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Suggested Methods for Determining the Efficacy of Vertebrate Control Agents in Developing Countries

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ABSTRACT: Toxic and repellent chemicals and devices are available in some countries as tools for reducing agricultural crop losses to vertebrate pests. Determining the benefits of these materials usually requires testing and evaluation programs in many environments and against many species. In developing countries, however, replicated test designs and the associated sophisticated statistics normally cannot be used. Varied sizes of test sites, nonuniformity of cultural practices, limited staff, varied ability of technicians, and the multiplicity of depredating species are some of the more important reasons for this. Some method of demonstrating efficacy, using acceptable procedures, needs to be conducted under the conditions of actual use. Systematic-random sampling patterns and simplified data collection procedures are suggested. Many examples are drawn from field trials conducted in developing countries, primarily in Africa, over the past several years.

KEY WORDS: cereal crop losses, bird pests, rodent pests, *Quelea*, *Rattus*, developing countries, Africa, Philippines, chemical test protocols, chemical test limitations, vertebrate pest control

The ultimate aim of developing and evaluating management techniques against vertebrate pests in any country is to reduce crop losses. In the United States it often is extremely difficult to accommodate all the criteria of good trial design as proposed by Ingram [*1,2*],[3] and the efficacy test requirements established by the U.S. Environmental Protection Agency (EPA) or sug-

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gested by the American Society for Testing and Materials (ASTM) are complex and difficult to attain.

Rodenticide test protocols exist, but bird toxicant and repellent protocols need to be developed [3]. Martin and Jackson [4] presented in detail some of the procedures and considerations in the actual application and testing of bird repellent chemicals to different types of cereal crops in Africa, but they did not fully discuss the logistic considerations inherent to these countries. The objectives of test protocols for bird chemicals are different in developed and developing countries. Test protocols in the United States serve producers, users, regulatory agencies, and environmental groups [3]. User and registration interests are of primary importance in developing countries, and since nontraditional methods for protecting crops from birds have only recently been introduced into developing countries, suitable testing methods are especially needed.

When working in developing countries, one must consider the unique circumstances. These include limited numbers of trained and motivated plant protection personnel, lack of technical expertise or appreciation by farmers, extreme financial limitations, and the absolute necessity for farmers or village cooperatives to harvest crops. Geographical isolation, frequently coupled with only one cropping season, accentuates the dependence of the traditional subsistence farmer on food production and puts additional pressure on researchers or technicians to find immediate relief for pest problems and to work within a short time frame and within the physical constraints of actual farming practices. Some degree of immediate crop protection often must take precedence over long-term, sophisticated research. Our purpose is to indicate some of the more prevalent limitations in developing countries, to propose ways to work within these constraints, and to consider the validity and usefulness of results derived from such demonstrations.

Site Selection and Test Design

Design is the most important part of any experiment [2]. According to Gomez and Gomez [5], proper experimental design should include replication, randomization, and local control or arrangement of any treatments to eliminate known causes of variation. In developing countries, these test design criteria can often be met on agricultural research stations, where extreme variation due to extraneous factors, such as individual farming techniques and chemical-use patterns, is minimized. The principal disadvantanges to working at these sites are that one usually obtains unreplicated, small, closely associated fields of <0.25 ha, and the use of small plots may give highly variable results and negate a valid evaluation of a chemical [6, 7].

Site selection and test design are important in an experiment to ensure that results are consistent, repeatable, and unbiased. Theoretical considerations

usually lead to conducting trials under conditions in which too many variables are removed. This can often lead to results that are impractical under actual farming situations.

It is our opinion that crop protection techniques ultimately must be field tested under conditions approximating actual cropping practices. For this reason, a random block design using small plots and incorporating more than one treatment, which was used in Chad [*8,9*], seems inappropriate for testing bird repellents. Such designs do not allow birds to make individual treatment-related responses, and they make interpretation of the results nearly impossible. It is also difficult to interpret the results of tests in which a single field has been split, either visually with markers or physically by a vegetationless band between plots.

Inflated positive results, for example, may occur because the birds simply moved from the treated to the untreated part of the field, as was the case at Darou, Senegal [*10*]. An "area repellency" effect, in which bird numbers in the untreated part of the field diminish, also may occur. Likewise, positive overall yield differences may be masked if repelled birds remain in the test area to feed in the untreated portion of the field but repeatedly visit the treated area, a situation that existed with rice fields in Afgoi, Somalia [*11*]. As noted by DeHaven et al [*12*], the importance of large, independent, separated fields in testing bird chemicals cannot be overemphasized.

In some situations, we feel it is preferable to forgo replication. If only two fields are available, one should be treated and the other left untreated, or if there is only one field, it should be treated and another criterion (such as observing the behavior of the birds) identified as a measure of control. Such trials become, in effect, simple plot demonstrations; these need to be qualified but can be considered replicated if similar techniques are repeatedly used elsewhere.

Several other alternatives to replication also exist. A number of small plots in a field might be put under protective netting to give a measure of expected yield with which chemically treated areas can be compared. Alternatively, damage and yields can be compared from year to year at a particular trial site. It is necessary to assess such results cautiously and over several years because of annual variations in farming practices, bird numbers, climate, and efficiency of government control operations; but trends become readily evident. For example, at Melkassa in Ethiopia, the Ethiopian Sorghum Improvement Project has applied methiocarb to 12 to 15 ha of variety trial sorghum since 1977, with only 2.0 to 22.1 percent loss. Losses of 42 percent occurred in 1976 when the chemical was not used [*4,12*].

Similarly, since 1976 in Tanzania, a private farmer has been spraying methiocarb on those parts of his 1125-ha farm that were being damaged by birds. The overall damage was <5 percent each year, except in 1978, when he was unable to obtain methiocarb and suffered 86 percent losses [*11*].

Neither of these situations is statistically testable, but both suggest the efficacy of the chemical; in both cases methiocarb probably will continue to be used as long as positive results are obtained.

Other examples demonstrate how evaluations can be performed despite test site limitation. In West Africa, we were asked to evaluate methiocarb and protective barriers of fishnets and Cryldé (an acrylic fiber which can be spread in a weblike fashion over a crop) on 2 ha of ripening rice [*14*]. Since herbicides had not been applied to 2000 m^2 at one end of the field, we also took the opportunity to gather some preliminary comparative data on the relationship of weed seed availability to bird damage in methiocarb-treated fields. Testing methiocarb was our primary objective, but from the plot design, and limitations in our quantities of fishnet and Cryldé, it became evident that replication and randomization possibilities were restricted (Fig. 1). Nevertheless, the results of this demonstration indicated that methiocarb has promise as a repellent, indicated the value and importance of herbicide treatments to successful protection efforts, and provided information on the usefulness of fishnets and Cryldé (Fig. 2). This work provided a basis for some preliminary suggestions to agronomists and farmers as well as some direction for future work.

Holcomb [*15*] also compensated for the absence of replication and control sites in an Av-Alarm trial on rice in Somalia by duplicating his test procedures at the same site in 2 successive years. He evaluated the Av-Alarm's success by quantifying the damage in concentric half-circles at regular intervals for 250 m and at 1200 m from the speakers. In both years, the damage increased linearly with distance.

Due to time limitation and crop phenology patterns, crop protection work in Uruguay by Calvi et al [*16*] was of short duration and usually consisted of single-plot demonstrations (Table 1). The results from several tests, in which each chemical and crop condition was consistent, showed that methiocarb seed dressing could protect sprouting crops, that methiocarb protection of ripening crops warranted further, larger-scale work, and that 4-aminopyridine (4-AP) affects monk parakeets and has potential use as a method of protection. Again these results provided the Uruguayan government with some potential crop protection methods and researchers with information on which to base future work.

Damage Assessment Methods

The methods used for assessing damage in crop protection work should be simple, yet accurate within logistic limitations. Several methods may be appropriate in large areas [*4*]. A systematic-random sampling pattern (systematically spaced transects and sampling points along the transects, with random selection of panicles at the sampling points), established throughout the fields at the trial onset, has many advantages. The sampling locations can be marked with stakes, which can be used as focal points for objective sampling

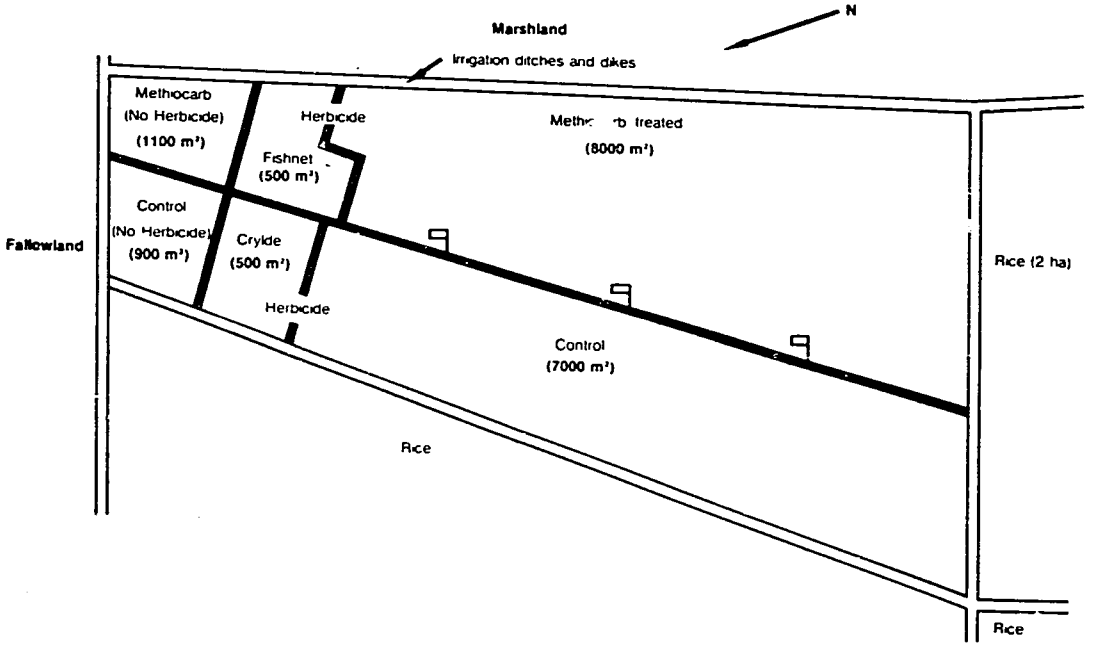

FIG. 1—*Plot design for field trials with methiocarb, herbicides, and netting in rice fields (Senegal).*

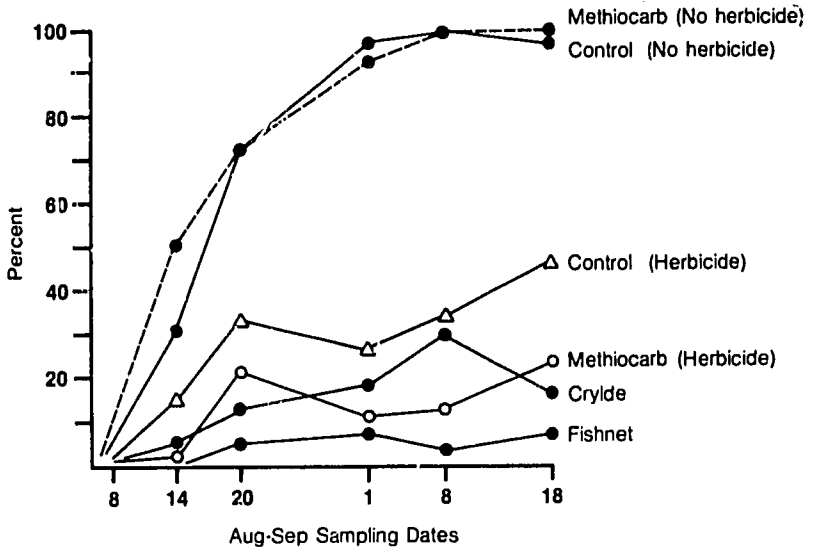

FIG. 2—*Percent of rice heads damaged by ploceids following chemical treatments or installation of nets.*

throughout the ripening period and at harvest. For partial field treatments (edge or alternate band), it may be advisable to have some sample locations in treated and untreated parts of the field for comparisons. Simple, objective, quantitative methods are highly desirable.

Rats (especially *Rattus rattus*) can be serious depredators of coconuts, and losses may be of considerable importance in island environments. As a basis for evaluating damage and the effectiveness of control measures, Wodzicki [*17*] established fourteen 2500-m^2 quadrats on various atoll islets in the Tokelau Islands. Rat-damaged nuts were counted (as high as 84 percent), but the variation was so great among the quadrats that conclusions could not be drawn on the success of the control operation.

Crop damage should be evaluated periodically throughout the vulnerable period to determine loss trends, observe sudden changes in damage rates, note the immediate effect of a chemical application, and provide a measure of results if the field is unexpectedly harvested early, as often happens. A useful method is to mark points in a field with plastic tape and repeatedly score a certain number of panicles (5 or 10 per sampling unit) as damaged or undamaged. It is necessary to compensate for heterogeneous development within the field. The drawbacks to visual assessment techniques are discussed by Martin and Jackson [*4*].

Final assessments of these demonstrations or trials can be based on the number of plants [*18*] or the weight of panicles within 0.5-m^2 or 1.0-m^2 plots [*11*]. Alternatively, linear measurements of damage on millet and maize [*20*] can be made on the premarked heads. Total harvest yields sometimes can be used but frequently are inaccurate because of extremely variable field sizes

TABLE 1—*Crop protection trials in Uruguay between 1973 and 1975.*[a]

Crops	Replications	Treatment Form	Chemical	Final Assessment		Bird Pests
				Untreated	Treated	
Sprouting						
Soybeans	1	seed treatment	0.25% methiocarb	34% loss	0.6% loss	doves
Rice	1	seed treatment	0.30% methiocarb	28 000 plants/ha	917 000 plants/ha	ducks
Sorghum	3	seed treatment	0.10% methiocarb	83% loss	0.2% loss	doves
Ripening						
Sorghum	1	ground application	methiocarb 5.6 kg/ha	21% increase	12% increase	doves
Sorghum	[illegible]	aerial application	methiocarb 3.0 kg/ha	29.1% increase	17.4% increase	doves
Sorghum	1	aerial application	methiocarb 3.0 kg/ha	14% increase	14% increase	doves
Corn	1	ground application to open ears	8% 4-AP[b]	...	95% reduction in bird numbers	monk parakeets, doves, cowbird (*M. badius*)
Corn	1	ground application to open ears	12% 4-AP	...	10 affected birds within 2 h	monk parakeets
Sunflowers	1	ground application to selected heads	4% 4-AP	...	33% reduction prior to rain	monk parakeets
Sunflowers	1	ground application to selected heads	16% 4-AP	...	60% reduction	monk parakeets

[a]Data compiled from the trial descriptions in Calvi et al [16].
[b]4-AP is used to designate 4-aminopyridine.

and dimensions and improper reporting of yields for various reasons. As previously mentioned, comparisons among annual yields are sometimes appropriate but do not permit statistical analysis.

Bird damage to fruits is obvious, usually occurs suddenly just prior to harvest, and often is devastating. The testing of methiocarb as a topical repellent has provided many examples of evaluation designs. The typical protocol in California [*20*] required plots several hectares in size with contiguous planting of one variety of one age. A randomized complete block experimental design was established, and complex damage evaluation techniques were used. In Ohio, where vineyards are smaller and contain grapes of mixed varieties and ages, the same procedure was inappropriate, so a systematic-random sampling procedure was used [*21*]. In developing countries, where such problems frequently are exacerbated, a further simplification of design is required. Often no more than a simple procedure (such as every other row, every tenth plant) can be justified for damage evaluation, and sample sizes may be small. Although formal statistical assessment may not be applicable, the results can be clearly obvious to those involved in the work.

More sophisticated evaluations are possible in developing countries where sufficient resources and training have been devoted to a pest problem. One excellent example is that of evaluation of rat damage to rice in the Philippines. Wholly randomized sampling procedures were used to determine cut tillers, and nearly 1600 rice fields throughout the country were surveyed [*22*]. This sophisticated and extended approach was possible because of the extensive cooperation between the Philippine government and the U.S. Agency for International Development, which provided for training of a cadre of field technicians.

The main value of rigorous test designs (unlike single plot demonstrations) is that they ensure that the right kinds and amounts of data will be collected during the experiment [*1*], thereby ensuring that the results can be statistically tested to remove subjectivity. However, a trial situation which cannot be statistically tested may, in fact, be biologically effective. When test designs that enable statistical assessments are not practical, the trial must rely on creative and innovative features that enable experienced observers to assess the results. If crop yields consistently satisfy the farmers, the control practices must be considered successful. Fall [*23*], commenting on the differences between proper research and practical evaluations of management strategies, concluded that a program is ultimately successful if it delivers repeatedly consistent protection.

Evaluating Vertebrate Pest Populations

Identifying pest species and obtaining detailed observations of their behavior patterns, food habits, and numbers are important components of any

crop protection field trial. The numbers of birds can be assessed relatively accurately by flushing them from the fields [*24*] and counting the departing birds. It also is desirable to collect some birds for food habit analysis, since the presence of large numbers of birds in a field is not always synonomous with heavy damage. At certain times of the year, they may be eating insects in cultivated crops, as was the case with village weavers (*Ploceus cucullatus*) in sorghum in The Gambia (Bruggers, personal observation) and red-billed quelea (*Quelea quelea*) in wheat in Tanzania [*25*]. The collection site must be carefully chosen and acceptable for mist netting, since gun permits may not always be obtainable.

The species composition can be determined by identifying birds flying past set locations or by counting the numbers of each species in a binocular's view in the field or along its borders at regular intervals. Pretreatment observations are necessary, because birds might abandon an entire trial site following application of a repellent, so that no yield differences between treated and untreated fields are evident. This situation occurred several times in evaluations of the repellent Curb [*26*].

It is desirable that all observations be made systematically throughout the duration of the trial and at regular intervals during the main feeding period (usually the morning and late afternoon for passerines and occasionally at night in waterfowl damage situations). However, because poor roads and vehicle and gasoline shortages plague most developing countries, it often is unrealistic to expect an observer to visit a site more than twice a week or to begin his observations at the same time each day. Schedule modifications will be necessary for many reasons unimaginable to people that have not worked in developing countries. The importance of bird observations in crop protection work in developing countries must be stressed, but their primary purpose is to supplement damage and yield data and, perhaps, to explain any inconsistencies in results. Reductions in bird numbers cannot be regarded as the sole measure of a treatment success, because other variables can greatly influence that success [*2*].

Many studies to evaluate rodent population reduction have required mark and recapture procedures that often are impossible in highly urbanized areas as well as in developing countries. The lack of budget or manpower and the loss or damage of traps are major impediments. Usually an estimate or determination of the actual population is not necessary, and some activity index is quite sufficient. The use of active rat burrows has been successful in Cleveland [*27*] and Chicago [*28*] in evaluating the efficacy of new rodenticides. The measure of control was the proportion of burrows reopened following burrow closure (pushing dirt into the entrance) [*29*]. Such an approach might be followed when evaluating treatments along rat-infested bunds in irrigated crops or in any situation where burrows are readily observed. Other evaluative techniques (tracks, droppings, bait consumption, movements, and so on) can be considered when appropriate [*30*].

Local Cooperation in Testing Situations

Optimally, crop protection techniques should be field tested with farmers after they have proven promising in controlled circumstances. However, working with farmers in developing countries presents additional concerns and test design difficulties. Compromises usually are necessary. For example, to have comparably sized fields with replication and similar sowing dates, flooding periods, and bird vulnerability in a rice seed dressing trial in Senegal, we were obliged to work with five different farmers. The level of experience varied from several years of farming to virtually none (newly resettled war veterans). As such, their locations in the irrigated scheme also varied: the farmers with the most experience had the preferred sites with the least chance of salinization. To eliminate additional variability, we visually separated their approximately 2-ha fields into treated and untreated plots of equal size. It was then necessary to ensure that the seeding rate (and variety) both in plots and among farmers was identical, that reseeding certain areas (particularly the untreated plots) was avoided, and that water control patterns and bird scaring activities were similar. These kinds of considerations are usual in most crop protection work in developed countries, but the chances that such variables will be inexplicably altered by individual farmers (without informing the researcher) seem much greater in developing countries.

The farmer's practice of scaring birds from fields is one that in many cases will have to be incorporated, and therefore considered, in most trial designs in developing countries. It is a traditional practice which a farmer is reluctant to abandon unless he is convinced that an alternative method is completely effective. One solution is to ensure that the farmer's scaring efforts are equal in treated and untreated fields; however, if a method is working in one part of the farmer's field, he is likely to concurrently increase his scaring effort in the untreated fields!

It is difficult to convince landowners participating in a trial that part of their crop should be left untreated. Landowners question the need for an untreated area if they expect it will receive heavy damage, and the use of such a check area can cause real problems in public relations. In such a situation, use past damage or perhaps pretreatment estimates (see Table 1 and Ref *16*) as a basis for comparison.

It also is difficult to evaluate the influence of human bird scarers on the trial results, because their success depends on such factors as their age, activity, and numbers, as well as on the bird population. Scarers are most effective when they are protecting their own rather than someone else's fields, as in an agriculture scheme. They can completely alter the outcome of repellent work in small fields but have much less effect in large fields.

It is becoming common practice in bird damage control trials in the United States to control this variable by reimbursing a farmer for damage in set-aside fields. In developing countries, researchers usually are not able to

purchase a field, so that it becomes preferable to work within the system. Despite the complicating influence of bird scarers, the trial should be initiated and some type of subjective appraisal of their impact on the results devised. One suggestion is to count their numbers in the fields throughout the trial, noting any reductions or shifts in activity. The farmer will cease his scaring efforts if he sees the alternative method is working. Second, observations of the size and behavior of feeding flocks as well as comparison of weekly estimates of damage to untreated but guarded fields will provide some insight into their effectiveness. The concept of a control strategy that integrates two or more techniques simultaneously or successively to reduce crop losses is entirely new in many developing countries, but one that can have increasing importance as the development of direct crop protection techniques continues.

It sometimes is possible and desirable to involve farmers or villagers directly in the work. For example, upon arriving in a village to collect or survey for rats (or other pests), the foreign investigator often is denied direct access into houses. Sometimes villagers can be given traps (or baits), but little control of the program (or materials) is possible, and few data result. It may then be preferable to hire a local student, preferably one high in the social order or well regarded by villagers, and train him in placement (traps, baits, tracking, boards), evaluation, and data-taking procedures on provided forms. In this way data may be collected after the team has gone. In such instances, some cross check must be built into the data collection system to ensure its validity. Another option is to concentrate work in an area where a technical associate or assistant has many relatives. Especially in a city, this can provide test sites where the security of placements and cooperation of residents can be ensured.

Conclusions

The early bird management literature in the United States contains numerous examples of demonstration and statistically unsophisticated studies. This was an understandable pattern in these early efforts but is the type of evaluative work on which we have been trying to improve in the United States since the late 1960s. Eventually the resources, trained personnel, and special tools became available as their need was demonstrated. In these early days the biological competence of the observer was the most important factor in assessments. While programs in developing countries should not repeat this evolution step by step, the restrictions and limitations that we have discussed indicate that some parallels exist.

After baseline laboratory research has shown that a technique merits field testing and preliminary tests also have shown promise, the need is to determine whether the technique can protect a crop under the actual farming conditions. In developing countries, the time frame is acute, and the objective is

immediate. The goal should be to maximize the use of local resources and opportunities even though they are limited. A technique will be accepted in developing countries, irrespective of the sophistication of the evaluation process, if it is demonstrated to be consistently effective, safe, and economical.

We are not suggesting that the constraints on test design or the conduct of experiments often encountered while working in developing countries are excuses for incomplete evaluation. Beck and Stein [*31*] note that a scientist does not compromise himself after recognizing study limitations if he proceeds as objectively and thoroughly as possible within the framework that the particular study conditions allow. We have identified these constraints so that others may be aware of their existence. Any practical evaluation must be based on sound principles, yet be flexible enough to accommodate unexpected situations. Knowledge ultimately comes from many sources of technical information acquired in diverse manners.

It certainly is necessary to critically evaluate the results of work obtained with less than optimum protocols. Early publication of the findings of such demonstrations or probes is desirable, and for many scientists technical journals are a preferred outlet. Yet attempts to use such media are too often (and sometimes justifiably) met with overt skepticism. Alternatives are needed for presentation and dissemination of results that cannot be totally evaluated with statistics. All too few outlets for communication now exist.

Some will argue that major journals should not accept documents lacking fully executed statistical analyses. Certainly the referee has performed his task if the study is viewed from the perspective of present agronomic statistical design. But this takes the study and the intention of the evaluation effort out of context. Considerable insight into problems and relationships can be lost when biological significance is completely subjugated by statistical significance. As we have indicated, many compromises in formal design must be made under field conditions in developing countries. Obviously to suggest an "all or nothing" approach to technique evaluation is impractical. Investigators need to be careful enough to guard against nonrandom error, astute enough to interpret biological significance, and open enough to accept alternative modes of data evaluation and analysis. Within this context, our objective is to systematize research as much as possible, without passing up opportunities to test techniques under operational conditions. Alternatives to monthly or annual progress reports for presentation and dissemination of these kinds of "imperfect" data are needed.

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