programs still represent one of the best examples of direct crop loss data.

In the U.S.A., pest intensity data is being collected for thirty-nine states through a pilot program of the Department of Agriculture. This program entered its second field season in 1983. Weekly abundance and damage data on pests (diseases and weeds) of major crops, averaged over a county, are sent via phone lines to a single computer in Colorado. States receive weekly summaries of their own data and may receive data on other states as well. We feel this is a significant development that will do much to stimulate research into survey methods. Within the U.S.A., some states have regular crop loss estimates. The North Carolina program, which relies on expert testimonies and surveys, is an example. This program documented 6.8% loss on tobacco from all diseases during 1979, equal to $72 million (Main et al 1979).

The reference publications on average crop losses nationally and internationally remain Cramer's book (Cramer 1967) and the 1965 USDA Handbook. Some authors have used these compilations, together with scientific literature, to derive best estimates for losses caused by pathogens, e.g. James (1981). The database from which all the above losses are estimated does not seem to have changed.

CONCLUDING REMARKS

We have seen much progress in the assessment of crop losses caused by plant pathogens since F.A.O. convened the first international symposium on crop losses in 1967. The symposium stimulated efforts at standardization of assessment methods, especially through the subsequent publication of the F.A.O. Crop Loss Assessment Methods, Supplements 1-3. Recently, progress in crop loss assessment was reviewed at a second international symposium devoted solely to the topic, in Minneapolis in 1980 (Teng & Krupa 1980). One outcome of this meeting was the increased realization of the interdisciplinary nature of crop loss assessment and of crop losses per se. Although there has been progress since 1967 in methodology for loss assessment, less has been achieved with obtaining actual field estimates of loss in spite of the potential use of regional loss data for guiding policies on crop protection.

The "computer revolution" has also made its impact on crop loss assessment especially through the development and implementation of loss models for decision-making at the field level. For example, in Minnesota, we have two such models that are contained in the memory of hand-held computers and may be carried to the field for deciding on the economics of applying a fungicide to control either bean or sweet corn rust (Teng & Montgomery 1982). Computer technology has also led to the widespread use of pest surveillance information systems, providing extension personnel timely information on disease intensity and loss during the growing season. We see here the multiple use of survey data, during and after the growing season, for different kinds of decision-making, making it easier to justify expensive survey programs.

For the future, we may expect to see a greater influence of the "systems approach", the holistic and interdisciplinary concepts that it embodies, on the science of crop loss assessment. We can also expect to see more realistic disease-loss models being developed and used, and the mechanics of handling crop loss information fine-tuned through computer technology both in the developed and developing nations. Hopefully, from these, more precise estimates of crop losses due to plant pathogens will become available.

REFERENCES

Bowen, K.L. (1983) Spatial Aspects of Epidemics of Puccinia recondita f. sp. tritici. M.S. Thesis., Department of Plant Pathology, University of Minnesota. 110 p.

Burleigh, J.E. (1980) Experimental designs for quantifying disease effect on crop yield. In: Crop Loss Assessment, P.S. Teng and S.V. Krupa (ed), University of Minnesota, pp. 50-62.

Chiarappa, L.; Gonzalez, R.H.; Moore, F.J.; Stickland, A.H.; Chiang, H.C. (1975) The status and requirements of the FAO International Collaborative Programme on crop loss appraisal. FAO Plant Protection Bulletin 23, 118-124.

Cramer, H.H. (1967) Plant Protection and World Crop Production. Pflanzenschutz Nachrichten Bayer 20, 3-524.

Gaunt, R.E. (1980) Physiological basis of yield loss. In: Crop Loss Assessment, P.S. Teng and S.V. Krupa (Eds), University of Minnesota, pp. 98-111.

Hau, B.; Kranz, J.; Dengel, H.J.; Hamelink, J. (1980) On the development of loss assessment methods in the tropics. In: Crop Loss Assessment, P.S. Teng and S.V. Krupa (Eds), University of Minnesota, pp. 254-261.

Hebert, T.T. (1982) The rationale for the Horsfall-Barratt plant disease assessment scale. Phytopathology 72, 1269.

James, W.C. (1971) A Manual of disease assessment keys for plant diseases. Canadian Dept. of Agriculture Publication 1458.

James, W.C. (1974) Assessment of plant disease and losses. Annual Review of Phytopathology 12, 27-48.

James, W.C. (1981) Estimated losses of crops from plant pathogens. In: Handbook of Pest Management in Agriculture, Volume 1. D. Pimentel (Ed), Boca Raton:CRC Press, pp. 79-904.

James, W.C.; Teng, P.S. (1979) The quantification of production constraints associated with plant diseases. In: Applied Biology, Volume IV, T.H. Coaker (Ed), Academic Press, pp. 201-267.

Jenkyn, J.F.; Bainbridge, A.; Dyde, G.V.; Todd, A.D. (1979) An investigation into interplot interactions in experiments with mildew on barley, using balanced designs. Annals of Applied Biology 92, 11-28.

Johnson, S.B.; Berger, R.D. (1982) On the status of statistics in PHYTOPATHOLOGY. Phytopathology 72, 1014-1015.

King, E.D. (1982) The Effects of late blight, Colorado potato beetle and weed populations on yield loss of potato. Ph.D. Thesis, Pennsylvania State University, College park. 81 p.

King, J.E. (1977) The incidence and economic significance of diseases in cereals in England and Wales. In: Proceedings 1977 British Crop Protection Conference-Pests and Diseases, Nottingham:The Boots Company Ltd., pp. 677-687.

Lin, C.S.; Poushinsky, G.; Mauer, M. (1979) An examination of five sampling methods under random and clustered disease distribution using simulation. Canadian Journal of Plant Science 59, 121-130.

Lindow, S.E.; Webb, R.R. (1983) Quantification of foliar plant disease symptoms by microcomputer-digitized video image analysis. Phytopathology 73, 520-524.

Loomis, R.S.; Adams, S.S. (1980) The potential of dynamic physiological models for crop loss assessment. In: Crop Loss Assessment, P.S. Teng and S.V. Krupa (Ed), University of Minnesota, pp. 112-117.

MacKenzie, D.R. (1983) Toward the management of crop losses. In Challenging Problems in Plant Health, T. Kommedahl and P.H. Williams (Eds), American Phytopathological Society, pp. 82-92.

MacKenzie, D.R.; King, E. (1980) Developing realistic crop loss models for plant diseases. In Crop Loss Assessment, P.S. Teng and S.V. Krupa (Eds), University of Minnesota, pp. 85-89.

Madden, L.V.; Pennypacker, S.; Antle, C.E.; Kingsolver, C.H. (1981). A loss model for crops. Phytopathology 71, 685-689.

Main, C.E.; Essex, B.W.; Bragg, A.W. (1980) Crop losses in North Carolina due to plant diseases and nematodes. Department of Plant Pathology special Publication Number 1. North Carolina State University,

Raleigh, NC, 106 p.
Pederson, V.D.; Fiechtner, G. (1980) A low-cost, compact data acquisition system for recording visible and infrared reflection from barley crop canopies. In: Crop Loss Assessment, P.S. Teng and S.F. Krupa (Ed.), University of Minnesota, pp. 71-75.
Pinstrup-Andersen, P.; Londono, N. de; Infante, M. (1976) A suggested procedure for estimating yield and production losses in crops. PANS 22, 359-365.
Richardson, M.J.; Jacks, M.; Smith, S. (1975) Assessment of loss caused by barley mildew using single tillers. Plant Pathology 24, 21-26.
Sands, P.J.; Hackett, C.; Nix, H.A. (1979) A model of the development and bulking of potatoes. Field Crops Research 2, 309-331.
Sherwood, R.T.; Berg, C.C.; Hoover, M.R.; Zeiders, K.E. (1983) Illusions in visual assessment of Stagonospora leaf spot of Orchardgrass. Phytopathology 73, 173-177.
Stynes, B.A. (1975) A Synoptic Study of Wheat. Ph.D. Thesis, The University of Adelaide, South Australia. 291 p.
Teng, P.S. (1981) Validation of computer models of plant disease epidemics. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz 88, 49-63.
Teng, P.S. (1983a) Estimating and interpreting disease intensity and loss in commercial fields. Phytopathology 73, In press.
Teng, P.S. (1983b) Construction of predictive models: II. Forecasting crop losses. In: Advances in Plant Pathology, Volume IV, C.A. Gilligan (Ed), Academic Press, In press.
Teng, P.S.; Gaunt, R.E. (1980) Modelling systems of disease and yield loss in cereals. Agricultural Systems 6, 131-154.
Teng, P.S.; Montgomery, P.R. (1982) RUSTMAN: a portable, microcomputer-based economic decision model for sweet corn rust control. Phytopathology 72, 1140.
Teng, P.S.; Oshima, R.J. (1983) Identification and assessment of losses. In: Challenging Problems in Plant Health, T. Kommedahl and P.H. Williams (Eds), American Phytopathological Society, pp. 69-81.
Van der Graaf, N.A. (1981) Increasing reliability of crop loss information: the use of 'indirect' data. In: Crop Loss Assessment Methods-Supplement 3, L. Chairappa (Ed), FAO/CAB, pp. 65-72.
Van der Plank, J.E. (1963) Plant Diseases: Epidemics and Control. Academic Press, New York.
Walker, P.T. (1983) Crop losses: the need to quantify the effects of pests, diseases and weeds on agricultural production. Agriculture, Ecosystems and Environment 9, 119-158.
Wiese, M.V. (1980) Comprehensive and systematic assessment of crop yield determinants. In: Crop Loss Assessment, P.S. Teng and S.V. Krupa (Eds), University of Minnesota, pp. 262-269.
Zadoks, J.C.; Schein, R.D. (1979) Epidemiology and Plant Disease Management. New York: Oxford University Press. 427 p.

THE EFFECTS OF WEEDS IN CERTAIN CROPPING SYSTEMS

W. KOCH, H. WALTER

University of Hohenheim, Institute of Plant Production in the Tropics and Subtropics, P.O. Box 700562, 7000 Stuttgart 70, FRG

ABSTRACT

The main emphasis is put on the discussion of the importance of weeds in cropping systems of different levels of intensity or variations in fertility level. The general aspects considered are supplemented by some specific examples of the influence of weeds in cereals.

INTRODUCTION

Weeds are plants which are more harmful than useful. Accordingly weed control is the reduction of a harmful plant stand to an extent where its benefits are superior over its negative effects. Hereby the inputs for weed control must not exceed the expected short- and long-term losses due to weeds. Hence weed control is the management of undesired vegetation by means of economically and ecologically justified control measures.

GENERAL ASPECTS OF WEEDS/CROPPING SYSTEMS INTERRELATIONSHIPS

According to Holm (1978) only about 200 weed species are involved in 95% of man's weed problems. Species of 12 families provide 70% of the world's main weed problems. The total number of weed species in a field largely depends on the natural environment on the one side and the cropping system on the other being usually low (10 - 15) in highly productive and intensive systems with a low diversity of crops grown in rotation; being high (up to 50 or even more) in extensively cropped fields in which a highly diversified crop rotation is practiced. In any case, however, only a few out of the total number of species encountered in a field will account for most of the damage.

Plant species are adapted to certain characteristics of their environment. If some factor of a cropping system changes, the weed flora will change too. From an analysis of the factors which influence weed development in a cropping system, it should be possible to predict the effects on the weed flora from changes in the system. Some examples for weed/cropping systems interrelationships are:

- increasing wild oats (*Avena* spp.) problems in wheat/fallow systems of North Africa and Near East when cultivated fallow is reduced
- increasing problems with *Cyperus rotundus* by reduction of deep soil cultivation in Sudan Gezira
- weeds and available methods of control may affect or determine
  - methods of planting crops; e.g. seeding or transplanting rice, cabbage, onions
  - soil cultivation and seed bed preparation; e.g. minimum cultivation
  - time of planting to minimize weed growth in the crop
  - water management in irrigated fields; e.g. rice, pre-watering of field crops to allow early weed growth which will be destroyed during seed bed preparation
  - spacing of many crops; e.g. groundnuts, soybeans, sorghum,small grain cereals, rice, maize, some vegetables; a change of weed control

technology will be of direct influence on the way those crops are grown. The cropping system may then have to be re-optimized in respect to spacing, giving priority to other agronomic requirements.
- area a farmer is able to crop; mainly in traditional cropping systems, the labour available for weed control is the limiting factor for the area which can be planted (never plant a garden larger than your wife can weed)
- crop to be planted as such and in interrelation to the harvest technology; e.g. no sugar beet without chemical weed control, no mechanical harvesting of peas resp. no peas without proper weed control in highly industrialized agriculture.

EFFECTS OF WEEDS IN CROPPING SYSTEMS

Potential crop losses and inputs required for weed control vary with crop tolerance, cropping system, and environmental conditions of site.

Moody (cited by Koch et. al., 1983) reported that in three Nigerian villages farmers spent 74, 61, 56% respectively of their time for weeding. In Ethiopia, 30 - 40% of total labour requirement for maize production goes into weed control and this accounts for the maximum peak of labour input at a certain time (Alkaemper, 1980). Somewhat lower figures are given by Attems (1968) for permanent cropping systems in the Usambara mountains in Tanzania (about 25 man days/ha for weeding maize and beans, and 50 for weeding two year old cassava). Weed control takes place late and is insufficient to prevent yield losses completely in these systems, obviously in order to prevent erosion. Parker (1973) found that weed control in maize requires out of the total labour input 29% in tropical rain forest areas and 16% in savanna areas.

One major factor which prevents man from permanent cropping and forces him into shifting cultivation is excessive weed growth after some years of growing arable crops. Yield decreases of 50% or more due to weeds within two or three seasons after clearing have been reported (Jurion & Henry and Brown, both cited by Moody, 1975). Weeds are often a greater problem in a monoculture or in simple crop associations than in the multicrop and multistoried crop associations that are practiced in certain areas. Weed control on the other hand is often easier in simple systems.

Harmful effects of weeds

According to certain authors weeds cause crop losses in the following principal ways:
- by reducing crop growth and yields by competition for water, mineral nutrients, light and possibly CO_2
- by necessitating the use of control measures which may themselves injure the crop and reduce the yield and by the costs of the control measures themselves
- by interfering with harvesting and other operational techniques
- by lowering the quality of the harvest yield through contamination with foreign matter (weed seeds in grain crops, leaves and stems in leafy vegetables) or through imparting off-flavours e.g. to milk by *Allium canadense*, *A. vineale*, *Helenium amarum* (Ennis, 1967)
- by increasing the moisture content of the harvest products of certain crops under certain conditions
- by increasing the risk of lodging of certain crops
- by being host plants to certain pests and diseases (see e.g. van Huis

1981, Moody & Whitney 1974, Yassin 1979, all cited by Koch, 1983)
- by poisoning food or feed (e.g. *Agrostemma githago* in cereals): Holm (1976, cited by Koch, 1983) reported on serious health problems in Afghanistan, obviously due to seed of *Heliothropium*, probably *H. eichwaldii*; he gave an estimate of 3,000 to 4,000 people having died and 10,000 falling ill from one season's harvest.

Indirect losses caused by weeds, such as the limitation weeds put to the area a farmer is able to crop, or to what kind of crop he is able to plant, could be added as well. Listing the potential losses due to weeds qualitatively as above is not difficult. However, there is a paucity of useful quantitative information on the losses available to decision makers in weed research, control and legislation, especially on a national or global basis, as Vere & Auld (1982) state in their review paper. Also Parker & Fryer (1975) noted the general lack of contemporary estimates of the losses caused by weeds; they pointed out that many evaluations of current losses are based on old statistics (such as those published by the USDA in 1965) and are therefore quite out of date. Solutions for this problem on a world wide scale, although highly demanded, are not in view. Recently Chandler (1980) provided some new figures on losses due to weeds in major crops in the United States, where inspite of weed control more than 12% loss in yield can be attributed to weeds. Some of the problems involved in gathering such information have been discussed in a previous paper (Koch et. al., 1983).

According to Ashby & Pfeiffer (1956), yield losses due to weed competition are higher in the tropics/subtropics (up to 50% and even more) than under the conditions of the temperate zones (on average up to 20%). Extreme weed growth is true especially for zones with high temperature and sufficient water.

Parker & Fryer (1975) estimate that 11.5% of food is being lost due to weeds despite the control measures taken. They point out the less developed the crop production system is, the greater are the losses.

Beneficial effects of weeds

Many weed species are used at times, especially in traditional rural societies:
- as food e.g. *Portulaca oleracea* in many parts of the world, *Corchorus olitorius* in many countries (e.g. Sudan, Togo, Thailand), *Gundelia tournefortii* in Syria, *Gynandropis gynandra* and *Bidens pilosa* in Togo, *Ipomoea aquatica* in many Asian countries
- as remedies or in tribal worship
- as feed e.g. grazing of fallow land after harvest (mainly in wheat/fallow systems) or feeding to animals after weeding e.g. *Echinochloa* spp. in the Philippines, *Avena sterilis* in Morocco
- as source of energy e.g. *Eichhornia crassipes* (for details see Philipp et. al., 1983)
- as ground cover to prevent soil erosion; in many cases weeds are retained to control erosion even though they reduce yield (Moody, 1975)
- as fertilizer: N-fixation by *Azolla/Anabaena* in rice and leguminous species in general, by some deep-rooting perennials (e.g. *Cirsium arvense*), nutrient transfer from subsoil to upper soil layers
- as reservoirs of predators of pests or as alternate hosts for pests (e.g. polyphagous larvae such as those of *Elateridae* may be less harmful to beets in a weedy environment as compared to weedfree).

It is difficult in most instances to quantify the benefits of weeds and this has hardly been tried yet. In estimating crop losses, the beneficial effects of weeds should be taken into account. They might be zero in many highly industrialized plant production systems. Beneficial effects may be high, however, in many traditional low input systems. Link (1983), for example, made an attempt to quantify the role of weeds, predominantly of *Avena sterilis*, as fodder in Morocco. Almost 2 t/ha of fresh weight of weeds in cereals at weeding time certainly is a substantial contribution to livestock feeding under the socio-economical situations under which it is practiced. With intensification of wheat production in those areas, the importance of weeds as food or feed gets less and finally it may be more economical just to control the weeds in time and to plant forage crops separately.

WEED DENSITY/CROP LOSS RELATIONSHIPS

A number of factors are influencing the weed density/crop loss relationships. This aspect has been touched to some limited extent in a previous paper (Koch et. al. 1983). Those factors are known but their quantification is still not possible with a satisfactory degree of accuracy and significance.

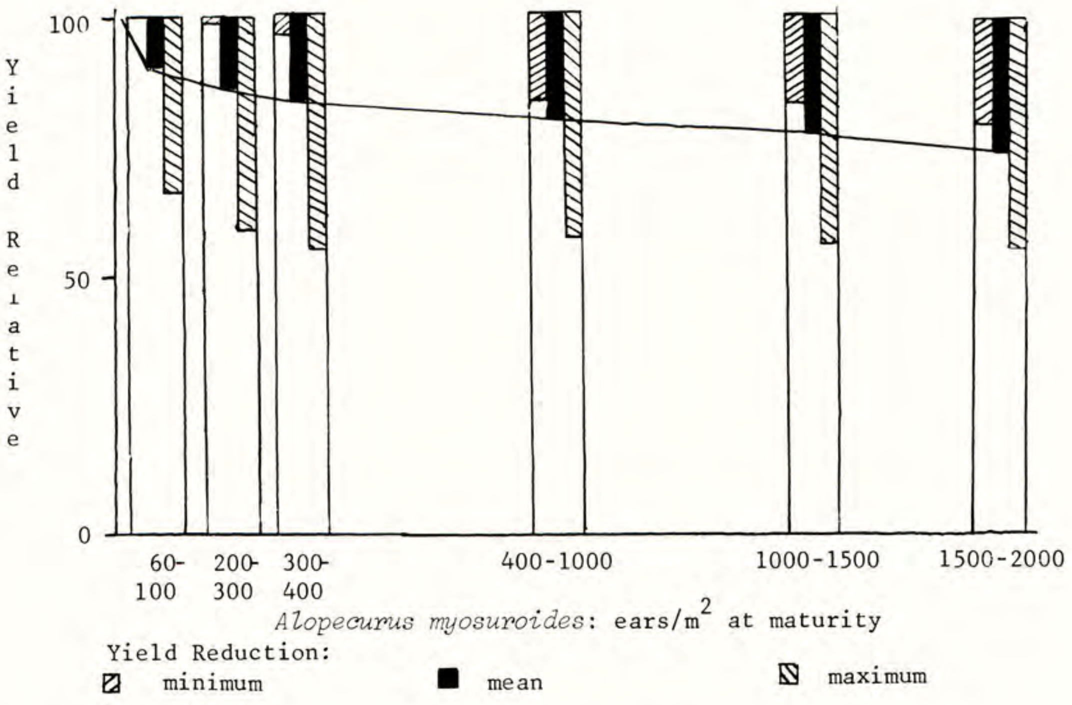


Fig. 1: Losses of grain yield of wheat due to different densities of *Alopecurus myosuroides* in southwestern Germany (data from more than 100 herbicide trials; controls had been more or less weed-free).

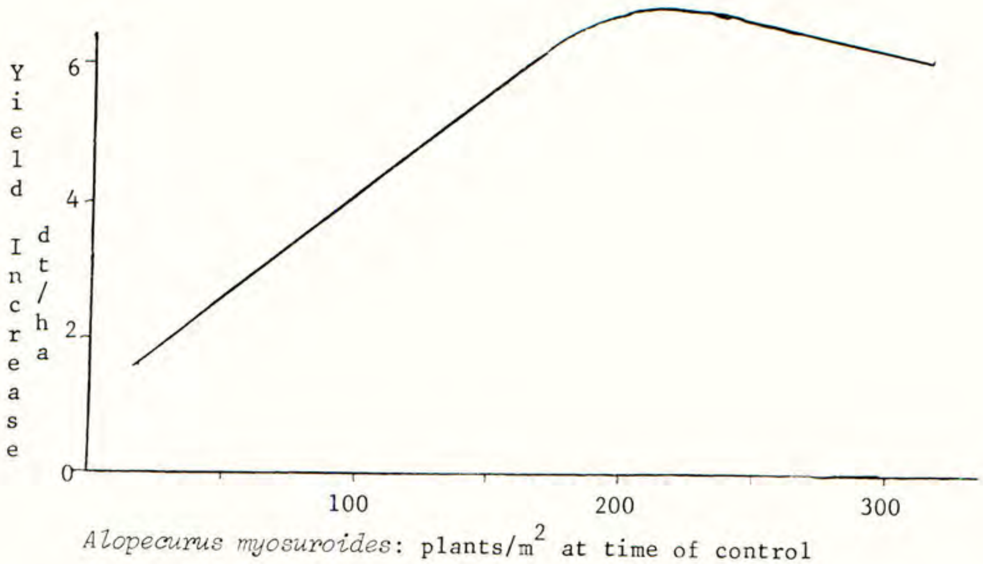


Fig. 2: Increases of grain yields of wheat as the result of control of different densities of *A. myosuroides* with herbicides - 87 trials in south-western Germany with an average efficiency of control of 85% (Kemmer et. al., 1980).

Usually no significant yield reductions occur at very low weed densities. For example, significant losses of grain yield of winter wheat at the 5% and 1% level were caused by 22 - 33 and 27 - 50 plants/m^2 respectively of *A. myosuroides* (biological threshold) in a study with a total of 87 experiments in south-western Germany over four years (Rauber et al., 1980). Above the biological threshold, crop losses follow some sort of a first order reaction with increasing weed densities due to increasing intraspecific competition within the weed species (fig. 1). This means that the degree of control must be higher at high weed densities than at low densities in order to bring or to keep the weed infestation below a certain threshold. For example, in a study of Rauber et. al. (1980) and Kemmer et. al. (1980) with *A. myosuroides* in winter wheat, the economical threshold for a certain herbicide application was 50 - 94 plants/m^2 at the 1% level of significance. Assuming a threshold of 25 plants/m^2, it would need 50% control at a density of 50 plants/m^2 and 95% at a density of 1,000 plants/m^2. In the study of Kemmer et. al. (1980) mentioned above, the average efficiency of herbicides against *A. myosuroides* was about 85%. This means that normal herbicide applications will lead to maximum yield increases only at low to medium infestations of *A. myosuroides*; up to about 165 plants/m^2 in this example. Figure 2 represents this relationship in the study of Kemmer et. al. (1980).

INFLUENCE OF THE PRODUCTIVITY OF THE SITE ON CROP LOSSES

It may be expected from the few reports available that differences in yield potentials of sites are of influence on crop losses due to weeds. Alkämper (1976) discussed the influence of nutrients, especially nitrogen, on weed/crop loss relationships in some detail. It becomes clear from this study but also from other reports that absolute yield losses due to weeds are usually but not always higher at high nutrient levels as compared to low supply.

As may be expected, different crop/weed combinations react differently on the nutrient level of the site. The losses of spring barley due to competition from *Avena fatua* were lower at low soil fertility than on soils with a high nutrient supply. This was different with an oat/*Sinapis arvensis* combination (fig. 3). This demonstrates that with changing fertility of the site the relative importance of weed species will change too and that the less competitive ones eventually will more or less disappear from this site. It becomes clear from this that results from a comparison of sites with a difference in productivity for a long time may differ from results obtained from experiments in which different levels of productivity have been obtained by fertilizing an originally poor soil. In the first instance, the weed flora has been adapted to the different levels of productivity, while it is adapted to low productivity only in the fertilizer experiment.

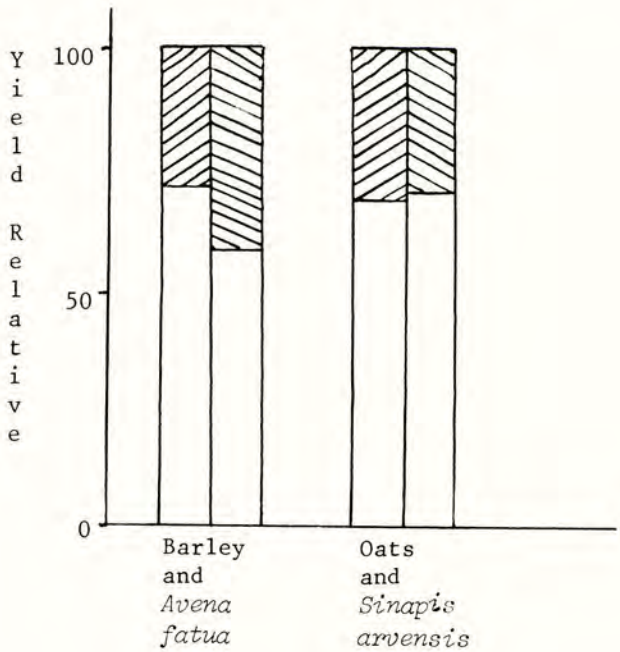


Fig. 3: Yield losses due to weeds at different levels (▨ low, ▧ high) of fertility (data from Koch, 1967).

Rauber (1977) found that a much higher density of *Avena fatua* was necessary to cause the same yield loss (in absolute terms) in spring barley at sites with a low yield potential as compared to sites with a high productivity. A yield reduction of 0.3 t/ha was caused by about 10, 30 and 300 plants/m^2 respectively having a yield of 6, 4 and 2 t/ha in weed-free.

It many cases, but obviously not always (some examples are given by Alkämper, 1976), higher yield increases are usually to be obtained by improving the productivity of a poor site than by weed control even though absolute losses usually increase with increasing fertility (fig. 4). After reaching a certain level of productivity this will be opposite and weed control will usually result in higher yield increases than further improvement of fertility.

It is difficult to decide whether there is a general rule that relative yield losses due to weeds remain the same over a wide range of fertility. The results presented in literature are somewhat conflicting (some details are given by Link, 1983). Experiments conducted by Link at sites of different yield potentials in Morocco indicate that relative losses of wheat are highest under conditions of low yield potentials (fig. 4). In other field experiments by the same author with different amounts of nitrogen applied, the results are somewhat inconsistent but there is a tendency that relative yield losses are increasing with different amounts of fertilizer given. There might be no general rule but the outcome might depend on the specific plant production system under consideration.

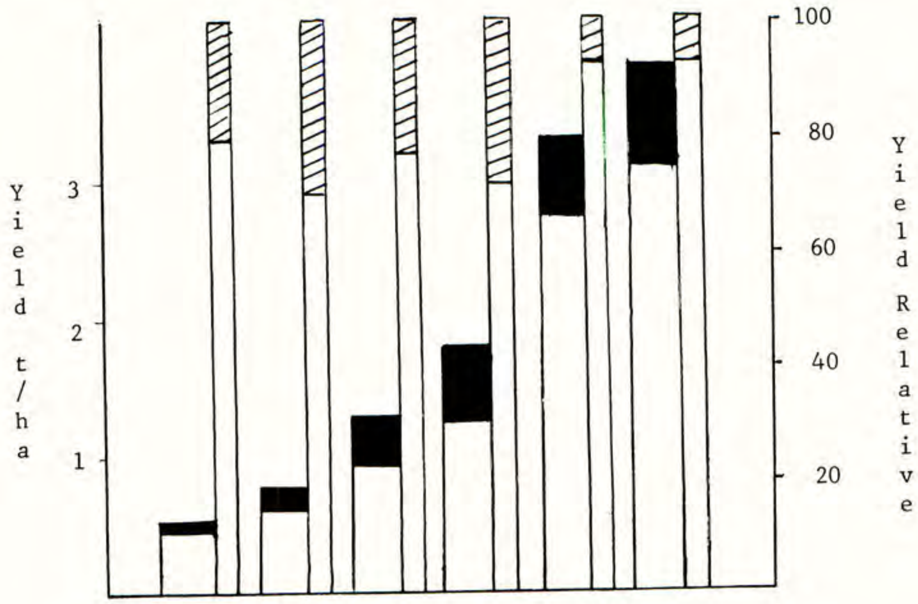


Fig. 4: Losses of grain yield of wheat (■ absolute ▨ relative) due to weeds at different levels of productivity of the site (one experiment at each site; data taken from Link, 1983).

REFERENCES

Alkämper, J. (1976) Einfluss der Verunkrautung auf die Wirkung der Düngung. Pflanzenschutz Nachrichten Bayer, 29, 191 - 235.

Alkämper, J. (1980) Überlegungen zur Entwicklung der Unkrautbekämpfung in tropischen Ländern. Giessener Beiträge zur Entwicklungsforschung, Reihe 1, 6, 59 - 68.

Ashby, D.G., Pfeiffer, R.K. (1956) Weeds A Limiting Factor in Tropical Agriculture. World Crops, 8, 227 - 229.

Attems, M. (1968) Permanent Cropping in the Usambara Mts in: H. Ruthenberg (ED): Smallholder Defarming and Smallholder Development in Tanzania. Afrika-Studien, 24, Weltforum Verlag, 137 - 174.

Chandler, J.M. (1980) Estimated Losses of Crops to Weeds. In: D. Pimentel (ED): CRC Handbook of Pest Management in Agriculture, 1, 95-109

Ennis, W.B. (1967) Economic Aspects of Crop Losses Caused by Weeds. In: Papers presented at the FAO Symposium on Crop Losses, FAO, Rome, 127-145.

Holm, Leroy G. (1978) Some Characteristics of Weed Problems in Two Worlds. 31st Meeting Western Society of Weed Science, Reno, 15 pp. (unpubl.).

Kemmer, A., Rauber, R., Roettele, M., Schuler, B. (1980). Bemerkungen zum Ackerfuchsschwanz. Ber. Fachgeb. Herbologie, Universität Hohenheim, Heft 20, 62 pp.

Koch, W. (1967) Untersuchungen zur Konkurrenzwirkung von Kulturapflanzen und Unkräutern aufeinander. 2: Schadwirkung von Samenunkräutern auf Getreide. Weed Research, 7, 22 - 28.

Koch, W., Beshir, M.E., Unterladstaetter, R. (1983) Crop Losses. FAO Plant Protection Bulletin (in print)

Link, R.J. (1983) Untersuchungen zu Vorkommen, Schadwirkung und Ökonomischer Bedeutung von Unkräutern im Getreide- und Zuckerrübenbau der Doukkala (Marokko). Dissertation Hohenheim.

Moody, K. (1975) Weeds and Shifting Cultivation. Pans,21, 188 - 194

Parker, C. (1973). Weeds in Arabia. Pans, 19, 345 - 352.

Parker, C., Fryer, J.D. (1975) Weed Control Problems Causing Major Reductions in World Food Supplies. FAO Plant Protection Bulletin, 23, 83 - 93

Philipp, O., Koch, W., Koeser, H. (1983) Utilization and Control of Water Hyacinth in Sudan. Schriftenreihe der GTZ, 122, 224 pp.

Rauber, R. (1977) Kurz- und langfristige Auswirkungen bei der Bekämpfung von Flughafer (*Avena fatua* L.) in Sommergerste. Z. Pflanzenkrankheiten und Pflanzenschutz, Sonderh. VIIIN, 107 - 117

Rauber, R., Kemmer, A., Koch, W. (1980) Untersuchungen zur Ermittlung einer Bekämpfungsschwelle für Ackerfuchsschwanz (*Alopecurus myosuroides* Huds.) in Winterweizen. Gesunde Pflanzen, 32(8), 177 - 181.

Vere, D.T., Auld, B.A.(1982) The Cost of Weeds. Protection Ecology, 4, 29 - 42

FIELD TRIALS TO ASSESS EFFECTS OF INSECT PESTS ON YIELD OF SPRING BARLEY

G.C. SCOTT

Rothamsted Experimental Station, Harpenden, Herts., AL5 2JQ., England

Background and objectives

In field trials to study the effect of barley yellow dwarf virus (BYDV) on spring barley (Jenkyn and Plumb, 1983) yields were increased by applying systemic insecticides to control the aphid vectors even in years when virus incidence was low. These increases were attributed to the prevention of direct damage by aphids and other insects. Further trials on spring barley in 1980-82, described in this report, investigated the effects of insect damage on several components of yield to obtain information on critical infestation levels.

Methods

Spring barley cv Georgie (1980) or Triumph (1981 and 82) was sown early (24 March 1980, 21 February 1981 or 15 March 1982) and late (28 April 1980, 14 April 1981 or 16 April 1982) in 0.01 ha plots in four randomised blocks. Insecticides were applied at commercially recommended rates as single sprays and repeated sprays (three applications). Aphids and thrips were counted on the plants (4 x 10 shoots/plot) in the field throughout the growing period. Plant samples were examined in the laboratory for stem borers. More samples were examined in the late sown plots where numbers of insects and severity of damage were greater than in early sown plots.

Results and conclusions

Fewer than 2% shoots were affected by BYDV in 1981 and 1982. In 1980, 12.6% shoots were affected in the untreated plots, but this appeared to have no effect on yield. Numbers of aphids (mainly *Metopolophium dirhodum* with a few *Sitobion avenae*) never exceeded 70/100 shoots. Numbers of thrips (*Limothrips spp.*) were also low, up to 70 adults/100 ears, but this may be an underestimate because larvae and adults concealed within plant tissues were not counted. All treatments with the systemic insecticides controlled aphids and thrips well. Damage by stem borers was observed from the third week in May when the late sown plots were at growth stage 23 (Zadoks scale) until full ear emergence. Early in the season, larvae of *Oscinella spp.* and the gout fly (*Chlorops pumilionis*) caused small shoots to turn yellow or to swell. In mid season when stems had begun to elongate, larvae of these two insects were found feeding at or near the developing flower spikes. This type of damage was not apparent on external examination. At ear emergence, larvae of the late generation of gout fly damaged developing grains and caused the characteristic groove in the stalk between the ear and the last node. Larvae of *Oscinella spp.* were generally small and difficult to find, particularly when dead, so it was not possible to measure direct effects of treatments on larvae. However, numbers of shoots damaged by stem borers were significantly decreased by the repeated treatments. Thus in 1982 at GS51 when 34% of untreated shoots were damaged, only 16% or 19% shoots were damaged in the plots receiving three applications of insecticide.

In the early sown plots, repeated treatments increased yield by 8% (control = 6.09t/ha) in 1980, 3% (control = 6.39t/ha) in 1981 and 10% (control = 7.04t/ha) in 1982. Greater increases (P = 0.001) were obtained in late-sown plots by the repeated treatments sprayed between GS's 23-70:- 25% (control = 3.77t/ha) in 1980; 17% (control = 5.90t/ha) in 1981 and 14% (control = 5.47t/ha) in 1982. The best responses to single sprays were those applied at GS60 or 70 giving yield increases of 14% in 1980, 12% in 1981 and 8% in 1982. The greater response to repeated treatments reflects the prolonged period over which stem borer larvae are causing damage. Within sowing dates, there were no significant differences in components of yield other than grain weight, except in 1982 when the treatment producing the largest grain yield also produced a higher 1,000 grain weight than the controls.

The results indicate that yield of spring barley is affected by a complex of pests particularly when sown mid April or later. Economic threshold levels have not been established for aphids or thrips in spring barley, but ADAS guidelines suggest that control measures are justified only when one third or more tillers are infested with aphids and more than two thrips/ear are present at booting. In the experiments reported here, these thresholds were not approached. There is even less information about stem borers in spring barley but because they affected between 12-34% shoots in these experiments, it is likely that much of the benefits of the treatments was due to the control of these pests. More work needs to be done on threshold levels and incidence of stem borers in other localities, but this study indicates that the role of stem borers in yield production of spring barley has been underestimated.

Reference

Jenkyn, J.F. and Plumb, R.T. (1983) Effects of fungicides and insecticides applied to spring barley sown on different dates in 1976-79. *Annals of Applied Biology* 102, 421-433.

1A—R2

EFFECT OF SOWING DATE AND SORGHUM CULTIVARS ON SHOOTFLY AND STEM BORERS

S.A. BA-ANGOOD, M.A. HUBAISHAN

Faculty of Agriculture, University of Aden, P.O. Box 6172 Aden P.D.R. Yemen.

Background and objectives

With the introduction of new high-yielding varieties and strains of grain sorghum to People's Democratic Republic of Yemen (PDR Yemen), new pest problems arose. The shootfly *Atherigona yorki* is now a well established pest of grain sorghum. Stem borers mainly *Chilo partellus* and *Sesamia cretica* are getting more important during the last three years. These insects attack sorghum crops within the first 3 weeks of sowing and are always found together The objective of this study was to test the newly introduced and recommended high-yielding varieties of grain sorghum for natural infestation of the shootfly and stem borers on different sowing dates to see their impact on yield compared with a local variety. The data obtained during these experiments can be used for developing insect management programmes for the control of sorghum pests in PDR Yemen.

Materials and Methods

Four trials were conducted. In 1980/81, two field trials were carried out. In the first, Dwarf White Milo (DWM) was planted on four different sowing dates 18 August, 13 September, 4 October and 9 November 1980 in a randomized complete block design with four replicates. The plot size was 12 x 8 m. Plants were left in each hole after thinning was done, 10 days after sowing. The quantity of seeds given to each plot was more or less the same at the rate of 18 kg/ha. The second field trial comprised of testing five recommended high-yielding varieties to see their response to natural infestation of the shootfly and stem borers. These varieties were:D55, DWM, 8454, D60 and B815. They were sown on 21 September 1980 in plots 7x4 m replicated four times in a randomized complete block design experiment.

In 1981/82 season, two trials were conducted testing five recommended high-yielding varieties and another local one, on different sowing dates. In the first spring-sown trial, the sowing dates were: 17 March, 8 April, 29 April and 24 May 1981. These sowing dates were arranged in a split plot experiment in a randomized complete block design with six replicates. Each main plot unit was devided into six subplot units. These comprised six different varieties of sorghum namely: D55, B815, DWM, W823, 8454 and the local variety "Baini". These varietal treatments were randomized to the subplot unit within each main plot unit. The layout of the second autumn sown experiment was similar to the previous one, except that five different sowing dates were used which were: 26 August, 16 September, 14 October, 27 October, and 17 November 1981. In both trials each subplot consisted of three rows each 6m long. Sampling in all trials was done three times started three weeks after sowing with an interval of 10 days between each.

Results and Conclusions

Sowing DWM on 13 September gave significantly high yield of grain sorghum in response to lower percentage of infestation of the shootfly and stem borers at that period, compared to sowing in October and November. DWM has been found to be more prone to infestation with shootfly and stem borers when compared with the local variety "Baini". However, DWM gave higher yield than the local variety. All tested varieties gave higher yields when sown in March, August and September than when sown in April, May, October or November. However, 26 August and 16 September sowing were the best sowing dates. B815, W823 and 8454 gave higher yields than the recently recommended high yielding variety DWM, in response to lower infestation with the shootfly and stem borers. B815 and 8454 gave higher yields when sown on 16 September. On the contrary, W823 gave higher yield when sown on 26 August.

Our results on the effect of sowing date on the percentage of infestation of the shootfly coincided with those obtained in India (Khan and Singh 1980). Many varieties were tested for resistance for either stem borers or shootfly. Some of them did well in one season but not in another growing season within the same country (Young 1981). In PDR Yemen, both insects attack the crop at the same stage of crop development. The crop grown was with only one irrigation usually by floods before sowing. The cost of chemical control is usually high and the role of indigenous natural enemies is not clearly evidenced. Accordingly, selecting a high yielding variety, grown in a suitable sowing date to escape the damage and attack of these insects should be recommended. This cultural method of control was practiced successfully in many parts of the world for the control of several cereal pests. (Ba-Angood and Stewart 1980).

References

Ba-Angood, S.A.; Stewart, R.K. (1980). Sowing date and cereal aphid infestations and damage to barley in Southwestern Quebec. Journal of Economic Entomology 73, 462 - 464.

ASSESSING PASTURE YIELD LOSSES CAUSED BY PORINA (HEPIALIDAE)

ALAN CARPENTER

Agricultural Research Division, New Zealand Ministry of Agriculture and Fisheries, P.O. Box 1654, Palmerston North, New Zealand. (Present address: School of Animal Biology, University College of North Wales, Bangor, Gwynedd LL57 2UW, United Kingdom.)

Background and objectives

Porina caterpillars (*Wiseana* spp.: Hepialidae) can cause extensive damage to pastures throughout New Zealand. This endemic pest lives in burrows in the ground, emerging to consume green herbage in direct competition with livestock. As costs of conventional chemical control measures have escalated, especially in hill country, it became necessary to assess the impact of the pest on pasture yield to provide a basis for estimating economic threshold densities. Existing estimates have been derived from glasshouse pot trials (Harris 1969), laboratory studies on the removal of excised herbage (French & Pearson 1981) and from pasture response to insecticide treatment (McLaren & Crump 1969). The research reported here was an attempt to artificially establish a range of pest densities in hill country pasture and to use regression analysis to relate insect numbers to pasture losses.

Methods

Porina eggs were collected from light traps at Coonoor (NZMS1 N150567256). The traps were cleared every 2-3 days from 25.11.80 to 10.1.81. The eggs were washed and counted in the laboratory and held at 4^{o}C until 15.1.81 on which date they were applied to plots at Coonoor of 3m x 3m at 4 densities: $1m^{-2}$, $10m^{-2}$, $100m^{-2}$ and $1000m^{-2}$. Each density was replicated 4 times and there were 4 control plots with no porina. Pasture yield was assessed by cutting 2 x 0.5 sq.m quadrats per plot to ground level. The rest of the plot was trimmed to 5 cm and 4 randomly selected areas were then cut to ground level to give a measure of the residue after trimming. Production was defined as the dry matter obtained by a cut to ground level at time 2 minus the residue at time 1. Pasture composition was measured by point analysis (100 points per plot) on 24.1.81 and again on 20.12.81. Porina density was assessed in August.

Results and conclusions

Establishment of caterpillars from sown eggs was poor. The highest density achieved was $28m^{-2}$. Pasture production over the period 19.3.81 to 30.9.81 was inversely related to porina density: Production (g dry matter m^{-2}) = 176.87 - 5.796 x porina density m^{-2} ($r = -.5258$). Extrapolation suggests that at a porina density of about 30 m^{-2} production would be nil. If just the winter period 30.6.81 to 30.9.81 is considered, the equation does not differ greatly from that given above but there is less variability in the data ($r = -.63787$, $P < 0.01$), because plant productivity was lowest over the winter period, and, as the porina caterpillars were approaching their maximum size, they were having their greatest impact on the pasture dynamics. Most of the porina in the trial pupated in October and production after that was not affected. Similarly no measurable loss of yield as a result of porina feeding was found before March when the caterpillars were still small.

The only pasture species found to be affected by porina was *Trifolium repens*. The decline in *T. repens* content of the plots, over the period of the experiment, was inversely correlated with porina density ($r = -.5322$, $P < 0.05$).

Calculation of average daily intake per caterpillar from this trial gave a figure of .0299 g dry matter m^{-2} day^{-1}. This contrasts with a figure of .0036 g d.m. m^{-2} day^{-1} from French & Pearson (1981) and is similar to the .0323 g d.m. m^{-2} day^{-1} from Harris (1969). The low value derived by French and Pearson (1981) is a function of the excised herbage technique they used. In the field porina will harvest more material than they utilise (Harris 1969, Carpenter unpub.).

Harris (1969) also showed that in a mixed sward porina preferred white clover, substantiating the results of the trial reported here.

In summary then, the seeding of eggs onto existing pasture has proven to be an effective means of assessing yield losses to porina. Further research is now needed to reduce the variability of the data and to reconcile estimates derived from laboratory studies with those derived from field studies.

References

French, R.A.; Pearson, J.F. (1981) Food intake and feeding behaviour of porina (*Wiseana* spp.: Lepidoptera:Hepialidae) larvae in the field. N.Z. J. expt. Agric., 9, 383-386.

Harris, W. (1969) Some effects of a porina caterpillar (*Wiseana* spp.) infestation on perennial ryegrass, cocksfoot and white clover. N.Z. J. Agric. Res., 12, 543-552.

McLaren, G.F.; Crump, D.K. (1969) An economic study of the use of insecticides for the control of porina caterpillar. Proc. 22nd N.Z. Weed & Pest Control Conf., 307-322.

1A—R4

AN OUTBREAK OF PROSTEPHANUS TRUNCATUS (HORN), THE LARGER GRAIN BORER, IN TANZANIA

P. GOLOB, R.J. HODGES

Storage Dept., Tropical Development and Research Institute, Slough, U.K.

Introduction

During 1980 farmers storing maize and cassava in the Tabora region of Tanzania recognised damage caused by an unfamiliar beetle. The insect was found to be *Prostephanus truncatus* (Horn), a bostrichid beetle, which has previously only been known as a pest of stored maize in Central America. Its presence has also been recorded from a few other locations, but never Africa. A widespread survey was undertaken in Tanzania to observe the distribution of the beetle and to quantify the damage.

Traditional Food Storage in Tabora

Maize is the major food staple of the predominantly rural population. Some 100,000t are produced annually, most of which is stored at the farm for home consumption.

Frequently Tabora is a major deficit region and to supplement the diet large quantities of cassava are grown. In the north-eastern district of Igunga, a much hotter, drier area, sorghum rather than maize is cultivated.

Maize is stored as cobs with the sheathing leaves intact either on vertical racks outside the house or on raised platforms inside the house, usually in the kitchen. Other commodities are stored in sacks, oil drums or wooden containers.

Most of the maize is harvested in April or May at the end of the single rainy season. There is very little fungal damage in the period immediately after harvest as the weather remains dry. Previously the main insect storage pests were *Sitophilus* species and *Sitotroga cerealella*. There are no well-founded estimates of loss of maize in storage in Tanzania.

The Survey

Fifty-six towns and villages from a total of 369 throughout Tabora were visited to give a representative sample throughout the region. In each village a sample of 36 cobs was collected from a farmer whose produce was known to be infested. In the laboratory the samples were examined for evidence of damage. Outside the Tabora region visits were made to local trading centres to examine maize sold in the markets.

The beetle was widely distributed in the Tabora region but was absent from the sorghum growing areas. In many cases infestation was very serious. After 3-6 months storage some farmers had suffered weight losses of above 30% which represents damage to at least 70% of the grain. Damage of this magnitude renders the grain valueless either as seed or food. The mean estimated weight loss was 8.7%. There was a large variation in the amount of damage between farms, the reason for which was not apparent.

Apart from maize, only cassava was consistently infested. Some damage to groundnuts was noted but no damage to paddy or sorghum was seen. Wooden storage structures, clothing and cooking utensils showed signs of boring.

P. truncatus was found in markets of trading centres in regions to the north of Tabora. Of special note was its presence in Mwanza on Lake Victoria, the port from which produce is exported to neighbouring countries.

Conclusions

The conditions under which this beetle may develop are such that it would be capable of spreading throughout most of East, Central and South Africa. Normally, on-farm storage weight loss in this area is less than 5% over a 10-12 month period. Clearly, the potential for this beetle to become a very serious pest of stored maize in the region is very great.

References

Shires, S.W. (1979) The influence of temperature and humidity on survival and development in *Prostephanus truncatus*. Journal of Stored Products Research, 15, 5-10.

De Lima, C.P.F. (1979) Appropriate techniques for use in the assessment of country loss in stored produce in the tropics. Tropical Stored Products Information, 38, 21-26.

IMPORTANCE OF CASSAVA, COWPEA AND MAIZE PESTS IN TOGO, WEST AFRICA

G. WALTER-ECHOLS, D. AGOUNKE, Y. AKPALOO

Direction de la Protection des Végétaux, B.P. 1263, Lomé, Togo

Cassava

The major damage is caused by two recently introduced dry-season pests. The cassava mealybug *Phenacoccus manihoti* first appeared in the eastern coastal region in 1979, and since then has dispersed westward into Ghana and 200 km to the north. In 1982 the mealybug was accidentally introduced to at least two locations about 350 km inland. In the humid south it appears that the importance of the mealybug has diminished due to heavy predation by the coccinellids *Chilocorus nigritus* and *Hyperaspis sp.*. It remains to be seen whether these predators will have a comparable effect on the mealybugs in the more arid north. The other introduced pest, the green spider mite *Mononychellus tanajoa*, was first observed in the coastal region in 1980 and had spread over most of the cassava producing area by the end of 1981. Yield reductions caused by both pests are difficult to assess. Official cassava production figures have not yet shown a decline, but the price of the tubers has doubled, indicating scarcity of the crop. Plant mortalities have not been observed, and yield reductions are estimated at 20 - 30%.

Cowpeas

Generally, 70 - 80% of the cowpea yields are destroyed by insect pests. Maximum seed losses of up to 100% have been observed from *Megalurothrips sjostedti*, 18% from *Maruca testulalis*, 10% from *Cydia ptychora*, 5% from *Piezotrachelus varius*, 2% from *Melanagromyza vignalis* and 30% from the pod-sucking bugs *Clavigralla tomentosicollis*, *Riptortus dentipes*, *Anoplocnemis curvipes* and *Nezara viridula*. Occasionally, *Ootheca mutabilis* causes substantial mortalities to young plants. Post-harvest losses, mostly due to *Callosobruchus maculatus*, are 40 - 60% by weight or 100% by quality after three months of storage. Presently, chemical control is the only means of reducing these losses.

Maize

This cereal is the staple food crop in the south where it is grown in the savannah and the western forest areas. The African army worm *Spodoptera exempta* occasionally causes total defoliation and loss, but the attacks are limited to small areas and change from year to year. Stemborers are an annual problem in the forest zones where infestations as high as 70% are possible, especially in the second wet season. The principal pests are *Sesamia spp.* and, to a lesser degree, *Eldana saccharina* and *Busseola fusca*. In the savannah zone the attacks vary greatly. During extensive surveys in 1982 less than 1% of the stems were infested, but there have been reports of substantial losses in other years. In order to reduce these losses the factors leading to high-risk years need to be identified.

1A—R6

THE EFFECT OF INSECT AND PLANT POPULATIONS ON THE YIELD OF COMMON BEANS

A. K. KAREL, R. M. K. MGHOGHO

Department of Crop Science, University of Dar es Salaam, Sub-Post Office, P.O. Box 3005, Morogoro, Tanzania

Background and objectives

Common beans, *Phaseolus vulgaris* L., is grown at various spacings and plant populations in Tanzania. However, it is not clear as to what plant population of bean should be recommended for optimum yield. This warrants investigations to determine yield response of common beans to various plant populations. Further, very little is known on insect pest population with various plant populations and their effect on the yield of beans. An experiment was, therefore, conducted to study the effect of plant populations, with and without insecticide application, on the insect pests and yield of beans.

Materials and methods

The experiment was conducted at Morogoro (Lat. 5'8^{o}, altitude 525m, oxisol fen soil) with Selian Wonder variety of bean (similar to Canadian Wonder) in a split plot design with sprayed and unsprayed plots as main treatment. Four applications of an insecticide were applied at 10, 30, 45 and 55 days after planting (DAP) at the rate of 600 g a.i./400 l water/ ha to control insect pests in sprayed plots. The subplots were four plant populations (P_1 = 100,000 plants/ha, P_2 = 200,000 plants/ha, P_3 = 300,000 plants/ha and P_4 = 400,000 plants/ha). Each subplot was 7 rows, 5m long. The distance between the rows was 50 cm. The spacing within the rows was 20, 10, 6.6 and 5cm for populations 1, 2, 3 and 4 respectively. 50 kg/ha P_2O_5 and 50 kg/ha N were applied after necessary land preparation. Two weedings were done by hand at 4 and 28 DAP.

Results and conclusions

Foliar beetle, *Ootheca bennigseni* was recorded as the most important preflowering pest of beans with high incidences on unsprayed plots. P_3 had the highest pest infestations followed by P_1, P_4 and P_2. The infestation of *Ootheca* resulted in foliar damage, which increased from 14 to 28 DAP and then decreased at 35 DAP in unsprayed plots. The infestation of flower thrips (*Taeniothrips sjostedti*) was high at population 2 followed by P_3, P_1 and P_4 at 30 DAP. However, at 40 DAP, P_3 had the highest thrip infestation. The unsprayed plots had more flower damage caused by pod borers, *Maruca testulalis* and *Heliothis armigera*, which increased from 28 to 40 DAP; the damage was high at P_1 followed by P_4, P_3 and P_2. The pod borers also caused a high level of damage to pods and seeds up to 50 DAP in all unsprayed plots with highest damage at P_4 followed by P_1, P_3 and P_2. The insecticide application effectively controlled the insect pests in sprayed plots.

The seed yield was significantly higher in the sprayed compared to unsprayed plots. Seed yield was low at P_1; it increased with P_2 and then decreased with P_3 and P_4. Sprayed plots recorded highest seed yield of 1275 kg/ha in P_2.

The decrease in yield of beans beyond population 2 (200,000 plants/ha) due to increased intraspecific competition between the bean plants at high plant populations (P_3 and P_4) on account of scarcity of nutrients, moisture, light etc. are discussed. The high yield at P_2 is also attributed to low insect pest damage at this plant population density compared to high insect pest damage at population 3 and 4. A positive correlation between seed yield and pods per plant ($r = 0.66$), seed size ($r = 0.25$) and seeds per pod ($r = 0.73$) was found indicating that an increase in these yield components also increases the seed yield. Moreover, a negative correlation coefficient was found between the seed yield and flower damage ($r = -0.843$) and pod damage ($r = -0.804$), indicating that the higher the flower and pod damage by pod borers, the lower will be the seed yield.

Acknowledgement

The study was supported by US-AID Title XII Bean/Cowpea CRSP between Washington State University and the University of Dar es Salaam.

FEEDING BEHAVIOUR OF POD BUGS: IMPLICATIONS FOR HOST PLANT RESISTANCE STUDIES.

L.E.N. JACKAI, Entomologist

International Institute of Tropical Agriculture, PMB 5320, Oyo Road, Ibadan

Background and objectives

Damage to cowpea by pod sucking bugs (PSB) is caused through the feeding activity of the insect on green pods. Pods shrivel and sometimes drop off, seeds abort or are damaged. Damaged seeds are discolored by fungal infection transmitted during feeding, and usually do not germinate.

The level of PSB damage to cowpea can be as high as 80 percent in the savanna belt of West Africa. Control of these bugs is presently only possible with insecticides. Unfortunately, high costs and unreliable supplies are two most important factors that have made use of insecticides by cowpea growers an uncommon practice. Research on alternative methods of control have intensified during the past few years, particularly the identification and development of resistant cowpea cultivars.

The pod sucking bug complex on cowpea comprises mainly of coreids, alydids and pentatomides, in that order of importance. Research on host plant resistance has therefore concentrated on the Coreids, specifically Clavigralla tomentosicollis the most devastating of them all. Despite the years of research no source of resistance has yet been identified. The lack of significant progress in this area has been mainly due to the lack of reliable resistance screening methodology. This paper focuses on the behavioral factors related to feeding that may influence the development of appropriate screening tests.

Past workers have utilized (feeding) punctures on the pod-wall as a measure of resistance (IITA, 1981). This involves opening the pods, scraping off the indumentum and then counting the punctures under magnification. In these tests no differentiation was made between males and females as a given number of unsexed insects were released in the cage. This method assumes (a) that once a puncture is made, the insect is feeding; (b) a puncture necessarily damages the seed; (c) that no difference exists between feeding by male and female. If the first assumption is true there should be a positive and significant correlation between number of punctures and weight gain by the insect. If the second assumption is true we would expect a positive correlation between number of punctures and seed damage. If the last assumption is true there should be no difference in seed damage and weight between males and females. It is important to note that damage to the seed, not simply the presence of punctures on the pod wall is of greater importance. Studies were carried out in 1982 to test the above assumptions.

Materials and methods

Newly emerged adults of C. tomentosicollis were held in mesh cages (30 x 30 cm), males separate from females. There were 4 replications of each sex with 5 insects and 5 cowpea pods per cage. Each day the weight of each individual insect was taken, the punctures on the pod walls counted and the percent seed damage/pod assessed. Fresh pods were provided daily for 30 days after which the experiment was terminated. The results were subjected to analysis of variance and regression tests.

Results and conclusions

It appears that sexual dimorphism exists in C. tomentosicollis with respect to weight and feeding behavior. Females weighed an average of 55.6 mg whereas males weighed about 38 mg. Seed damage and number of punctures for females were 20.4% and 3.3%, respectively each day; for males the values were 17.4% and 2.5%, respectively. These values (♂s vs ♀s) were significantly different ($p < 0.05$). These results suggest that the sexes must be separated, or equal ratios of both sexes have to be used for each test cultivar, if erroneous and misleading interpretation of results is to be avoided.

Data on correlation showed that seed damage and puncture counts were highly correlated ($r = 0.88$ for males and 0.76 for females). This means that either seed damage or puncture counts can be used but seed damage is to be preferred as it is much faster and more precise and definitive with respect to damage.

Correlation between punctures and weight ($r = 0.19$ and 0.31 for male and female respectively) and seed damage and weight ($r = 0.25$ and 0.16 for males and females respectively) was generally poor. Presence of punctures does not therefore necessarily suggest feeding activity.

In designing a bioassay for evaluating cowpea resistance to PSB one must (1) use either one sex or both in the same ratio; (2) use seed damage estimates rather than puncture counts; (3) remember that the presence of punctures is not necessarily an indication of feeding by the insect.

Reference

IITA, 1981. Annual Report for 1980. International Institute of Tropical Agriculture, Ibadan, Nigeria. 185p.

1A—R8

THRESHOLDS FOR PEA APHID AND POTATO LEAFHOPPER ON ALFALFA

GERRIT W. CUPERUS, EDWARD B. RADCLIFFE

Department of Entomology, University of Minnesota, St. Paul, MN 55108

Background and objectives

Pea aphid, *Acyrthosiphon pisum*, and potato leafhopper, *Empoasca fabae*, are major pests of alfalfa, *Medicago sativa*, in North America, reducing dry matter yields and forage quality. Reliable economic thresholds are needed for alfalfa pest management decisions. Because alfalfa is grown primarily as animal feed, thresholds should incorporate measurements of percent crude protein, total digestible nutrients, and dry matter yields. With this information forage value can be computed from costs of a substitute ration, e.g., corn and soybean meal.

Materials and methods

Large scale field trials were conducted in south central Minnesota on the 2nd and 3rd cuttings (regrowth) of established (2nd or 3rd year) alfalfa. Population gradients of pea aphid were established on '520' and 'Vernal' alfalfa by use of several insecticides and varying rates of application. Population gradients of potato leafhopper were established on 'Vernal' alfalfa by use of several insecticides, varying rates of application, and cultural (cutting) management of alfalfa bordering the plots. Thresholds were calculated using regression analysis. Critical times of infestation were determined by varying the timing of effective control measures.

Results and conclusions

For pea aphid, calculated economic injury levels were 3948 aphid-days/pendulum sweep (38 cm dia. sweep net), 3850 aphid-days/vacuum sample (0.48 m^2), or 114 aphid-days/stem. Economic thresholds, 2 weeks before harvest (determined to be the critical time for application of control) were 70 aphids/sweep, 58 aphids/vacuum sample, or 1.2 aphids/stem. Stem sampling was the most precise and time-efficient sampling method. For potato leafhopper, calculated economic injury levels were 37.3 leafhoppers/25 180° sweeps, or 30.3 leafhoppers/vacuum sample. Economic thresholds ranged from 0.32-0.50 leafhoppers/pendulum sweep on alfalfa stubble (the critical time for control) at 5-17 cm regrowth. Vacuum sampling was more precise, but sweep net sampling was more time efficient for sampling adult leafhoppers.

References

Cuperus, G.W., E.B. Radcliffe, D.K. Barnes, and G.C. Marten. 1982. Economic thresholds for pea aphid, *Acyrthosiphon pisum* (Harris), on alfalfa. Crop Protection 1: 453-463.

Cuperus, G.W., E.B. Radcliffe, D.K. Barnes, and G.C. Marten. 1983. Economic injury levels and economic thresholds for potato leafhopper on alfalfa in Minnesota. J. Economic Entomology 76: (in press)

EFFECT OF COTTON STAINERS (DYSDERCUS SPP.) ON URENA LOBATA SEED QUALITY

P.J.C.HARRIS

Department of Biological Sciences, Coventry Polytechnic, Coventry, U.K.

Background and objectives

Urena lobata has been cultivated as a jute-substitute fibre crop in several tropical countries including Sierra Leone where experimental plantings have been made over a number of years. A high yielding cultivar, Ex-Mokwa, has been introduced into Sierra Leone but premature fruit senescence and abscission, and a seed viability often below 50% combine to reduce viable seed yield. Furthermore, many seeds produce abnormal seedlings with curved hypocotyls, adventitious root growth replacing the apparently necrotic radicle, and delayed cotyledon expansion. Two earlier studies (Harris, 1981; 1983) implicated the feeding activity of cotton stainers (Dysdercus superstitiosus and D.voelkeri) as responsible for seed damage and viability loss. This report provides further illustration of, and evidence for, the effects of cotton stainers on U.lobata seed quality.

Materials and Methods

All experiments were carried out at Njala in the Southern Province of Sierra Leone. Urena lobata cv Ex-Mokwa was sown in May at the start of the rainy season and produced seed between October and December. Observations of insect pests were made from 1979 to 1982 in crops to which no pest control treatments had been applied. Viability of immature embryos was determined after soaking the seeds in a 0.5 mg/cm^3 solution of 1,3,5-triphenyl tetrazolium chloride for 24h in darkness. Viable embryos stained pink or red. Direct counts of flowers and ripe fruit were made within the same crop. Cage experiments were carried out in the field in 1981 and 1982 by surrounding branches bearing three-day-old fruit with 4.5 cm diameter perforated plastic tubes secured to the branch and sealed at both ends. Adult insects were introduced into the tubes and fruit examined for damage after various intervals. The relationship between fruit age, viability and insect attack was established in 1979 by monitoring a large number of fruit labelled individually at the flower bud stage with 2.5cm^2 polyethylene labels loosely attached to the peduncle with cotton thread.

Results and conclusions

The percentage viability of U.lobata embryos declined rapidly between 8 and 24 days after flowering. Little further change in viability was detected during subsequent seed development, between maturity and harvest or during typical storage periods. Amongst the possible causes of this viability loss were the cotton stainers (D.superstitiosus and D.voelkeri) well known as pest of other cultivated Malvaceae. Adult stainers migrated to the crop soon after the start of flowering and remained throughout the period of seed production. The insects bred within the crop, achieving high population densities before seed maturity. Severe infestation with stainers coincided with low seed viability. Adult and immature stainers were observed feeding on developing fruit.

When removed from their carpels immature seeds from crops with substantial stainer populations frequently exhibited marks or holes on the testa often surrounded by necrotic or water-soaked areas clearly visible to the naked eye. Examination of seed samples over a two-year period established a significant correlation between the incidence of such symptoms and loss of embryo viability. Additionally, many seeds with these symptoms contained embryos with abnormal or necrotic radicles but normal cotyledons. These abnormalities, which were not consistent with those observed in germinating seedlings, did not occur in seeds without testa damage. Strong circumstantial evidence therefore linked the feeding activity of cotton stainers with the observed non-viability and abnormality of seeds. This link was further suggested by the direct observations that stainers did not feed on buds, open flowers or very young fruit, feeding preferentially on older immature fruit of the age at which viability was most frequently lost. During the three years of this investigation cotton stainers were present in all U.lobata seed crops. Although other species of Hemiptera were recorded feeding on U.lobata these were of isolated occurrence and in small numbers.

Caging experiments in the field confirmed that adults of both D.superstitiosus and D.voelkeri caused the characteristic testa damage and that some seeds so damaged contained abnormal or non-viable embryos. Seeds enclosed in cages soon after fertilization and maintained insect-free did not exhibit damage or lose viability. Cotton stainers were thus confirmed as important pests of U.lobata causing a reduction of seed yield and quality.

References

Harris,P.J.C.(1981) Seed viability, dormancy and field emergence of Urena lobata L. in Sierra Leone. Tropical Agriculture (Trinidad) 58, 205-213

Harris,P.J.C.(1983) Dysdercus spp. as pests of Urena lobata in Sierra Leone. Tropical Pest Management 29, 1-6

1A—R10

EFFECT OF EUROPEAN RED MITE (<u>Panonychus ulmi</u>) ON QUALITY AND YIELD OF APPLES

R.T. BAKER

Plant Health Diagnostic Station, Ministry of Agriculture & Fisheries,
Mt. Albert Research Centre, Private Bag, Auckland, New Zealand

Introduction

European red mite is one of the major pests of pip fruit in New Zealand. Although the need to control it is well recognized the quantitative impact of this mite on fruit in New Zealand has not been documented. The experiments described in this report provide evidence on loss of yield and quality of apples which can be ascribed to the presence of European red mite.

Field Trials

A trial on 90 Red Delicious trees compared the effects of three different mite populations on fruit yield and size. Initially mite numbers were manipulated by the use of sprays and predators to provide (a) unlimited populations throughout the season; (b) unlimited populations until February, then all mites eliminated; (c) no mites. During the 2nd and 3rd seasons no mites were allowed in any treatment.

A second trial, on 160 Sturmer trees, compared five different mite regimes. The mite populations were manipulated during the first season to provide peak populations at different times e.g. (a) high populations (exceeding 20 per leaf from November to February, with a peak in January); (b) as in (a) but with a peak in December; (c) high populations only during January; (d) high populations only during March; (e) very low populations throughout. During the second season no mites were allowed on any treatment.

Results

On Red Delicious the highest mite populations (which exceeded 50/leaf for 6 weeks and 20/leaf for 10 weeks) led to premature leaf fall, very small fruit and significantly reduced yields. Compared with the no mite regime yields were depressed by 27% during the 1st season and 51% during the 2nd season, with no significant difference after 3 seasons. Fruit size was reduced by 48% during the first season but was not affected in subsequent seasons.

On Sturmer high mite populations during December and January led to low yields, small fruit and premature leaf and fruit fall. High populations in March alone had no effect on yield or quality. Any yield effects carried through to the second season. It was calculated that a 50% yield reduction could be expected if 80% of leaves had more than 8 mites/leaf, or 18% of leaves had more than 64 mites/leaf, during the critical period (late November-late January). Size was reduced by 33% and there was 41% premature fruit fall on trees which sustained mite populations of 20/leaf during December and January. This was only a one season effect however whereas yield was depressed by 57% in the first season and by 46% in the second season.

DAMAGE TO APPLE FRUITS BY APPLE RUST MITE, ACULUS SCHLECHTENDALI

M.A. EASTERBROOK and M.G. SOLOMON

East Malling Research Station, Maidstone, Kent ME19 6BJ, U.K.

Background and objectives

The eriophyoid *Aculus schlechtendali*, the apple rust mite, has become more numerous in English apple orchards in recent years. This is probably due mainly to changes in spray programmes, involving increased use of non-acaricidal fungicides and of insecticides that are toxic to the predators of the mite. More luxuriant tree growth probably also makes some contribution. It has been known for some time that high rust mite populations will cause leaf damage in the form of browning of the undersides but recently rust mites have also been implicated in cases of russet on the fruit. With increasingly rigorous quality standards for apples, russet can result in downgrading of the fruit. Field experiments were carried out to investigate whether the mites fed on the young fruits and whether this led to russet.

Materials and methods

Contrasting mite populations were established by applying an acaricide pre-blossom to individual blossom clusters or to whole trees, whilst leaving other clusters or trees untreated. Samples of young fruitlets were taken and the mites removed and counted. Other fruitlets were sectioned and examined for cell damage. Fruit from treated and untreated clusters or trees was examined for russet at harvest.

Results and conclusions

Mites were found to feed on the flower receptacles and then the young fruitlets from full bloom until early July. Histological sections through mite-infested fruitlets showed damaged epidermal cells, probably caused by mite feeding; this damage could lead to later russet formation.

Good correlations were obtained between estimates of mite numbers per blossom on trees at full bloom and the amount of russet on the calyx-end and cheek of fruit at harvest, though not with stalk-end russet. Similarly, fruit from clusters on which mite numbers had been greatly reduced by an acaricide had much less calyx-end and cheek russet than fruit from clusters with large mite populations.

It seems, therefore, that the feeding of large numbers of apple rust mite in the spring can lead to russet on the fruit which in some cases can result in downgrading. Chemical treatment to reduce mite numbers should be applied pre-blossom for maximum effect.

References

Anon. (1979) Bramley crop cracked by rust mite. *Grower* 92(20), 20.

Easterbrook, M.A. The biology and control of the rust mites *Aculus schlechtendali* and *Epitrimerus piri* on apple and pear in England. *Proceedings of the VIth International Congress of Acarology, 1982*. (In press)

1A—R12

SUSCEPTIBILITY OF DATE PALM VARIETIES TO THE INFESTATION OF LESSER DATE MOTH

E.M.T. AL-HAFIDH

Department of Agricultural Biology, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, UK

Background and objectives

The lesser date moth *Batrachedra amydraula* Meyr. (lepidoptera, Cosmopterygidae) is an important pest on date palm in Iraq, the most infested zone of date palms in Basrah (South Region).

The lesser date moth was originally described in 1916 by Meyrick from Bengal.

The present work was carried out in Basrah provinces to get more detail of the lesser date moth's life history, its economic importance and susceptibility of six date palm varieties to the infestation of this pest.

Material and methods

Two bunches were chosen as a random sample from five trees of date palm, and transferred to the laboratory for testing. Each sample contains four stalks. The investigation was carried out from April to July, which represents the optimum activity of the lesser date moth.

Six commercial varieties of date palms (Sayer, Khidrawi, Hillawi, Zahdi, Barhy and Bram) at Hababok, Chimri and Khalal stage of date fruits (the developing stages of date fruits) were subjected to study for the infestation of *Batrachedra amydraula* larvae at first, second and third generation. From the same replicates, the fallen fruits were also collected every ten days to determine the infestation during the same generations.

Results and conclusions

Data indicated that lesser date moth has three generations in Basrah during April, May, June and July. The average infestations were 11.3, 8 and 2.1% during the first, second and third generations respectively.

There are different infestations on the varieties of date palm in Basrah. A light infestation is 12.6% in Sayer variety, while Hillawi and Zehdi varieties have a heavy infestation, 43.6% and 42.6% in the fallen fruits, respectively. The results of infestation on these three varieties are almost the same. Others think that the infestations on the bunches are light at the level 1 - 5%, moderate 5 - 10% and heavy at more than 10%.

Thus, it is obvious that the greater increase of infestation in these varieties may be due to the different percentage of protein, carbohydrate and other elements, which are necessary for the developmental process of this insect.

Bram variety has the highest number of larvae during the first generation - 23 larvae, while Sayer variety has the lowest level - 7 larvae. In the second generation, Berhi variety has the highest number of larvae. There are few larvae on the fruits of the six varieties during the third generation.

All these results indicated that the variety is a very important factor in the infestation and possibly in the development stage of the larvae.

COLLECTION OF DATA ON CROP LOSSES DUE TO PESTS

P.T. WALKER

Tropical Development and Research Institute, Porton Down, Salisbury, Wiltshire SP4 OJQ

Importance

Crop loss data are important in deciding research priorities, in the economic assessment of different control strategies and in forecasting food or cash crop production.

Classification and type of loss

Losses can be divided into pre- and post-harvest, classified according to cause: insects-mites, mammals, birds, nematodes, diseases, weeds; cross-classified by crop and country.

Losses are recorded as absolute data, e.g. tonnes, or as rate of loss, e.g. kg/ha or percent loss. Actual losses in the absence of control measures may be quoted, or potential losses, in the presence of controls, or even as a potential loss when the crop cannot be grown.

Methods of assessment

Data are generated by surveys of yield lost or by surveys of pest incidence or intensity, using known pest-yield relationships. The disadvantages of some methods of assessment are given, with examples.

Sources of data

Reviewed by Van der Graaff (1981), other sources are published or unpublished reports of research stations, of regional government agricultural offices and of commercial organisations.

Difficulties encountered

Often unresolved complication or error may result from data on mixed cultures in one crop, multiple crops in one year, perennials, crop varieties of different susceptibility to pests, the presence of more than one pest or disease and the interaction of losses due to different causes, coupled with the distribution of pests and losses. Compensation by crops for pest attack may occur.

Data output

Examples are given for different countries, pests and crops. Losses may be expressed in monetary value terms, which have the disadvantages of variable values and exchange rates, or as loss equivalent (Ordish) area, or in terms of energy or labour equivalents.

Future indications

Refinement of data by experiment and qualification according to its source and with added information on the difficulties above will increase reliability.

References

Bardner, R; Fletcher, K.E. (1974) Insect infestations and their effects on growth and yield of field crops: a review. Bulletin of Entomological Research 64, 141-160.

Van der Graaff, N.A. (1981) Increasing the reliability of crop loss information: the use of indirect data. In: Crop Loss Assessment Methods: Supplement 3. L. Chiarappa (Ed.), FAO and CAB, Slough, pp. 65-69.

Walker, P.T. (1983) Crop losses: the need to quantify the effects of pests, diseases and weeds on agricultural production. Agriculture, Ecosystems and Environment 9, 119-158.

1A–R14

INCIDENCE AND EFFECTS OF NEMATODES ON WHITE CLOVER

R. COOK, R.A. PLOWRIGHT

Welsh Plant Breeding Station, Plas Gogerddan, Aberystwyth, UK

Background and objectives

Stem nematode (*Ditylenchus dipsaci*) damages plots of white clover at Aberystwyth. The clover cyst-nematode (*Heterodera trifolii*) has also been associated with the disappearance of sown white clover from grass swards. There is no reliable information on the incidence of *D. dipsaci* in Britain. *H. trifolii* is known to be widely distributed but there has been no study of its population dynamics in relation to clover growth. The present work was undertaken to provide some information on the distribution and effects of these nematodes on the establishment, yield and persistence of white clover in grass mixture.

Methods

Soil samples from 67 Welsh grassland sites were examined for cysts of *H. trifolii*. Further soil samples were collected from white clover/perennial ryegrass plots, on NIAB trial sites and the GRI/ADAS experiment GM23, in England and Wales. The soil samples were examined for cysts of *H. trifolii*. Infestation by *D. dipsaci* was assessed *in situ*. Yields from GM23 plots receiving no nitrogen fertilizer were used to assess clover persistence.

Field experiments were made at WPBS using nematicide on nematode infested sites. The first trial used a GM23 site infested by *H. trifolii* from which white clover had disappeared. Seedlings of white clover were transplanted into the plots, and half plots treated throughout the growing season with nematicide. At the second site a *D. dipsaci* damaged sward was ploughed and nematicide applied to half the plots. Four white clover cultivars were sown in mixture with S.23 perennial ryegrass. Further topical applications of nematicide were made throughout the first full year.

A pot experiment with sterilized loam inoculated with a series of *H. trifolii* densities and sown with two white clovers studied the effect of this nematode on early growth.

Results and conclusions

H. trifolii occurred in 75% of samples from Welsh grassland, incidence increasing with age of the pasture. At NIAB sites 3 of 7 with white clover trials were infested with *H. trifolii* and mean densities of up to 40 eggs g^{-1} soil were recorded. At one site density of *H. trifolii* increased with age of the trial but at another site nematode densities were lower in 3 year old than 2 year old plots. At the third site very low densities of nematode were present on all trials. At the latter two sites a nematode infecting fungus was observed. Five of the sites were visited and one found to be infested with *D. dipsaci*. Four of the 12 GM23 trial sites sampled were infested with both *H. trifolii* and *D. dipsaci*, one with *H. trifolii* alone and one with *D. dipsaci*. Mean *H. trifolii* densities of up to 20 eggs g^{-1} were found. Third year yields showed marked declines, associated with poor clover growth, on sites infested by both nematodes.

In the field trial, establishment of transplants was not affected by nematicide, nor was it related to initial cyst-nematode density. However, mean yield per established plant over 3 cuts was 1.5 times greater on treated than on untreated plots. On untreated plots yield per plant was significantly negatively correlated with initial *H. trifolii* density. In the second trial, regular application of the nematicide controlled both *D.dipsaci* and *H.trifolii* throughout the two harvest years. Yield differences between treated and untreated plots were very marked in the establishment year and in early cuts during the second year. The differences were greater for the two more susceptible cultivars. In the first cut of the second year, treated plots of these yielded six times more than the untreated controls, compared with a three-fold increase for the less susceptible cultivars. At cut 2 increases were 3.8 and 2.4 times respectively, and at cut 3 yields of all cultivars were increased 1.8 times by treatment. In untreated plots *D.dipsaci* damage was obvious, with more than half the area affected in some plots.

In pots yields of two white clover cultivars 8 weeks after sowing were significantly reduced by *H. trifolii* inocula of 20 eggs g^{-1} soil.

These observations and results indicate that two nematodes apparently widespread in grassland areas of England and Wales, can reduce establishment and persistence of white clover. They have a direct effect but also, through reducing clover vigour, render plants less able to survive competition from companion grasses and more susceptible to the effects of other adverse factors. Their occurrence in mixed infestations complicated assessment of their individual effects in the field. The nematicide used has a wide spectrum of activity, so that although no other pests were prominent, the trial responses may not be conclusively attributed to either nematode. However, the results justify selection for resistance, as part of the continuing assessment of the effects of *D. dipsaci* and *H. trifolii* on white clover decline and unpredictability.

LOSS OF YIELD AND QUALITY IN POTATOES DUE TO POTATO CYST-NEMATODES

A.G. WHITEHEAD

Rothamsted Experimental Station, Harpenden, U.K.

Potato cyst-nematodes, Globodera rostochiensis and G. pallida, can seriously reduce the yield and quality of potato tubers. Yield losses depend on (i) numbers of nematodes in the soil at planting (Seinhorst, 1965), (ii) cultivar grown (Whitehead, Tite, Fraser & French, 1980a), (iii) soil moisture stress (Whitehead, Tite, Fraser & French, 1980b), (iv) virulence of the nematode population (Mugniery, pers. comm.) and (v) interacting organisms e.g. Verticillium dahliae (Corbett & Hide, 1971).

In field experiments, mostly on peaty soils with Majestic or King Edward potatoes, tuber yields were related to numbers of nematodes in the soil at planting by negative linear regressions and yield losses varied from 0.4 to 4.0 t ha^{-1} per 20 eggs g^{-1} soil (Brown, 1969). Yield losses may be greater than this. For example, in a sandy loam infested with G. rostochiensis yield loss in Désirée potatoes was 8.2 t ha^{-1} per 20 eggs g^{-1} soil. Nematode damage to the tubers, affecting tuber quality, was proportional to nematode numbers.

Loss of yield and quality in potatoes can be prevented by thorough incorporation of an effective granular nematicide in the seed bed. In soils infested with G. rostochiensis, yield response to the nematicide varied with the cultivar grown, being least in Cara and Maris Piper and greatest in Croft, Pentland Dell, Désirée and Record. In soils infested with G. pallida, Cara and Maris Piper responded as much to the nematicide as did other cultivars.

References

Brown, E.B. (1969) Assessment of the damage caused to potatoes by potato cyst eelworm, Heterodera rostochiensis Woll. Annals of Applied Biology 63, 493-502.

Corbett, D.C.M. & Hide, G.A. (1971) Interactions between Heterodera rostochiensis Woll. and Verticillium dahliae Kleb. on potatoes and the effect of CCC on both. Annals of Applied Biology 68, 71-80.

Seinhorst, J.W. (1965) The relation between nematode density and damage to plants. Nematologica 11, 137-154.

Whitehead, A.G.; Tite, D.J.; Fraser, J.E.; French, E.M. (1980a) Effects of aldicarb and oxamyl in peaty-loam soil on potato cyst-nematode, Globodera rostochiensis, and on resistant and susceptible potatoes. Journal of Agricultural Science, Cambridge 95, 213-217.

Whitehead, A.G.; Tite, D.J.; Fraser, J.E.; French, E.M. (1980b) Control of potato cyst-nematode, Globodera rostochiensis, in a three course rotation. Journal of Agricultural Science, Cambridge 95, 293-304.

1A—R16

CROP-LOSS APPRAISAL IN WHEAT GLUME- AND LEAF-BLOTCH (SEPTORIA NODORUM)

W. AHRENS, H. FEHRMANN

Institut für Pflanzenpathologie und Pflanzenschutz, University, Goettingen, W.Germany

Background and objectives

In field experiments in winter wheat with artificial inoculation with *Septoria nodorum*, crop-loss appraisals were carried out. Fungicides were not applied. Disease assessment data from different plant organs and data for yield components, respectively, were taken from individually labelled plants (single-tiller analysis).

Results and conclusions

When glume-blotch assessments were made at flowering (GS 61/69), in two spring wheat varieties ('Selpek' and 'Kolibri'), the correlation coefficient for the relationship between single-grain weight at harvest and ear attack was quite high - between 0.81 and 0.91. Corresponding data for single-ear yield varied between 0.70 and 0.86, if glume-blotch data or *S.nodorum* leaf-blotch data from the flag- and the second leaf were used for calculation. According to these results, between 50 and 83 % of the variance for yield-loss could be explained by *S. nodorum* attack on either plant organ. By other diseases such as powdery mildew on ears, take-all and others the data were modified. For cv.Selpek, about 1 % glume-blotch (necrotic glume area) caused 1 % loss in single-ear yield; 1 % flag-leaf blotch caused about 0.4 % loss in single-grain weight, as was shown for both cultivars. On the other hand, only about 0.5 % loss in single-grain weight could be attributed to 1 % glume-blotch in cv.Diplomat. In the latter case, data were modified by eyespot.

As shown by multiple regression analysis, in the experiments crop-losses were caused mainly by the attack of the blade and the sheath of the flag-leaves, followed by the second leaves. Glume-blotch caused only about 20 % of the total crop-loss. However, the relative importance of leaf- and glume-blotch varies, depending on weather conditions and other circumstances.

References

Ahrens, W. (1981) Verlust-Schätzung bei Befall mit *Septoria nodorum* und anderen Schaderregern des Weizens mit Hilfe der Einzelhalm-Methode. - Med.Fac.Landbouww.Rijksuniv. Gent, 46.

Ahrens, W.; Fehrmann, H. (1983) Weizenbefall durch *Septoria nodorum* und Ährenfusariosen. I. Schadensanalyse. - Z.PflKrankh.PflSchutz, in print.

Fehrmann, H.; Ahrens, W. (1983) Weizenbefall durch *Septoria nodorum* und Ährensfusariosen. II. Spritzanwendung kurativ wirksamer Fungizide. - Z.PflKrankh.PflSchutz, in print.

THE RELATION BETWEEN GRAIN YIELD AND MILDEW (*Erysiphe graminis*) LEVEL IN SPRING BARLEY

T M WEIGHT

ICI Plant Protection Division, Jealott's Hill, Bracknell, Berkshire, England

Materials and Methods

During 1978-1982, ICI carried out a large number of spring barley fungicide trials in the UK in which disease level and grain yield were assessed. The data obtained are used here in an analysis of the effect of mildew on grain yield.

The trials were all large plot (20-30 x 2-4 metres), 4 replicate, randomised block trials with between 7 and 16 treatments. All trials included at least one control treatment (untreated) while most of the treatments were active fungicides from ICI's areas of interest during the period. Disease assessments were made at various times during the trials usually on the lowest green leaf.

Mildew assessments at, or close to, two growth stages (Zadoks 44 and 57) have been analysed. Suitable data were available from 36 trials at the earlier growth stage and 59 trials at the later stage. From the assessments, other diseases were noted as present or absent in each trial; such diseases were observed on between 30-64% of the trials depending on the level used to define presence.

Linear regression analysis of yield (t/ha) on mildew (% leaf cover) was carried out for each trial separately, using the treatment means. The equation fitted was of the form:-

Yield in tonnes/hectare = a + b (% leaf cover)

where b is the slope of the line (the slopes can therefore be used to predict the effect of disease on yield). The slopes obtained were plotted against the untreated disease level and trial mean yield, and analysed in relation to the presence or absence of other diseases. These analyses were repeated after transforming the disease level, firstly using the arc-sine transformation and secondly using the square root transformation.

Results and Conclusions

The most striking feature of the results was the dependency of the slope on the level of disease in the untreated control. There was strong evidence of, on average greater proportional responses at lower disease levels and this was not explained by control of other observed diseases. For this reason, the slopes were reanalysed dividing the data into five disease level ranges; 0-2, 2-5, 5-10, 10-30 and >30%. The mean slopes obtained in each range have been used to predict yield benefit from complete disease control over the appropriate part of the range. The results are given in table 1 (some lack of smoothness is due to the predictions being independent at different levels).

TABLE 1
Predicted Effect on Grain Yield (t/ha)

Mildew on Untreated	GS44	GS57
1%	0.25 (0.16)	0.27 (0.18)
3.5%	0.24 (0.31)	0.45 (0.34)
7.5%	0.32 (0.45)	0.55 (0.48)
20%	0.64 (0.73)	0.74 (0.81)
50%	1.00 (1.16)	1.05 (1.29)

These results are consistent with at least 2 models; either the relation between grain yield and disease level is non-linear or the relation is approximately linear but some yield benefit from fungicide treatment is obtained even in the absence of mildew (or other observable disease). This latter hypothesis has been suggested and explanations proposed by a number of authors, for example Priestley and Bayles, 1982.

A non-linear relation was obtained by use of the transformations considered. However, some dependency of slope on disease level still remained with yield benefit tending to be under-estimated at low disease level. The two transformations gave very similar predictions but for comparison those from the square root transformation are given in brackets in table 1. (A smooth set of predictions result since only one equation was fitted over the whole range). Notable benefits were still predicted at low disease levels, from 'disease control'.

References

Priestly, R.H.; Bayles, R.A. (1982) Effect of fungicide treatment on yield of winter wheat and spring barley cultivars. Plant Pathology 31, 31-37.

1A—R18

EFFECTS OF BARLEY POWDERY MILDEW ON GRAIN FILLING IN CONTRASTING ENVIRONMENTS

J.F. JENKYN

Rothamsted Experimental Station, Harpenden, Herts., U.K.

Background and objectives

Fungicides applied to cereals to control leaf pathogens commonly give substantial yield benefits but the increases obtained do not always correlate well with the amounts of disease present before the treatments were applied or the decreases in disease which the treatments achieve. Circumstantial evidence from field experiments at Rothamsted has, however, suggested that the damage done to spring barley by powdery mildew (Erysiphe graminis f.sp. hordei) may be determined, at least partly, by the length of the grain-filling period. Other work has shown that the rate and duration of grain filling are themselves largely determined by temperature (Stoy, 1980). An experiment was, therefore, done which compared the effects of barley powdery mildew on grain filling out-of-doors and in a heated glass-house.

Materials and methods

The experiment tested all combinations of two sowing dates, with and without mildew control, and two contrasting environments during grain filling. Plants were grown in large plastic buckets containing a mixture of Kettering loam and a soil-less compost. The buckets were sown with cv. Zephyr at 10 per bucket, half on 10 March and the remainder on 24 April. After sowing, buckets were kept in an unheated glasshouse until seedlings emerged but were then kept out-of-doors until the start of grain filling. Powdery mildew was allowed to develop naturally except half of the buckets of each sowing date were treated with fungicides to control the disease. Grain filling was assumed to have begun 5 days after 50% of the main-stem ears had completely emerged from their flag-leaf sheaths and on these dates half of each treatment of the early- and late-sown buckets, respectively, were transferred to a heated glasshouse with supplementary lighting ('warm' environment). The remainder were kept out-of-doors ('cool' environment).

Results and conclusions

Mildew became more severe on the late-sown barley than on the early-sown. At ear-emergence, it was only slight on the fungicide-treated, early-sown plants but there were moderate amounts (c. 16% on leaf 3) on the fungicide-treated, late-sown plants.

Fungicides increased total grain yield of the late-sown barley more than that of the early-sown (+ 50.2% and + 20.4% , respectively) and much more in the warm environment than in the cool. On average, fungicides increased grain yield in the cool environment from 52.5 to 61.8 g/bucket (+ 17.7%). Small increases in numbers of grains/ear (+ 3.3%) and thousand-grain weights (TGW) (+ 2.4%) contributed to this increase but it could principally be attributed to an average increase in numbers of ears in both environments (which did not differ significantly) of 20% which explains why the fungicides increased amounts of grain produced by the main stems in the cool environment by only 2.3% but the total produced by tillers in the same environment by 22.7%. Contrastingly, fungicides increased average grain yield in the warm environment from 31.6 to 50.0 g/bucket (+ 58.2%), attributable to increases of 19.0% and 73.6% in grain yield from main stems and tillers, respectively. Effects of the fungicides on numbers of ears were similar to, and effects on numbers of grains/ear (+ 4.7%) somewhat greater than, those in the cool environment. However, the much greater responses to fungicides in the warm than in the cool environment can principally be attributed to their much larger effects on grain size. On average, grains produced in the warm environment were 31.2% smaller than those produced in the cool environment but the average effect of the fungicides in the warm environment was to increase TGW from 28.1 to 33.5 g (+ 19.2%). The increases for grain produced on the main stems and tillers were 15.5 and 22.4%, respectively.

The greater benefits of the fungicides, and, by implication, the greater damage done by powdery mildew to grain filling, in the warm than in the cool environment cannot, unequivocally, be attributed to differences in temperature because the two environments clearly differed in other ways and especially in light intensity. Future experiments will specifically examine the effects of powdery mildew on grain filling at different temperatures and light intensities. The results reported here do, nevertheless, illustrate the potential risks involved in using data obtained under one set of circumstances to predict what will happen in another especially when environments differ as greatly as glasshouses and fields.

References

Stoy, V. (1980) Grain filling and the properties of the sink. In : Physiological Aspects of Crop Productivity, Proceedings of the 15th Colloquium of the International Potash Institute, Wageningen, The Netherlands.

THE "FOOTROT COMPLEX" AND ITS EFFECT ON VINING PEA YIELD

A.J. BIDDLE

Processors & Growers Research Organisation, Gt. North Road, Thornhaugh, Peterborough, U.K.

Background and objectives

Vining peas grown for freezing and canning occupy some 56000 ha annually in the U.K. and are valued at £51M. Although major advances in production have been made over the last 20 years, the national average yield has remained around 4.5 tonnes ha^{-1}. A contributing factor may be foot and root rots caused by soil borne diseases. Biddle (1979) showed the positive relationship between frequency of cropping peas and disease incidence and that footrot often occurred as a complex of pathogens, but no data were available to correlate yield loss with disease. The objective of this research was to establish the relationship between the level of disease brought about by past overcropping and yield loss.

Methods

The project was carried out during 1981 and 1982. In both years, pea fields were selected on the basis of past cropping, to provide a range of pea cropping frequencies. Each field was visited when the crop had reached the full flower stage, and traversed in a "W" pattern, plants being dug at random stations. The soil was washed carefully from the root systems using water and a mild liquid detergent. The root systems and stem bases of each plant were examined for symptoms of footrot. Because the pathogens cause different symptoms, the footrot assessment method of Clarkson (1978) for Fusarium solani infection was modified as follows. Both the stem base and the root system of each plant were separately assigned a score between 0 and 5; 0 = no discolouration and 5 = complete blackening or browning of root or stem base tissue. The two assessments were combined in the following way; total score for stem base + total score for root system/2 x number of plants examined to give a crop footrot index. Root tissue and stem bases from selected plants were cultured and pathogens were isolated and identified. At the end of each season, the variety, date of sowing and crop yield of each field were obtained from information provided by the growers.

Results and conclusions

The number of fields examined in 1981 and 1982 were 20 and 50 respectively. The pathogens isolated and the percentage of the fields in which each pathogen occurred are as follows:-

	% (1981)	% (1982)
Phoma medicaginis var. pinodella	40	34
Fusarium solani f. sp. pisi	55	50
F. oxysporum	15	8
F. culmorum	0	2
Mycosphaerella pinodes	10	8
Thielaviopsis basicola	30	2

Many crops were found to be infected by more than one pathogen. In each year the crops were separated into early and maincrop varieties and the footrot index for each group and for all crops was correlated with the harvested yield. The results of these analyses are shown below.

1981	Early varieties	$r = -0.81$	$p = 0.05$	$y = 5.53-0.85x$
	Maincrop varieties	$r = -0.89$	$p = 0.05$	$y = 5.75-0.5x$
	All crops	$r = -0.54$	$p = 0.05$	$y = 6.13-0.84x$
1982	Early varieties	$r = -0.81$	$p = 0.01$	$y = 7.25-0.92x$
	Maincrop varieties	$r = -0.47$	$p = 0.05$	$y = 5.92-0.33x$
	All crops	$r = -0.48$	$p = 0.01$	$y = 6.3-0.46x$

In both years, significant negative correlations were obtained, the diseases having a greater effect on the early varieties than the maincrops. However, the overall average yield loss for early crops in the survey was 0.9 $tonnes^{-1}$ for each increase of 1.0 on the footrot index, costing around £200 per hectare. Therefore, the work demonstrates the effect on yield of both subclinical and high levels of disease.

The author wishes to thank the growers for their help in this work, Mrs. Fiona Herbert for her technical assistance and the Perry Foundation for the necessary finance.

References

Biddle, A.J. (1979) Pests and diseases - a review. Proc. A Conference on vining peas. Processors & Growers Research Organisation 27-31.

Clarkson, J.D.S. (1978) Pathogenicity of Fusarium spp associated with footrots of peas and beans. Pl. Path., 27, 110-117.

1A—R20

APPLE POWDERY MILDEW: DAMAGE, LOSS AND ECONOMIC INJURY LEVEL

D.J. BUTT, K.J. MARTIN and A.A.J. SWAIT

East Malling Research Station, Maidstone, Kent ME19 6BJ, England

Backgound and objectives

Apple mildew (Podosphaera leucotricha) can be severe in the United Kingdom; intensive spray programmes are necessary each year on most important cultivars, including Cox's Orange Pippin. If the management of any plant pathogen is to be optimised the economic injury level (EIL) must be known, because this is the level of disease at which the economic benefit of any particular treatment is at its greatest. With this objective, the effects of apple mildew on tree growth, cropping and crop value are being quantified at levels of disease incidence typical of many commercial orchards.

Materials and methods

A range of mildew incidence was achieved annually since 1974, on 42 trees of each of four cultivars grown on M.9 (dwarfing) rootstock, by means of spring and summer programmes of a standard fungicide, differing in spray interval but not concentration, applied at high volume by hand lance. The dependence of eight variates on the midsummer incidence (% mildewed leaves) of secondary mildew in the period 1974-1981 was examined using a multiple regression model. Other explanatory variates took account of initial size of tree, position in orchard and any 'side-effects' of the fungicide programmes other than on summer mildew (e.g. phytotoxicity). Crop values were calculated from annual fresh fruit wholesale prices paid according to fruit size. Control costs were based on the amount of fungicide applied to each tree, and labour costs for an assumed mist-blowing operation.

Results

On Cox, increasing the mean annual midsummer incidence of mildew from 2% to 19% (the observed extremes) resulted in the following reductions in growth and yield in the period 1974-1981: trunk growth, 27%; shoots/tree, 32%; leaves/shoot, 19%; fruit size, 27%; crop weight, 15%; and crop value, 33%. Jonathan (highest incidence 27%) suffered less damage than Cox, with reduced shoots/tree, shoot length and fruit set and increased fruit skin russet. On Golden Delicious (highest incidence 13%), damage was limited to shoots/tree and fruit size and on George Cave (highest incidence 8%) to leaves/shoot.

The incremental cost of control at c. 2% incidence was estimated to be only one quarter of the corresponding increase in crop value.

Conclusions

Damage and loss varied with cultivar and were more evident on Cox than on the more mildew-susceptible cultivar Jonathan. Also, there was no consistency between cultivars in the components of growth or yield damaged by mildew.

Some growers consider an incidence of 20% mildew 'commercially acceptable'. In this study the damage thresholds on Cox were below 20% for five variates and the data suggest that the thresholds are below 10% incidence. Of more importance was the loss of Cox crop value, due largely to relatively low mildew levels reducing crop weight and fruit size. (It is noteworthy that fruit size was sensitive to mildew control in spring as well as summer.) The loss threshold was also less than 20% incidence, and was probably below 10%. The EIL was very low, with no evidence of an optimum above c. 2% incidence. The implication is that on Cox, treatment with the fungicide used in this study was worthwhile at incidences near zero. Two conditions that could raise the EIL are less efficient spraying and less cost-responsive fungicides.

Acknowledgement

We are indebted to Mrs. Joyce Robinson for so diligently recording this trial and processing the data.

DISEASES AFFECTING SOFT FRUIT QUALITY

T. BROKENSHIRE

East of Scotland College of Agriculture, Edinburgh, Scotland.

Background and objectives

The main soft fruit crops in Scotland are raspberries and strawberries. In today's competitive market it is important to produce berries of the highest quality. Fungal disease is one important factor which can reduce fruit quality and yield. Under Scottish conditions the two main berry diseases of both crops are grey mould and powdery mildew caused by *Botrytis cinerea* and *Sphaerotheca macularis* respectively. Fruit rots caused by *Rhizopus* and *Mucor* species are uncommon because of the relatively cool growing season. Growers have long been aware of the ravages of grey mould but the importance of powdery mildew has not been fully appreciated. In recent years the incidence of powdery mildew has increased particularly in the raspberry crop. Cultivar choice is very limited and greatly influenced by the processors. The early strawberry cv, Cambridge Vigour and the two common raspberry cvs, Malling Jewel and Glen Clova are prone to serious mildew infections. The object of the trial programme has been to determine the importance of both diseases in Scotland with particular reference to their effect on fruit quality.

Materials and Methods

All field experiments on powdery mildew were carried out using the strawberry cv, Cambridge Vigour and the raspberry cv, Malling Jewel. Fungicides were used in conjunction with untreated controls to evaluate the effects of the disease on fruit quality. In the strawberry mildew trials the fungicides were applied as a 3-spray programme starting at the pre-flowering stage with subsequent sprays at 10% flowering and full flower. Raspberries were sprayed at 10% flower, full flower and at the green fruit stage. Leaf assessments were carried out during the growing season. Berries were assessed on a surface area basis and scored on a 0-3 scale. Berries scored in classes 2 and 3 significantly affected fruit quality.

A similar method was used for the grey mould trials with the protectant fungicides applied as a 3-spray programme at flowering. All berry samples were incubated for 3 days at 20°C prior to a final disease assessment.

Results and conclusions

Both diseases significantly reduced berry quality and yield. Strawberry and raspberry fruit infected with powdery mildew were usually malformed, small and lacked the bright appearance of healthy fruit because of the surface fungal mycelium. Severely infected berries were covered with a dense matt of white mycelium. Even low numbers of severely infected berries significantly reduced the quality of the fruit for both the fresh and processing market. Leaf infection in strawberries resulted in a loss of plant vigour and was probably responsible for the small fruit. The level of fruit infection varied with the season and the location of the plantation. Warm dry summers appeared more conducive to disease development and sheltered plantations usually developed more disease than exposed crops. Maximum infection levels recorded in untreated plots were 72% and 82% infected berries for strawberries and raspberries respectively. However, only those berries classified in disease categories 2 and 3 affected fruit quality and only those in category 3 significantly affected yield. Timely fungicide applications significantly reduced disease incidence and severity and increased marketable yield and quality.

Yield losses through grey mould attacks were significantly more serious than powdery mildew. All grades of grey mould infection resulted in a direct yield loss. Latent infections, particularly in raspberries, developed after 3 days incubation and reduced the shelf life of the fruit. Fungicide sprays significantly reduced disease incidence and the results confirmed the importance of routine preventative fungicide sprays at flowering.

References

Brokenshire, T. (1980) Control of strawberry mildew in S.E. Scotland. *Annals of Applied Biology, Supplement, Tests of Agrochemicals and Cultivars* 1, 38-39.

Brokenshire, T. (1982) Evaluation of new fungicides for strawberry mildew control. *Annals of Applied Biology, Supplement, Tests of Agrochemicals and Cultivars* 3, 60-61.

1A–R22

THE CONTROL OF ALOPECURUS MYOSUROIDES AND AVENA FATUA IN WINTER WHEAT

J.H. ORSON

Agricultural Development and Advisory Service, ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford, England OX5 1PF

Background and objectives

Alopecurus myosuroides and Avena fatua are major annual grass weeds of winter cereals in England. In a comprehensive survey carried out in 1977, A. myosuroides was present in 22 percent of the cereal area of England, mainly in the South and East (Elliott et al, 1979). In the same survey Avena spp., mainly A.fatua, were present in 67 percent of the cereal area of England.

In the late 1960's there was a considerable increase in the number of herbicides available for the selective control of A. myosuroides and/or A. fatua in winter cereals. Due to these introductions, the Agricultural Development and Advisory Service increased the number of trials in order to investigate their efficacy and cost effectiveness.

Materials and methods

Herbicides at various rates and timings were included in the trials, but the yield responses discussed only relate to commercial recommendations.

In the majority of trials, weed assessment methods were selected to give a guide to seed return. A. myosuroides was assessed on total length of seed heads cut out of plots in late June and A. fatua on total panicle dry weight cut from quadrats in July. Yields were either assessed by hand sampling method and threshing in a stationary drum or by combine harvester. The trials were carried out on commercial farms and cover a wide range of soil types, crop and cultivation systems. Most of the sites were in East and South East England. They were of randomised block design with the herbicides being applied with precision plot sprayers powered by bottled gas.

Results and conclusions

In a series of 106 trials, primarily for the control of A. myosuroides, time of application was studied in detail (Baldwin, 1979). Applications from pre-emergence of the crop to post-emergence applications to the end of January and into February gave higher levels of weed control and yield than later applications. Recent trials have confirmed these findings. During the winter when growth was slow, the yield response was much more dependant on the eventual control of A. myosuroides achieved by the range of herbicides, with time of application not appearing to be important until the early spring. The inference of these results agrees with the conclusion that competition of A. myosuroides with winter wheat is mainly for nitrogen and becomes serious over a very short period in very early spring when temperatures rise (Naylor, 1972). The use of population counts of A. myosuroides as a means of predicting likely yield responses did not emerge as a very practical solution. In general terms it was obvious that the denser the weed, the more serious the likely yield depression, but much depends on cultural factors, fertility levels and vigour of the crop.

Another series of 51 trials on the control of A. fatua from spring applications of herbicides was carried out in October-November drilled crops, mainly in the East of England. There was a good yield response from applications up to the second-node detectable stage of the crop and after this yield responses showed a sharp decline. Observation of the trial plots showed that where A. fatua were killed at this late stage the crop was unable to exploit the extra room made available for leaf development and gaps persisted in the crops where the weeds had been. Unlike A. myosuroides there was a closer relationship between the population of A. fatua and yield response and it would appear there is an almost direct substitution of winter wheat grain and Avena fatua panicles where the weed was efficiently controlled at the fully tillered to first-node detectable stage of the crop. More recently in 1980-82, trials in October-November drilled crops in the East of England have shown no yield advantage of autumn/winter removal of A. fatua over spring applications made before the first-node detectable stage of the crop.

References

Baldwin J.H. (1979) The chemical control of wild-oats and black-grass. A review based on ADAS agronomy trials. ADAS Quarterly Review. 33, 69-101

Elliott, J.G.; Church, B.M.; Harvey, J.J.; Holroyd, J.; Hulls, R.H. and Waterson, H.A. (1979) Survey of the presence and methods of control of wild-oat, black-grass and couch grass in cereal crops in the United Kingdom during 1977. Journal of Agricultural Science 92, 617-634

Naylor, R.E. L. (1972) The nature and consequence of interference by Alopecurus myosuroides Huds. on the growth of winter wheat. Weed Research 12, 137-143

THE EFFECT OF WEEDS ON YIELD AND QUALITY OF WINTER CEREALS IN THE UK

B.J. WILSON, G.W. CUSSANS
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford, OX5 1PF

Background and objectives

There is need to establish the economic effects of weeds in cereal crops, so that damaging weed populations may be anticipated at an early stage, so aiding decisions on whether or not spraying is justified.

This report covers the response of winter cereal crops near Oxford to control of either *Alopecurus myosuroides* or various broad leaved weed species.

Materials and Methods

Weeds were removed in 15 wheat and 14 barley replicated experiments in 1980/81 and 1981/82 using autumn applied herbicides to remove either *A. myosuroides* or broad leaved weeds. Weeds were counted and plots harvested to give grain yields which were corrected to give clean yields $>$ 2 mm at 85% dry weight. Moisture contents and in some cases weed seed contamination of the harvested grain were assessed.

26 earlier experiments were also reviewed and cereal yield response to the use of herbicides related to the autumn removal of *A. myosuroides*.

Results and Conclusions

Yield

A. myosuroides reduced yield significantly ($p = 0.05$) in 8 out of 9 experiments in 1980/81 and 1981/82. Yield losses ranged from 0.16 t/ha (18 seedlings/m^2) to 3.23 t/ha (377 seedlings/m^2). Average yields were reduced from 6.71 to 5.04 t/ha by an average of 143 seedlings/m^2 present in the autumn.

At these high levels *A. myosuroides* is very competitive. Decisions on whether or not to spray are more difficult at lower populations. The relationship between cereal yield response and autumn *A. myosuroides* population was reviewed in all experiments carried out at WRO since 1976. A non linear regression gave an exponential curve of the form $y = a + be^{-cx}$ where y = % yield loss, x = weed seedlings^{-2} with a, b, and c as constants. This was satisfactory for low populations with an average yield loss of 1% from 8, 5% from 19 and 15% from 54 seedlings/m^2. Although 2 experiments differed from the average yield response by $\pm$ 30%, the variation in 20 experiments was less than 10%. This suggests that cereal yield reduction from *A. myosuroides* may be predicted with reasonable confidence from the autumn seedling population.

Broad leaved weeds reduced yield significantly ($p = 0.05$) in 10 out of 20 experiments in 1980/81 and 1981/82. Average yields were reduced from 6.54 to 5.80 t/ha. However, yield losses were much less predictable than with *A. myosuroides* due largely to the wide range of species encountered. The largest yield losses per weed seedling occurred with *Galium aparine*, *Papaver rhoeas*, *Matricaria* spp. and *Raphanus raphanistrum*, species with a climbing or tall growing habit. Lower growing species such as *Viola arvensis*, *Aphanes arvensis*, *Stellaria media* and *Veronica persica* were less competitive individually, but at high populations caused significant yield losses.

Quality

Weeds increased the moisture content of the harvested grain in 17 of the 29 experiments in 1980/81 and 1981/82. Moisture contents were increased by over 1% in 10 and by over 2% in 4 experiments. No increase occurred where harvesting was carried out in really dry conditions; with less optimal harvesting conditions high densities of weeds especially if harvested green (e.g. *Matricaria* spp.), increased grain moisture contents.

Most species did not contaminate the grain with weed seeds. However, in one experiment, *G. aparine* (26 plants/m^2) produced a dense mat over the crop at harvest. This reduced the speed of harvesting, contaminated the grain sample with weed seeds (23% by weight), and reduced grain yield by 57%.

It was observed that the early presence of high densities of weeds (*S. media*, *A. arvensis*, *V. arvensis* and *V. persica*) predisposed the crop to lodging, even though these weeds had died back well before harvest.

References

Moss, S.R. The agro-ecology and control of black-grass, *Alopecurus myosuroides* Huds., in modern cereal growing systems. ADAS Quarterly Review (1980) 38, 170-191.

Makepeace, R.J. Broad-leaved weed control in cereals: Progress and Problems - a review. Proceedings 1982 British Crop Protection Conference - Weeds.

1A—R24

COMPETITION OF APERA SPICA-VENTI IN WINTER WHEAT

H. ROLA, J. ROLA
Institute of Plant Cultivation, Fertilization and Soil Science, Wroclaw, Poland.

Background and objectives

Research on effects of competition between cultivated crops and weeds (Kees 1968, Zimdahl 1980, Rola 1982) proves a close correlation between obtained yields and both weed infestation level and spectrum.

Apera spica-venti is one of the most common grass weeds appearing in winter cereals in Middle Europe. It has infested almost one million ha, mainly wheat and rye, at populations of 200-400 panicles/m^2, (80-160 plants/m^2). At these levels yield losses of 15-30% are common. Research during 1972-80 evaluated the influence of A. spica-venti on winter wheat yield under differing agronomic conditions.

Materials and Methods

The research was based on analysis of wheat ear samples taken from production fields with different A. spica-venti infestations accompanied by nonsignificant infestations of other weeds. Altogether 1,479 samples of ears were analysed, collected from 163 production fields of winter wheat in different ecological regions of Poland. This enabled the evaluation of wheat yields and some factors which influence final yield.

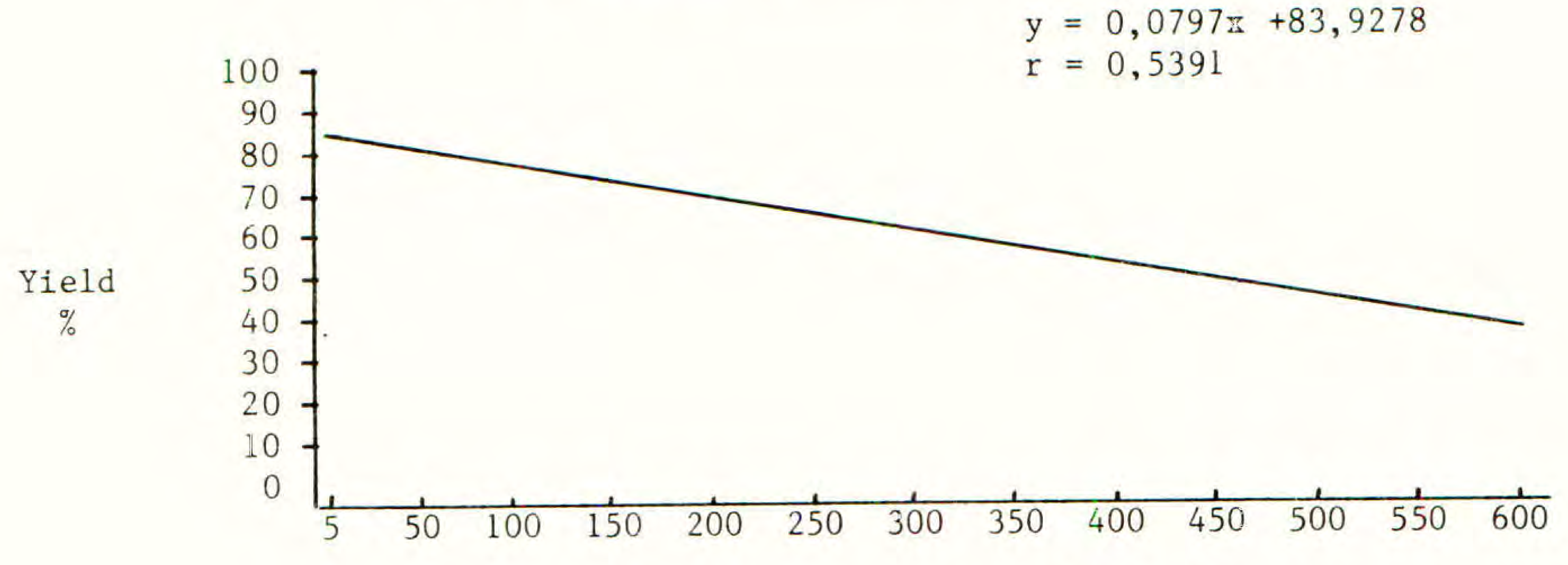
Results and conclusions

Collected data confirmed the decrease of wheat yield as a function of increasing A. spica-venti infestation. Grain losses caused by infestation reached 60% (Fig. 1) due to reduced ear numbers, as well as a reduction of ear length and mass of grain on the ear. Regression analysis confirmed correlation between the analysed factors. Each increase of 5 panicles of A. spica-venti/m^2 caused a 0.4% yield loss of winter wheat. A. spica venti growing on lighter soils was less competitive to wheat than on heavier soils due to its shallow rooting system which limits uptake of nutrients and water compared to the wheat crop.

The competitive influence of A. spica-venti could be modified by some agronomic factors. At low infestations (100 panicles/m^2) in winter wheat (var. Grana), its effect was limited by increased seed rate and nitrogen fertilization.

A comparison of the value of yield losses caused by different infestations enabled calculation of an economic threshold level. This threshold infestation for Poland for A. spica-venti has been established as 10-20 weeds/m^2. This figure establishes an economic basis for application of suitable herbicides to control this weed.

Fig 1. Effect of Apera spica-venti on winter wheat



References

Kees, H.(1968) Zur Konkurrenz zwischen Windhaln(Apera spica venti) und Winter-weizen. Zeitschrift für Pflanzen-krankheiten. Pflanzenschutz IV. 71-74

Rola H. (1982) Zjawisko konkurencji wśród roślin i jej skutki na przykładzie wybranych gatunków chwastów występujących w pszenicy ozimej. Wydawnictwa IUNG, Puławy, Poland, R /162/, 1-63.

Zimdahl, L.R. (1980) Weed-crop competition. A review. International Plant Protection Centre. Corvallis. 1-195.

WEED-CROP COMPETITION STUDIES IN SWEDES

J. C. FORBES

The North of Scotland College of Agriculture, 581 King Street, Aberdeen AB9 1UD, United Kingdom

Objectives

Experimental field studies of weed-crop competition have been carried out in swedes (*Brassica napus* var *napobrassica*), a fodder root crop still widely grown in Scotland. The main objectives were to relate crop yield loss to time of weed removal and to the competing weed species, their density and location (whether in or between the crop rows) and thus identify the weed control requirements of swedes.

Materials and Methods

Experiments were conducted in field grown crops of swede cv Ruta Øtofte precisic drilled at 15 cm spacing on ridges at 66-71 cm, at various sites in north-east Scotland over the three years 1980-82. Treatments involved careful, sometimes selective, hand-weeding in plots ranging from 3.3 to 10 m^2 in area. The main weeds present were *Polygonum aviculare*, *P. persicaria*, *Stellaria media*, *Spergula arvensis*, *Matricaria matricarioides* and *Poa annua*. In some experiments crop and weed biomass and crop leaf area index were recorded at intervals throughout the growing season, and all experiments were taken to crop yield in October or November.

Results and conclusions

Weed competition in unweeded plots reduced the dry matter yield of swede roots by 42-79% when compared with plots kept weed-free all season. If weeds were removed only once, the time of weed removal strongly influenced the degree of yield loss. In 1980 and 1981 weed removal earlier than the third week of June (six weeks after crop sowing) allowed subsequently emerging weeds to become competitive and reduce crop yield. If weed removal was delayed beyond this time it was too late to prevent damaging competition from weeds that emerged with the crop. However, a single weed removal six weeks after sowing resulted in a crop yield not significantly ($P = 0.05$) lower than that of weed-free plots. In 1982 the early part of the growing season was very dry and weed growth was retarded. In this case a single weed removal any time from four to seven weeks after sowing was adequate to prevent yield loss.

Virtually all the damaging competition occurs between six and twelve weeks after sowing. Weed removal later than this gives a crop yield as low as if weeds are not removed at all. The effect of weed competition appears to be to reduce both the number of leaves formed at the shoot apex and the maximum size these leaves can attain, even if weeds are later removed. The resulting reduction in leaf area index leads to a proportional reduction in root yield.

Competition from weeds in the furrows between the crop rows is equally as damaging to yield as that from weeds on the ridges. When ridges are kept weed-free, the optimum time for cultivation to prevent competition from weeds in the furrows is again around six weeks after sowing. In an experiment where all weeds except *Polygonum aviculare* were removed, this species proliferated to cause almost as great a yield loss as the original mixed weed population. Yield loss was proportional to *P. aviculare* biomass and to the square root of *P. aviculare* plant density. *Spergula arvensis* proliferated less than *P. aviculare* in response to removal of other weed species and therefore caused less damage to crop yield. However, at equal plant densities, *S. arvensis* was just as competitive as *P. aviculare*.

The results suggest that any pre-emergence herbicide for swedes must have broad-spectrum activity which persists for at least six weeks. The best time to practise inter-row cultivation or apply a post-emergence herbicide is around six weeks after sowing.

References

Fiveland, T.J. (1974) The competition between swedes or carrots and annual weeds. *Meldinger fra Norges Landbrukshøgskole* 53 (21), 15 pp.

Hewson, R.T.; Roberts, H.A. (1973) Effects of weed competition for different periods on the growth and yield of red beet. *Journal of Horticultural Science* 48, 281-292.

Ivany, J.A. (1980) Effect of weed competition and weed control programs on rutabaga yield. *Canadian Journal of Plant Science* 60, 917-922.

Lawson, H.M.; Wiseman, J.S. (1978) Competition between weeds and transplanted spring cabbage: effects of selective weed removal. *Horticultural Research* 18, 113-126.

Scott, R.K.; Wilcockson, S.J. (1976) Weed biology and the growth of sugar beet. *Annals of Applied Biology* 83, 331-335.

1A—R26

THE EFFECT OF WEEDS AND GRASS ON APPLE YIELD AND QUALITY

D. ATKINSON, CAROL M. CRISP

Pomology Department, East Malling Research Station, Maidstone, Kent ME19 6BJ, U.K.

Background and objectives

Apple trees, like other crops, are adversely affected by competing vegetation, e.g. weeds, or grass sown as a soil cover to aid management (Atkinson and White 1981). The value of a fruit crop is influenced by its volume and a range of quality factors, size, colour etc. Effects of weeds or grass on these have infrequently been quantified.

In addition to increasing cropping good weed control also increases shoot growth. In newly-planted and in young orchards this is vital to early ground coverage and the development of a cropping framework. Grass competition can reduce growth by over 70%. In the older tree enhanced growth may result in excessive shade, fewer fruit buds and poorer fruit colour. Modified orchard management, involving plant growth regulators, is needed to control this vigour.

Materials and methods

Experiment 1. Trees of Cox/M.26 were planted in spring 1966 at 2.4 x 3.7 m and maintained in a 1.5 m herbicide-treated strip with grassed inter-rows. In 1973 the plot was divided and a) the herbicide strip was kept clean (control) or was allowed to become infected with b) grass weeds, or c) annual weeds, e.g. *Senecio vulgaris*, or with other specified weeds.

Experiment 2. Trees of Cox/M.26 were planted in spring 1973 at 4.5 x 4.5 m and grown a) in a 0.6 m wide herbicide strip with grassed inter-rows, b) as in a) but with irrigation to maintain a high soil water potential, c) in a 2.0 m herbicide strip, d) under total herbicide management. In both trials growth, yield and crop quality were recorded.

Results and conclusions

In both trials and even for established mature trees the effects of either weed or grass competition were substantial and adverse in all years. In Experiment 1, during the two years following the establishment of treatments (1974-5) the annual weed trees produced 35% less crop than control. For the years 1975-6 it was estimated that weed competition would have reduced financial returns by £834/ha, at 1979 prices. 1981 was not a stressful season but crop was reduced 17% as a result of grass or annual weed competition. This resulted from 12 and 19% reductions in fruit numbers and 13 and 6% reductions in fruit size respectively for grass and annual weed treatments. The decrease in fruit size was associated with a decrease in the weight of fruit >90 g (>60 mm diameter approx.) from 13.7 to 12.0 and 12.4 kg/ha respectively. As this fruit sells at a higher price, 40.7 p/kg >60 mm compared with 30.8 p/kg for ≤60 mm, this loss is very important. Varying the severity and extent of grass competition also reduced the amount and quality of fruit in Experiment 2. Data from 1979 and 1980 is given as an example. Crop in 1979, mean 31.7 kg/tree was heavier than in 1980, 16.5 kg/tree. Shoot growth was higher in 1980 giving a lower proportion of red fruits (Table 1). Greatest effects were on the total herbicide treatment. In 1980 there was no effect on fruit size but in 1979 the proportion of fruit >60 mm diameter was increased in the total herbicide and irrigated treatments. The price differential for fruit of varying sizes makes this a more significant decrease than its simple effect on crop volume.

TABLE 1

Effect of soil management on apple yield and quality

Treatment	Crop (kg) 1979+80	% fruit >60 mm 1979	% fruit >60 mm 1980	% fruit >70 mm 1979	% fruit >70 mm 1980	% fruit surface >⅓ red 1979	% fruit surface >⅓ red 1980
Narrow strip	38	53	89	4	45	90	81
" + water	66	72	89	8	50	79	79
Wide strip	53	66	87	12	44	87	76
Total herbicide	62	74	83	17	45	88	71

A reduction in the relative magnitude of adverse effects of grass or weeds on crop, in mature compared with young orchards is usual. This is partly due to the larger (total herbicide or irrigated grass) trees filling their space and then being prevented from expanding further but also to effects of shade on fruit bud initiation and fruit colour. In this situation there is an increased need for chemical growth control. The advent of effective weed and grass control make necessary changes in other aspects of orchard management.

References

Atkinson, D.; White, G.C. (1981) The effects of weeds and weed control on temperate fruit orchards and their environment. In: Pests, Pathogens and Vegetation. J.M. Thresh (Ed), London: Pitman, pp. 415-428.

RUBBERY WOOD OF APPLES IN THE USSR

V.S. PONOMARYOVA

All-Union Research and Technological Institute for Quarantine and Plant Protection, Ministry of Agriculture of the USSR, USSR, Moskovskaya obl., pos. Bykovo, Pogranichnaya 32

Background and objectives

As a result of importation in the USSR of seedlings of spur varieties of apple from Bulgaria, Hungary and Romania, outbreaks of rubbery wood of apple were recorded in 1975-1978 in Moldavia, Ukraine, Kabardino-Balkaria and in Krasnodar and Stavropol regions. Later on, after the delivery of seedlings from Moldavia, the disease manifested itself in Georgia, Armenia and Azerbaijan. The development of measures aimed at elimination of the foci presupposes the necessity of evaluating the quarantine importance and potential of the disease.

Materials and methods

Tests were conducted to estimate the effects of the disease in commercial orchards. In Moldavia and Kabardino-Balkaria, ten trees in three replicates were examined, whereas in Ukraine, 100 each healthy and affected trees per site were examined. The parameters measured were tree height, stem circumference, crown width, shoot increment, total fruit yield and single fruit weight. In Kabardino-Balkaria shoot, xylem and phloem thickness was also determined, the amount of sugars of 1st, 2nd and 3rd groups was determined by method according to Bertrand. The ash of shoot xylem and phloem was analysed for non-organic phosphorus (method of Déniger modified by Levitsky) and calcium with the use of trilon. Analyses were made at the following stages: bud burst, end of shoot extension and beginning of fruit ripening. Sugar estimations were made on 24 May, 12 July and 9 October. Results were analysed mathematically. Macro- and microelement content in the phloem of shoots was determined by the mass spectrograph Lamma-500 (FRG). The necessary samples were prepared by fixation in glutaraldehyde, osmium tetroxide, dehydration in a set of spirits with further pouring into epons.

Results and conclusions

The studies showed that the disease occurrence in gardens varies from 8 to 34% and yield losses from 30 to 67%. The disease potential is expressed first of all in the death of young trees and of separate branches, the decrease of the crown width, stem diameter, tree height, in chat fruit of fruit-bearing trees, and reduction of 50 g in mean fruit weight.

The most susceptible varieties were Goldspur, Golden Delicious, Stark Spur, Stark Crimson and Yellow Spur. In affected shoots, the 20% expansion of the outer phloem, 9 - 22% decrease of the xylem layer, 15 - 21% decrease of the specific density as compared with healthy shoots were recorded; e.g. the specific density of 1 - 2 year old shoots in Golden Delicious was 609 ± 122.25, while that in Stark Crimson was 648 ± 108.87, the most pronounced decrease of the specific density was recorded for Wagner's Prizovoy (501 ± 67.11).

Wood tissue friability leads, as a rule, to the decrease of resistance to low temperatures as well as to the loss of resistance to fungal and bacterial attacks.

Biochemical analyses conducted have shown the disbalance in sugar and phosphorus and calcic metabolism evident in the changed ratio of carbohydrates in the first and second groups, total sugar and disaccharide, in the surplus accumulation of reducing sugars, especially during the bud incipience phase and in the end of vegetation, as well as in the increase of calcium to phosphorus ratio in the beginning and in the middle of vegetation. Calcium to phosphorus ratio in healthy plants was more stable than that in the affected ones.

The difference in ion accumulation of potassium, calcium and some heavy metals (Mo, Sc, Cr) in contaminated and healthy plants was detected by the mass spectrometric method, and this is the evidence of ion disbalance under pathogenesis. The loss of calcium by cell walls may lead to the formation of cavities and wood tissue friability. This conclusion is well supported by the X-raying of shoots. Radiographs of affected shoots show porosity correlated with the degree of contamination. Evidently, radiography can be used for rubbery wood detection.

Based on the above, it can be suggested that rubbery wood of apple is a serious disease resulting in yield losses and the affected trees' decreased resistance to unfavourable environmental conditions and their premature necrosis.

Therefore, inspite of the fact that this disease was not subjected to quarantine, measures were applied to eliminate foci, these include the destruction of heavily affected trees, deep pruning of branches in slightly affected trees, the transference of nursery fields not less than 3 km away from contaminated plantings, prohibition to procure cuttings in foci, maintaining of high soil fertility.

References

Rubin B.A. (1978) Practical work on plant physiology. Moscow, "Vishaya shkola"
Petersburgsky A.V. (1968) Practical work on agro-chemistry. Moscow, "Koloss"
Ponomaryova V.S. (1981) Plant Protection 6, 36 - 37, Moscow, "Koloss"

1A—R28

SOME OCCURRENCE AND EFFECTS OF CYST AND ROOT-KNOT NEMATODES IN KAZAKSTAN

A.O. SAGITOV

Kazakh Research Institute of Protection of Plants, USSR.

Background and objectives

More than 20 species of cyst nematodes have been identified on the roots of different plants in Kazakstan. Bidera avenae, Heterodera schachtii, H. trifolii, H. paratrifolii, H. gradumi, H. rosii, Globodera artemisiae, Cactordera cacti are widely distributed within the region. The recording of more than 10 species of cyst nematodes during a short period of time demonstrates the need to conduct more thorough specific investigations of plant infection by these nematodes.

Materials and methods

The occurrence and damaging effects of Heterodera Schachtii and Bidera avenae were studied under the conditions of the South of Kazakstan. Population dynamics and crop rotations to minimise damage were investigated.

Results and conclusions

Both southern and northern species of root-knot nematodes are most damaging and affect almost all outdoor and glasshouse grown vegetables. The southern root-knot nematode Meloidogyne incognita is especially harmful in glasshouses, reducing cucumber yields 5-6 fold. In the field the northern root-knot nematode M. halpa reduces vegetable yields by 2-15%. Measures for combatting parasitic nematodes in integrated production have been developed involving cultural, chemical and physical methods. The effectiveness of the nematicides 1,2-Dibromo-3-chloropropane, Dichloropropane-dichloropropene mixture, isozophos, aldicarb, metham-sodium, calcium cyanamide, dazomet and others was studied under the conditions of Southern and South-eastern Kazakstan. Several of these nematicides gave good control. Interesting interactions between cyst nematodes and fungal diseases were observed; nematode attack promoted fungal rotting.

INSECT DAMAGE AND GRAIN YIELD OF FABA BEAN, LENTIL AND CHICKPEA

G. HARIRI

University of Aleppo, Aleppo, Syria

O. TAHHAN

ICARDA, P.O. Box 5465, Aleppo, Syria

Background and objectives

Studies on the economic importance of insect pests of faba bean, lentil and chickpea in Syria during the 1980, 1981 and 1982 growing seasons have revealed that the main insect pests are *Aphis craccivora, A. fabae, Bruchus dentipes, Apion spp., Lixus algirus* and *Sitona limosus* on faba bean; *A. craccivora, Acyrthosiphon pisum, Bruchus ervi, Apion spp., Sitona macularius* on lentil and *Heliothis armigera, H. viriplaca* and *Liriomyza cicerina* on chickpea.

Field trials have been conducted to estimate losses due to these major insects.

Materials and Methods

Field plots of different sizes were planted with faba bean, lentil and chickpea crops during the 1980, 1981 and 1982 seasons to obtain different levels of insect infestations. Insecticides to kill chewing and sucking insects were used in these plots.

Levels of infestation in treated and untreated plots were estimated by means of different scales which varied according to the part of the plant attacked and the type of damage. Insect populations in treated and untreated plots were estimated for thrips, black and pea aphids on lentil, *B. dentipes* on faba bean. Grain yields in treated and untreated plots were also measured.

Results and conclusions

The root nodules of lentil plants were attacked by *Sitona spp.* larvae up to 98%, and adult feeds on leaflets by chewing semi-circular notchings up to 85%. The complete control of these stages increased insignificantly the grain yield by 16%. When other foliage insects were controlled, the yield increased by 29%.

Upon harvest, *B. dentipes* infestation of faba bean seeds did not influence quantitatively the grain yield. The infestation reached up to 76%, and foliar sprays reduced the infestation to 1.6%. Other foliage insects did not significantly influence grain yield.

Foliar sprays were efficient in controlling *Heliothis spp* and leafminer populations. This is turn reflected in a 20 - 30% yield increase in spring planted chickpea and 13 - 19% increase in the yield of winter planted chickpea.

References

Hariri,G.; Tahhan,O. (1983) Updating results on evaluation of the major insects, which infest faba bean, lentil and chickpea in Syria. Arab Journal of Plant Protection 1 (1), 13 - 21.