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Experimental verification and development of EPIPRE, a supervised disease and pest management system for wheat

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Abstract

From 1981 to 1984, 27 experiments were carried out to evaluate and develop the EPIPRE system for supervised pest and disease management in wheat. The results of these experiments led to an adjustment of the EPIPRE recommendation for control of *Septoria* spp. After this adjustment only minor differences remained between EPIPRE and the general recommendation in the number and type of sprays and in net yields. The EPIPRE advice models for stripe rust, leaf rust, mildew and cereal aphids were reliable. More research is needed on *Septoria* spp. and the modelling of pesticide action and efficiency. Reduction in pesticide application as a result of using EPIPRE was less than was expected at the start of the EPIPRE project. A reason for this is that pesticide use in wheat in the Netherlands is low in comparison with surrounding countries. Application of sprays above the level of EPIPRE recommendation were often found to be economically worthwhile, but their economic advantage, compared to the adapted EPIPRE recommendation or to the general recommendation, was small and did not justify intensive, high-input crop protection strategies. EPIPRE had positive educational effects, but probably few short-term economic benefits for the farmer. This limits the participation in the advice system. In the future the EPIPRE information on disease and pest management will be incorporated into a computerized management system for wheat growing, that comprises all crop husbandry measures from sowing to harvest.

Additional keywords: supervised control.

Introduction

EPIPRE is a computer-based pest and disease management system for wheat, aimed at cost-efficient crop protection. Farmers receive recommendations on the timing of field observations, the decision whether or not to spray and the choice of pesticides. Field observations and recommendations are made on an individual field basis. The farmer uses a standardised observation method to inspect his fields. The advice model performs a cost-benefit analysis for each disease or pest and for combinations of diseases and pest. The expected damage for a disease or pest is calculated in three steps:
1. Incidence counts by farmers are transformed to degrees of severity.
2. The increase in the disease or pest population is predicted for a restricted period. Relative growth rates depend on the developmental stage and are adjusted for soil type, nitrogen fertilization, application of growth regulators and varietal susceptibility. The length of the prediction period depends on the development stage of the crop.

3. The predicted severity at the end of the prediction period is related to a damage expectation in kg ha^{-1}.

The advice program and the organization of EPIPRE were developed at the Wageningen Agricultural University in 1978-1981. In 1981 the initial development phase was considered to be finished, and EPIPRE was handed over to the Reasearch Station for Arable Farming and Field Production of Vegetables at Lelystad, which operates the system in cooperation with the Regional Extension Services. In the period 1982-1984 participation stabilized at about 600 farmers with about 1200 wheat fields per year. Other EPIPRE versions have been in operation since 1982 in Belgium, Switzerland, Sweden and Great Britain. Detailed historical and decriptive information on the EPIPRE system has been given by Rabbinge and Rijsdijk (1983), Reinink (1984) and Zadoks (1984).

The data used in the EPIPRE model are based mainly on the results of field experiments where a small number of aspects of a particular disease or pest were studied in detail, with exclusion of other pathogens. Although the individual relations may be scientifically correct, the functioning of the total advice system must be checked again; the results depend not only on the validity of the individual relations but also on interactions between diseases, and between the advice system and the user.

Development and evaluation of the EPIPRE system have been closely linked since the start of the system. New advice rules were immediately checked on several hundreds of farmers' fields. At the end of each wheat growing season, 100 to 150 of these fields were visited for inspection of the results of the EPIPRE recommendation. Evaluation meetings were held in winter to discuss the results of the EPIPRE system with extension officers and participants. This system created a very fruitful interaction between crop protection research and cereal growers. New scientific results from field experiments, which are always on a small scale, could be evaluated the next year on hundreds of farmers' fields. Failures in the disease and pest management system were immediately revealed by its use on a large scale; this could lead in the same year to adjustments of the advice model or to the proposition of new research.

In addition to this evaluation of the EPIPRE system based on farmers' fields and experiences, a set of field trials was started in 1981. In these trials the EPIPRE recommendation was compared to other spraying regimes. The aims of these trials were to evaluate the economic benefits of EPIPRE for the farmer, and to identify disease situations where a further development of the EPIPRE system might be needed.

In this article the results of four years of trials are presented.

Materials and methods

From 1981 to 1984 27 trials were carried out on experimental farms located in several regions of the country and on several soil types. Four disease and pest management schemes were compared in these trials:

U: Untreated; no disease or pest control.

E: EPIPRE recommendation, based on field observations. No routine sprays.

G: General recommendation on crop protection in wheat, as issued by the Extension Service and interpreted by the manager of the experimental farm. One routine spray at ear emergence stage.

I: Intensive routine spraying according to an inflexible scheme (Table 1). This treat-

Table 1. Scheme of the intensive routine spraying treatment.

Spray number	Type of pesticide	Target (disease/pest)	Growth stage of the crop
1	fungicide	eyespot	30-31
2	fungicides	diseases on the leaf	32-37
3	fungicides + insecticide	diseases and aphids on leaf + ear	57
4	fungicides + insecticide	diseases and aphids on leaf + ear	71
5	insecticide	aphids	75

ment was introduced in 1982, and was thus not used in the 1981 trials.

The trials had a randomized block design with four to six replicates. Plot size was 105 tot 162 m^2 of which 32 to 54 m^2 was combine harvested. All crop husbandry measures, except disease and pest control, were taken according to local usage. Twenty-five trials involved the varieties Arminda or Okapi. These two varieties covered more than 80% of the winter wheat area in the Netherlands during the period 1981-1984. Field observations for the EPIPRE recommendation were made by the farm manager. The first observations were made in the last week of April and the last observations in the third week of July. The number of observations ranged from 4 to 8. For each treatment the equivalence in kernel yield of the costs of disease and pest control was subtracted from the kernel yield. Costs were calculated using the 1984 price of 0.45 Hfl kg^{-1} wheat. All costs were expressed per kg wheat per ha. For each spray three types of costs were calculated: 1) the costs of pesticides, 2) the costs of labour and use of machines, and 3) the costs of damage caused by driving through the field with the spraying machine (wheeltrack damage). For the costs of the pesticides the 1984 prices were used (Noordam and Van der Ham, 1984). The added costs of labour and use of spraying equipment were put at 50 kg ha^{-1}. This is about half the price a wheat grower would pay to have the spraying done by a contractor (Noordam and Van der Ham, 1984). For wheeltrack damage a fixed loss of 50 kg ha^{-1} per spray was assumed. This is about 0.5% of the total kernel yield.

Growth stages (GS) of the wheat crop are expressed using the decimal scale of Zadoks et al. (1974).

Statistical analysis of net kernel yield (yield after subtraction of costs) comprised analysis of variance. Least significant differences were calculated with Tukey's test at the 5% significance level.

Results

Table 2 shows the incidences of diseases and cereal aphids during the grain filling period in 1981-1984. These data were obtained from the 'Dutch Survey of Cereal Pests and Diseases' (Stol, 1985). Disease and pest severities in EPIPRE fields were scored in the second and third week of July (GS 73-77). *Septoria* spp. (*Septoria nodorum* (Berk.) Berk. and *Septoria tritici* Rob. ex Desm.) and cereal aphids (mainly *Sitobion avenae* (F.)) caused serious problems in all four years. Stripe rust (*Puccinia striiformis*

Table 2. Mean incidences of diseases and pests during the period 1981-1984. Observations were made in farmers' fields in the second and third week of July (GS 73-77).

Disease/pest	Year			
	1981	1982	1983	1984
eyespot	21[1]	10	35	10
stripe rust	<0.5	0.5	2	0.6
leaf rust	33	11	39	0.8
powdery mildew	12	7	9	22
Septoria spp.	40	47	36	36
cereal aphids	25	28	19	27

[1] Incidences are given as percentages of green leaves showing disease symptoms (rust, powdery mildew and *Septoria* spp.) or percentages of tillers with symptoms (cereal aphids and eyespot).

Westend. var. *striiformis)* was of only minor importance in this period. Eyespot *(Pseudocercosporella herpotrichoides* (Fron) Deighton) was a serious problem in 1983. Yield loss caused by leaf rust *(Puccinia recondita* Rob. ex Desm. f. sp. *tritici)* was important in 1981 and 1983. Powdery mildew *(Erysiphe graminis* DC. ex Mérat f. sp. *tritici)* was very important in 1984 and was also a problem in 1981 and 1983. On the whole, of these four years 1982 can be classified as a year with a low disese level, the other three years had relatively high disease levels.

The effects of disease incidence are reflected in the yields from the untreated plots. Table 3 gives the net yields (ton ha^{-1}), and the number of sprays against eyespot (f), diseases on leaf (1), diseases on ear and leaf (e) and aphids (a). Fungicide sprays (apart from MBC fungicides used against eyespot) were classified as belonging to class 1 (sprays against diseases of the leaf) if applied before ear emergence.

The low disease level in 1982 resulted in high yields in the untreated plots, and small benefits from treatments E, G and I. In all four years the mean benefit from use of EPIPRE was slightly less than, or equal to, the general recommendation. The intensive spraying scheme was introduced in 1982 and had a negative net effect on yield in that year. In the next two years treatment I yielded the greatest financial benefit, although in 1984 the differences with treatments E and G were very small.

The number of sprays in the various classes shows that there is a certain development in the EPIPRE recommendation. The advice model of the EPIPRE system was adapted at the end of each year. The main adaptation in the period 1981-1984 was a large reduction of the threshold values for spraying against *Septoria* spp. When incidences of leaf and ear diseases, and the yields from the untreated plots are compared, the years 1981 and 1983 are much alike. In 1981 EPIPRE recommended a disease spray after ear emergence in only one out of the eight trials. In 1983 this changed to three out of four trials. This spray, which is aimed mainly at controlling *Septoria* spp. during the grain filling period, is the main difference between treatments E and G: EPIPRE does not recommend routine spraying. After reduction of the thresholds for *Septoria* spp. the difference between treatments E and G was very small, as can be seen by comparing the yields and numbers of sprays in E and G for 1984.

Table 3. Yields and number of sprays in the EPIPRE verification trials. Kernel yields (in ton ha^{-1} at 16% moisture or as a percentage of the yield from untreated plots) after subtraction of the costs of disease and pest control.

Year	Region	Yields				Lsd	Number of sprays											
		U[1] (ton ha^{-1})	E (%)	G (%)	I (%)	T (%)	E				G				I			
							f	l	e	a[2]	f	l	e	a	f	l	e	a
1981	NC[3]	7.24	117	116		21	•	•	•	1	•	•	1	1				
	NC	6.92	101	104		9	•	•	•	1	•	•	1	2				
	CC	8.02	105	109		3	•	•	•	1	•	1	1	2				
	CC	7.56	99	100		—	•	•	•	1	•	•	1	1				
	SC	7.33	103	108		2	1	1	•	2	1	1	1	1				
	SC	7.23	113	113		9	•	1	1	1	1	1	1	1				
	SS	5.83	101	114		5	•	1	•	1	•	1	1	1				
	LS	5.86	118	119		8	•	1	•	2	•	1	1	2				
mean		7.49	107	110														
1982	NC	8.14	98	102	101	9	•	•	1	1	•	•	1	1	1	1	2	2
	NC	7.76	100	100	98	9	•	•	•	•	•	•	1	2	•	•	2	3
	CC	8.91	102	103	96	6	•	•	•	1	•	•	1	2	1	1	2	3
	CC	8.62	100	98	92	4	•	•	•	1	•	•	1	2	1	1	2	3
	CC	8.79	101	104	94	3	•	•	•	1	•	•	1	1	1	1	2	3
	SC	8.07	103	103	95	7	•	1	•	1	•	1	1	1	1	1	2	3
	SC	9.96	100	99	95	5	•	•	•	•	•	•	1	1	1	1	2	3
	PS	7.42	100	111	109	10	•	•	•	•	•	•	1	2	•	1	2	2
	SS	6.17	102	102	93	7	•	•	1	•	•	•	1	•	1	1	2	1
	LS	6.73	108	109	113	8	•	1	1	1	•	1	1	1	1	1	2	2
mean		8.06	101	103	98													
1983	NC	6.45	101	127	129	13	•	•	1	1	1	•	1	1	1	1	2	2
	CC	7.90	103	101	102	5	•	1	•	1	•	1	1	1	1	1	2	3
	SC	7.51	100	100	102	4	•	1	1	1	•	1	1	1	1	1	2	2
	PS	5.51	97	92	109	10	•	2	1	1	•	1	1	1	1	1	2	2
mean		6.48	100	105	110													
1984	NC	7.07	105	99	103	—	1	•	•	1	1	•	1	•	1	1	2	3
	CC	7.50	107	105	111	5	•	•	1	2	•	•	1	1	1	1	2	3
	SC	7.80	107	107	103	4	•	1	1	•	•	1	1	1	1	1	2	2
	PS	3.92	146	160	163	7	•	1	1	1	•	1	1	1	•	1	2	2
	LS	7.97	99	103	98	5	•	1	1	1	•	•	1	1	1	1	2	2
mean		6.85	109	109	110													

[1] Treatments: U) untreated; E) EPIPRE recommendation; G) general recommendation; I) intensive spraying scheme. T: least significant difference (Tukey).

[2] Sprays: f) spray against eyespot; l) spray against diseases on the leaf (before ear emergence); e) spray against diseases on ear and leaf (after ear emergence); a) spray against cereal aphids.

[3] Regions: NC) northern marine clay; CC) central marine clay; SC) southwestern marine clay; PS) peaty soil; SS) sandy soil; LS) loess soil.

Table 4. Number of positive and negative differences in net kernel yield between treatments and number of significant differences.

Value	Differences between treatments					
	E-G[1]	E-U	G-U	E-I	G-I	I-U
Positive						
total	9	19	23	8	11	11
significant	0	9	12	7	7	6
Negative						
total	16	6	4	11	8	8
significant	7	0	0	3	2	4
Equal	2	2	0	0	0	0

[1] Treatments: U) untreated; E) EPIPRE recommendation; G) general recommendation; I) intensive spraying scheme.

Table 4 gives for all the trials of the period 1981-1984 the total number of positive and negative differences in net kernel yield and the number of significant positive and negative differences. The EPIPRE recommendation gave a higher net yield than treatment G in nine trials, but none of these cases were significant. In sixteen trials treatment G resulted in a higher net yield than the EPIPRE treatment, seven of these cases being significant; three of these were on peaty or sandy soil, where *S. nodorum* is a main problem. In nine cases (33%) the EPIPRE plots gave a significantly higher net yield than the untreated plots. For the G plots such was the case in twelve trials (44%). In none of the trials did the untreated plots have a significantly higher net yield than the plots with treatments E or G. In four cases the untreated plots gave significantly higher yield than those under treatment I, whereas in six cases the reverse result was obtained.

Table 5 gives the mean treatment indices for the years 1981 to 1984. The treatment index is the number of spraying operations for disease and pest control per field. The treatment index for the routinely sprayed treatment I was fixed at 4 or 5. In 1983, the opportunities for spraying were limited by extremely wet weather, and treatment I had

Table 5. Mean treatment indices for the four treatments in the trials and for the participants of the EPIPRE system in the period 1981-1984.

Year	U[1]	E	G	I	Participants
1981	0	1.9	2.8	•	1.6
1982	0	1.1	1.9	4.4	1.4
1983	0	2.8	2.8	3.8	2.1
1984	0	2.4	2.2	4.6	2.3

[1] Treatments: U) untreated; E) EPIPRE recommendation; G) general recommendation; I) intensive spraying scheme.

Table 6. Average total costs (kg ha^{-1}) and average costs of pesticides for the treatments in the trials.

Year	Total costs				Pesticide costs		
	U[1]	E	G	I	E	G	I
1981	0	340	640	•	150	360	•
1982	0	230	490	1190	120	300	750
1983	0	690	800	1090	410	520	710
1984	0	570	590	1210	330	370	750

[1] Treatments: U) untreated; E) EPIPRE recommendation; G) general recommendation; I) intensive spraying scheme.

a mean treatment index of 3.8. In 1981 and 1982 the treatment index of treatment E was 0.8-0.9 less than that for treatment G. In 1983 and 1984, two years with high disease pressure, the treatment indices of treatments E and G were similar. The increase in the treatment index of the EPIPRE treatment was caused by the adjustment of the EPIPRE model for *Septoria* spp. and the development in mildew of insensitivity to some important chemicals; this led to repeated recommendations to treat mildew. Comparison of these treatment indices with the mean treatment indices of the fields of EPIPRE participants shows that in 1981 and 1983 the treatment index on farmers' fields were lower than those in our trials. In 1982 and 1984 the mean treatment index in farmers' fields was between the values for treatments E and G; it was about half the value of that in the intensively sprayed treatment.

Table 6 gives the average total costs and the average pesticide costs for disease and pest control. Comparison of two years with similar disease incidences, 1981 and 1983, shows that the changes in advice rules in the EPIPRE model and the development of insensitivity of mildew to some chemicals doubled the total costs of disease and pest control. The costs of pesticides had increased more than twofold. In 1983 and 1984 the differences in mean costs between treatments E and G were small. In 1984 treatment G had higher mean costs than EPIPRE, but had a lower treatment index; expensive mixtures of pesticides were used in the general recommendation.

Discussion

In 1978 several factors led to the introduction of the EPIPRE system for supervised disease and pest control in wheat. The farmers demanded more information on crop protection in wheat, after the heavy outbreaks of stripe rust and the introduction of new, powerful fungicides (triadimefon, fenpropimorph and propiconazole). A completely new approach was introduced: the demand was present and the means (epidemiological knowledge, especially on stripe rust, and computer facilities) were available. Other factors that stimulated the initiation of this advice system were an awareness of the environmental dangers of the increasing use of pesticides in wheat, and doubts about the economic benefits of that approach. The start of EPIPRE coincided with a lively discussion on the applicability, in the Netherlands, of intensive wheat cropping systems with high inputs of pesticides and fertilizer. This discussion was stimulated by the development of such systems in Germany.

The results of the trials show that in 1981 and 1982 the EPIPRE recommendation was more restrictive of the number of pesticide sprays than the general recommendation. The total cost of the EPIPRE treatment was half, or less, of the costs of treatment G. For the costs of pesticides the ratio was even lower. The main difference between EPIPRE and the general recommendation was the application of a mix of fungicides (mainly against *Septoria* spp. after ear emergence for protection of the flag leaf and the ear during the grain filling period. In 1981 the disease level was relatively high, whereas 1982 had an extremely low disease level. Comparison of the net yields of the EPIPRE treatments with the general recommendation led to a considerable adjustment of the EPIPRE recommendation, especially for the *Septoria* spp. This is reflected in the number of sprays in 1983 and 1984. The difference with treatment G disappeared, in those two years of relatively high disease pressure.

After adjustment of the EPIPRE recommendation at the end of 1982, the recommendations for leaf and ear diseases were satisfactory, but the differences with treatment G were slight. In 1983 and 1984 the EPIPRE treatment resulted in equal or higher yields compared to treatment G in six out of the nine trials. However, in none of these six trials was there a significant difference. In the three trials in which EPIPRE yielded less than treatment G, two of the differences were significant. In one case (1983) this was caused by an unexpected outbreak of eyespot, in the other case (1984) the time delay of the EPIPRE recommendation was the cause of the difference. This delay, caused by slow postal communication was a disadvantage for EPIPRE for many years. At the end of 1984 communication by mail was abandoned and recommendations are now given by telephone.

The development of the EPIPRE system, based on experiences both on farmers' fields and in experimental plots has not resulted in a large reduction of pesticide use compared to the general recommendations. To be economically equivalent to treatment G, about the same intensity of pesticide use was required, although the number of pesticide mixes as recommended by EPIPRE is somewhat lower. With the increased applicability of the EPIPRE system for farmers, positive effects on environment declined. On the other hand it should be noted that the considerable attention paid to the EPIPRE system by farmers, scientists and politicians has influenced general recommendation. Dutch farmers did not turn, in large numbers, to high-input cropping of wheat with many routine sprays. With only one or two routine sprays, Dutch cereal farming cannot be classified as very intensive, in comparison to the intensive wheat production systems in the UK and W. Germany (ADAS, 1983). In those systems at least ten sprays are applied to control pests and diseases.

The 'general recommendation' treatment was intended to give results comparable to those of the average farmer. It is highly questionable whether this comparison is valid. Despite some efforts it was not possible to avoid an interdependence between the treatments E and G. For practical reasons, in most cases the observations for the EPIPRE recommendation and the decision to spray in treatment G were taken by the same person. The spraying decisions for treatment G were undoubtedly influenced by the repeated and precise observations done for the EPIPRE treatment. Althoug this does not change the facts that in many cases treatment G gave better results than EPIPRE, it is doubtful whether a farmer who does not use the EPIPRE observation method would reach the same results. Treatment G therefore could be better described as disease and pest management applied by a farmer with above average knowledge of wheat growing and crop protection (a manager of an experimental farm) who inspects his crop repeatedly using a good observation method, and then makes his own decision about spraying. Clearly this is a rather uncommon situation, and the trials show that such a farmer does not need the EPIPRE recommendations. Farmers with less knowledge of disease protection may still profit from the EPIPRE system. Blokker (1984) interviewed 232 EPIPRE participants and 125 non-participants. Participants reported an improved discipline in disease and pest observation and an increased knowledge of disease symptoms, spraying thresholds and pesticides. Blokker found no yield differences between participants who followed the EPIPRE recommendation and farmers who sprayed more often. he concluded that the educational effects of the EPIPRE system should be emphasized. The results of these trials confirm his conclusions.

Intensive routine spraying did not give good results in a situation when disease incidences were low (1982), although, surprisingly, the high costs of this system were almost compensated by higher yields even in a healthy year such as 1982. In 1983 and 1984, with high disease levels, treatment I gave the highest average net yields, although the advantage over the EPIPRE and the general recommendation was very slight in 1984. Yield levels were very high in these trials (in 11 out of 19 trials the gross yield of treatment I was above 9 ton ha) and, in most cases, were not limited by nutritional factors or water supply. Gross yield in these trials shows a high degree of elasticity: in most cases the costs of one or two additional sprays will be compensated by an increase of yield. The reason for this is probably incomplete control of the diseases by the pesticides. EPIPRE recommends a spray when the predicted severity at the end of the prediction period is above the threshold value for a disease or pest. it is assumed that practically no damage will result when a spray is applied at this stage. This assumption is true only when three conditions are satisfied:

First, the prediction of the development of disease or pest severity must be accurate. Relative growth rates must be correctly related to crop development stage, varietal susceptibility, nitrogen fertilization, soil type and other factors. Although under extreme weather conditions the EPIPRE predictions for a particular disease can be wrong (e.g. eyespot predictions in 1983), in general we do not believe that this is the main reason for the unexpected yield increases when more sprays were applied than EPIPRE recommended.

Second, the duration of the prediction period must be long enough. The damage that has already occurred when the spray is applied should only be a minor fraction of the economic threshold. For some diseases (e.g. leaf rust) EPIPRE makes a prediction up to the development stage of the crop when disease development will stop. In some cases the chance of making large errors in predictions has led to shorter periods: for cereal aphids the longest prediction period is 14 days. In general, the prediction periods in the EPIPRE model do not seem to be too short. In most situations spray recommendations are given at low incidences, when very little damage is likely to have occurred. The delay caused by postal communication in some cases increased the damage that had already occurred when the spray was applied or has led to disease levels at which effective control was no longer possible. That was the case with a spray against *Septoria* in the 1984 experiment on peaty soil.

Third, the pesticide should control the disease completely. EPIPRE was originally concerned with stripe rust, a disease that can be almost completely eradicated with the pesticides now available. In cereal aphids a 100% kill is also nearly possible. pesticides recommended for the *Septoria* species and for leaf rust only partially control the development of these diseases. For mildew in 1978 the situation was comparable to that of stripe rust, but because the fungus has developed insensitivity to some pesticides, many sprays now give incomplete control. When the development of a disease is only partially controlled by a chemical we can expect 'the law of diminishing returns' to hold when a number of sprays is applied to control this disease. R.A. Daamen (pers. comm.) has estimated that one spray with captafol can prevent only two thirds of the damage caused by *S. nodorum*. Additional sprays, above the level of EPIPRE recommendation, may often be economically worthwhile because of this incomplete disease control. For a further development of the EPIPRE system, in addition to the models for disease and pest development, modelling of the activity and efficiency of pesticides is needed.

Even though the ratio of pesticide costs to effectiveness currently favours high inputs, that crop protection strategy has other disadvantages that make it unattractive. The mean net yield of treatment I is hardly higher than that of treatment G, but a much greater input of pesticides was used; the quality of food and environment is unnecessarily endangered. Furthermore, the economic gains from use of treatment I can be expected to fall in the next years owing to the decline in wheat prices in the European Community and in the efficacy of pesticides. Even the fairly restricted use of ergosterol biosynthesis inhibitors in Dutch wheat growing since 1978 has led to a decreased sensitivity to some of these chemicals in the mildew population within five years (De Waard et al., 1985). On fields sprayed routinely against eyespot, five sprays were sufficient to select for insensitivity. In the long run, high input routine spraying strategies are not stable and are not in the interest of farmers, consumers or pesticide producers.

Comparable trials in Switzerland (Forrer and Amiet, 1983; Forrer, 1985) gave better results for the EPIPRE system. In both 1982 and 1984, EPIPRE had a mean treatment index of 0.6 while the treatment indices of the spraying scheme based on the farmers' decision were 1.2 and 1.4, respectively. Net yields from the two treatments were equal in 1982 (5.7 ton ha^{-1}) and in 1984 the net yield of the EPIPRE treatment was 1% higher (7.3 ton ha^{-1}). The low yields in the Swiss experiments, compared to the Dutch trials, seem to indicate that other factors than diseases and pests are limiting wheat production. This could be the reason that in Switzerland additional sprays are rarely of benefit.

In Belgium the EPIPRE system was tested in five trials in 1983 (Geypens, 1983). The results were satisfactory for the EPIPRE system: an average increase in net yield of 15% relative to that in untreated plots, whereas the treatment based on the farmers' decision gave a mean net yield increase of 13%. Here also, however, the conclusion was that the timing and character of the sprays recommended by EPIPRE were very similar to those in the farmers' decision treatment.

After seven years of practical experience with EPIPRE and four years of verification trials the following conclusions can be drawn. EPIPRE has had a positive effect on Dutch and European phytopathological research; simple and reliable observation methods have been developed; relations between incidence and severity and between severity and damage have been determined experimentally; the development of insensitivity to pesticides has been monitored and contacts between epidemiologists and farmers have intensified. The EPIPRE advice models for stripe rust, leaf rust, mildew and cereal aphids have been shown to be reliable. the advice model for *Septoria* spp., especially *S. nodorum* on peaty and sandy soils, requires further improvement.

Problems with the prediction of severity and damage of septoria diseases are the main reason that EPIPRE had better results on clay soils, where these diseases are less dominant, than on sandy or peaty soils. During the course of these EPIPRE trials, some large research projects have been started to improve the advice model for *Septoria* spp. The EPIPRE system has influenced general crop protection practice and has helped to prevent the introduction of high-input, routine spraying. In this way it has had positive effects on environmental protection, although the effective reduction in pesticide use by EPIPRE was smaller than was expected at the start of the project. Farmers report that they appreciate the educational aspects of EPIPRE (Blokker, 1984), but EPIPRE probably gives few short term economic benefits for the farmer. The increase of gross yields when extra sprays are applied above the level of EPIPRE recommendation limits the participation in the EPIPRE system. Participants benefit from the educational effects of the EPIPRE system; they can reach the same level as experienced managers of experimental farms, but after some years of experience they probably no longer require the EPIPRE recommendations, provided they are disciplined enough to continue making field observations at regular intervals. The future of the EPIPRE system lies therefore in a change from a decision system to an information system, with direct access of the farmer to the information programmes by means of his own microcomputer or terminal. New varieties, new pesticides or reduced efficiency of pesticides will create a demand for information, e.g. about a pesticide strategy that will lengthen the lifetime of pesticides. This system of information on disease and pest management can be incorporated into a computerized management system for wheat growing, that will also include information on nitrogen application, weed control, use of growth regulators and choice of variety.

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Samenvatting

Experimentele verificatie en ontwikkeling van EPIPRE, een systeem voor geleide bestrijding van ziekten en plagen in tarwe

Van 1981 tot 1984 werden 27 proeven uitgevoerd om het EPIPRE-systeem voor geleide bestrijding van ziekten en plagen in tarwe te evalueren en verder te ontwikkelen. De resultaten van deze experimenten gaven aanleiding tot een forse aanpassing van het EPIPRE-advies voor *Septoria* spp. Na deze aanpassing verschilden het EPIPRE advies en het Algemene advies, zoals gegeven door de Voorlichtingsdienst, nog slechts weinig wat betreft het aantal en het type van de bespuitingen en de netto opbrengst. De EPIPRE-adviesmodellen voor gele roest, bruine roest, meeldauw en bladluizen bleken te voldoen. Voor *Septoria* spp. en het modelleren van de werking en efficiëntie

van bestrijdingsmiddelen is meer onderzoek nodig. De reductie in het gebruik van bestrijdingsmiddelen door gebruik van EPIPRE bleek minder te zijn dan aanvankelijk werd verwacht. Een van de redenen hiervoor is dat het gebruik van bestrijdingsmiddelen in de tarweteelt in Nederland laag is in vergelijking met omringende landen. Vaker spuiten dan EPIPRE adviseerde bleek vaak economisch verantwoord, maar het voordeel t.o.v. EPIPRE of het Algemene advies was klein en geeft geen reden om over te gaan tot intensieve bestrijdingsregimes. Deelnemers aan EPIPRE waarderen de educatieve aspecten van het systeem, maar hebben waarschijnlijk op korte termijn slechts weinig economische voordelen van deelname. Dit bemoeilijkt de uitbreiding van het aantal deelnemers. In de komende jaren zal de EPIPRE-advisering ingebouwd worden in een compleet geautomatiseerd teeltbegeleidingssysteem, dat alle belangrijke teelthandeling van zaaien tot oogsten zal bevatten.

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