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MANAGEMENT OF ON-FARM YIELD TRIALS FOR TESTING ADAPTABILITY OF CROP VARIETIES

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SUMMARY

Farmers themselves are allowed to manage on-farm variety adaptability trials (VATs), to represent farmer management practices in preference to research management. In this approach, within-trial uniformity and thus the scientific value of VATs will be lost. A study was conducted using rice to ascertain whether representation of farmer management in VATs is necessary and to test an approach that represents farmer management without losing within-trial uniformity and the scientific value of VATs. In the proposed approach, both the representation of farmer management and within-trial uniformity are reasonably assured through implementation of site-specific farmer practices by research personnel. This approach was compared with complete research management using recommended practices in a VAT conducted with five rice varieties in six farmers' fields over two seasons. When farmer management was implemented by research personnel, popular varieties among farmers were judged most adaptable. However, when VATs were managed using recommended practices, popular varieties among farmers were judged least adaptable. This provided direct evidence to show the usefulness of representation of farmer management and the validity and practical feasibility of the proposed approach in managing VATs.

INTRODUCTION

Crop varieties must be adaptable over diverse farm environments if they are to be accepted by farmers within a region. The adoption of new technologies has been slow in diverse, less productive, heterogeneous and risk-prone areas (Rambo and Sajise, 1985; Chambers and Jiggins, 1986). Often the underlying major reason for the low adoption rate has not been the farmer or the farm, but the technology itself and the process whereby it was developed (Chambers *et al.*, 1989).

In identifying crop varieties acceptable to farmers, a number of approaches have been tried. These include providing farmers with varied genetic materials for their own selection (Chambers, 1989), testing advanced lines with villagers and identifying superior material preferred by farmers (Maurya *et al.*, 1988), and choosing promising varieties from a wide range grown in farmers' fields, after they had first been selected by the same farmers in research field yield trials (Sperling *et al.*, 1993). However, the commonest approach is to expose a few promising newly developed varieties to diverse farm environments in order to evaluate and predict their performance if they are to be grown by farmers upon their release. Varietal performance in farmers' fields is predicted in terms of adaptability which implies the capacity to perform well over

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diverse environments. On-farm adaptability evaluation is the link between research station varietal development and the actual acceptance of those varieties by farmers (Nene, 1993).

Testing of varieties in farmers' fields is usually done at two levels, namely, introductory and adaptive (Jashi and Witcombe, 1995), or on-farm research trials and on-farm trials respectively (Thakur, 1995). In Sri Lanka, these two levels of varietal testing are termed on-farm variety adaptability trials (VAT) and large-scale variety adaptability trials (LSVAT) respectively. In VATs, several newly developed promising varieties are tested for the first time in farm environments in replicate trials with the intention of exposing them to diversity in the physical environment as well as to management practices found on farms. Farmer management can be defined as an array of combinations of varying levels of different agronomic practices that vary from farmer to farmer.

VATs should not be conducted using recommended cultural practices across farms as these do not represent varying levels of actual farmer management. However, no direct experimental evidence is available to support this idea. Therefore, some researchers conduct VATs under uniform research management on farms. However, VATs should not simply be managed by farmers themselves because accurate estimates of varietal performances cannot always be achieved due to the non-uniformity of management. Our experience was that the data from VATs totally managed by farmers were most of the time unrealistic, inaccurate and incomplete so that they were not useful.

Both complete research management by research personnel and management by farmers themselves are biased in one way or another. This has been a universal problem in on-farm research and has not yet been adequately addressed. The main issues in this context are to provide experimental evidence to ascertain whether the representation of farmer management is necessary in VATs and to find a way to incorporate varying levels of farmer management while keeping within-trial uniformity. The most appropriate way to do this is to implement site-specific farmer practices in yield trials by research personnel. This is a kind of farmer participatory approach, as farmer participation does not necessarily mean that farmers themselves have to manage on-farm trials. However, this approach has not yet been empirically tested. Thus the objectives of the study reported here were to test whether: i) representation of farmer management on VATs is necessary; and ii) implementation of varying levels of site-specific farmer management by researchers is practically feasible, effective and valid in managing VATs. Trials to test the above objectives were conducted with rice (*Oryza sativa*), a crop which has a well established VAT programme in farmers' fields in Sri Lanka.

MATERIALS AND METHODS

A set of five rice varieties in the $3^{1}/_{2}$ month maturity group, namely Bg 94-1, Bg 350, At 85-2, At 90-22 and At 87-358, was used in the study which was conducted in southern Sri Lanka. Bg 94-1 and Bg 350 are recommended varieties for cultivation. Bg 94-1 is one of the most popular varieties among farmers but Bg 350 is not as popular as Bg 94-1 in the southern region. The other three varieties were promising newly developed lines from the Rice Research Station, Ambalantota. These varieties were tested under two types of management, namely recommended practices (research-managed) and site-specific farmer practices (farmer-managed) over six locations in two agro-ecologically different Zones in the southern region, the Wet (mean annual rainfall 2400 mm) and the Dry (mean annual rainfall 1400 mm). Five different locations in the Dry Zone and one location in the Wet Zone were selected to represent the physical environmental diversity as well as diversity in farmer management. Trials were conducted during two seasons, dry (March to August) and wet (September to February) in the same six locations.

Recommended practices and site-specific farmer practices were factorally imposed on the five varieties in the trial at each location in each season. Both recommended practices and farmer practices for individual locations were the same over wet and dry seasons. Furthermore, recommended practices were the same at all locations except for the Zone specific differences in fertilizer recommendations between location 6 and the rest (Table 1). Trials were conducted in a split-plot arrangement laid out in a randomized complete block design with two replications. Management practices were assigned to the main plots and varieties were assigned to the subplots (6 × 3 m). Information on farmer practices was obtained from the farmer for each site and these were implemented on plots with farmer management by the research personnel so that within-trial uniformity was maintained. Farmer practices varied across locations whereas recommended practices remained the same within a given agro-ecological zone. As the objective was to represent varying levels of farmer management, very precise representation of farmer practices in each location would not be necessary as long as variability was assured. An ideal situation would have been to include another treatment with trials managed by farmers themselves using farmer practices. However, such a treatment was not included in this study because data from trials managed by farmers themselves are most of the time unrealistic, inaccurate and incomplete and the uniformity of farmer managed trials is so poor that accurate estimates of varietal performances would not have been achieved.

Grain yield data were recorded after removing a 0.30 m border from each plot, if the method of stand establishment was direct sowing or random transplanting. In the case of transplanting with the standard spacing (0.15 m × 0.15 m), two rows around the plot were removed before harvesting. The grain weight from each plot was adjusted to 14% moisture content.

Data were subjected to statistical analysis using SAS. Combined analyses were not run on the variety × management data generated over locations for the wet and dry seasons as the location effects were confounded with the management effect that differed with location. Instead, adaptability of the five rice varieties over diverse environments was evaluated separately under recommended and farmer practices for both seasons using the method described by Abeysiriwardena (2001). In the variety × location data set replicated within locations, the grain yield deviation of each variety in each replicate (each plot) from the maximum plot grain yield

Table 1. Recommended practices and farmer cultural practices in rice cultivation adopted at different locations used in the present study.

Zone/management practice/location (L)	Cultural practices: Land preparation	Stand establishment	Seed rate (Kg ha^{-1})	Fertilizer (Kg ha^{-1}): Basal	Top dressing mixture
Dry Zone					
Farmer practices					
L1	Ploughing and tilling Time taken 10 days	Random transplanting Dapog‡	200	V_1 mixture 123	74 7 WAP†
L2	Tilling with rotavator after using Gramaxone Time taken 7 days	Direct seeding	150	V_1 mixture 148	not applied
L3	Ploughing and tilling after using Gramaxone Time taken 7 days	Direct seeding	210	V_1 mixture 148	74 6 WAP
L4	Tilling with rotavator Time taken 7 days	Random transplanting. 18 day old seedlings	100	V_1 mixture 128	128 6 WAP
L5	Ploughing and tilling Time taken 10 days	Direct seeding	200	V_1 mixture 128	12 8 WAP
Recommended practices	Two ploughings at 7 day interval and then tilling after 7 days. Time taken 14 days. If Gramoxone is applied as a total weed killer, application of Gramoxone is followed by one ploughing and then tilling. Time taken 7 days	Direct seeding (row seeding or broadcasting) or standard transplanting (TP) with 18–21 day old seedlings at 20 × 15 cm spacing and 2–3 plants per hill or dapog TP with 10 day old seedlings and 8–10 plants per hill with the same spacing as in standard TP	100 for broadcasting, 75 for row seeding, 50 for transplanting and 87 for dapog transplanting	V_1 mixture 187	125 6 WAP
Wet Zone					
Farmer practices					
L6	Tilling with rotavator after using gramaxone Time taken 10 days.	Direct seeding	148	5:15:15 mixture 123	123 6 WAP
Recommended practices	Same as in the Dry Zone	Same as in the Dry Zone	Same as in the Dry Zone	5:15:15 mixture 250	125 6 WAP

† WAP: Weeks after planting.
‡ In the dapog method, seeds are germinated on a level surface, with a covering that prevents seedling roots from penetrating to the soil layer, and then transplanted.

(plot deviations) in each location was computed, and an analysis of variance was performed on these values. Mean (D_i) and the variance (V_i^2) of varietal deviations across locations for each variety were computed as follows;

$$D_i = \sum_{j=1}^{n} \bar{d}_{ij.}/n = \left[\frac{1}{n}\sum_{j=1}^{n} Y\max_j\right] - \bar{y}_{i.}$$

where, $\bar{d}_{ij.}$ = mean plot deviation of the i^{th} variety in the j^{th} environment and n = number of locations.

$$\bar{d}_{ij.} = Y_{\max j} - \bar{y}_{ij.}$$

where, $Y_{\max j}$ = maximum plot yield recorded in the j^{th} environment $\bar{y}_{ij.}$ = mean plot yield of the i^{th} variety in the j^{th} environment.

$$V_i^2 = \left[\sum_{j=1}^{n} d_{ij.}^2 - \frac{\left(\sum_{j=1}^{n} d_{ij.}\right)^2}{n}\right] / q(n-1)$$

where, q = number of replications, n = number of locations and $\bar{d}_{ij.}$ = plot deviation of the i^{th} variety in the j^{th} environment summed over replications.

D_i and V_i^2 were tested for significance against the pooled error. The selection for general adaptability was made simultaneously for significantly lower D_i and non-significant V_i^2. The most adaptable variety was the one with the lowest significant D_i and non-significant V_i^2.

RESULTS

The grain yield of the five rice varieties under recommended and farmer management practices at the five locations in the Dry Zone and one location in the Wet Zone during the wet and dry seasons are presented in Table 2. Acceptable yield levels were achieved and the observed data from the different treatments were complete. Location differences observed in both seasons under recommended and farmer practices indicated that adequate variability among locations existed for the evaluation of varietal adaptability over diverse environments.

Farmer practices showed a tremendous variability between locations. Distinct examples were land preparation, seed rate, stand establishment,and the use of fertilizer at farm level (Table 1). All these farmer practices deviated highly from recommended practices. For example, although the recommended seed rate is 100 kg ha^{-1} for direct seeding and 50 kg ha^{-1} for transplanting, farmers always use higher seed rates than those recommended.

Varietal adaptability over diverse environments was evaluated using plot deviations under both recommended and farmer management practices in the wet and dry

Table 2. Grain yields of five rice varieties of the 3½ month maturity group at five locations in the Dry and one location in the Wet Zone during dry and wet seasons under recommended and farmer management practices in Sri Lanka (t ha^{-1}).

		Location (L)						
		Dry Zone					Wet Zone	
Management/season	Variety	L_1	L_2	L_3	L_4	L_5	L_6	Mean
Recommended practices								
Wet	At 85-2	7.17	6.23	7.36	6.47	5.99	5.59	6.47
	At 90-22	7.24	4.30	6.43	6.65	6.81	5.77	6.19
	At 87-358	6.45	5.86	7.99	5.49	5.40	5.06	6.04
	Bg 350	7.26	4.36	6.55	4.18	5.61	5.08	5.51
	Bg 94-1	7.36	4.68	5.10	4.19	4.55	4.67	5.09
	Mean	7.09	5.09	6.68	5.40	5.67	5.23	
Dry	At 85-2	5.93	4.51	4.73	3.65	5.85	4.49	4.86
	At 90-22	5.60	4.00	5.75	4.19	6.02	5.16	5.12
	At 87-358	6.52	3.83	4.55	2.80	5.07	3.91	4.44
	Bg 350	5.03	3.65	5.68	3.28	6.13	4.15	4.65
	Bg 94-1	5.65	3.08	5.26	3.40	4.95	3.06	4.23
	Mean	5.75	3.81	5.19	3.46	5.58	4.15	
Farmer practices								
Wet	At 85-2	7.81	6.22	6.47	6.39	6.55	5.94	6.56
	At 90-22	7.77	2.95	5.19	5.38	6.42	5.98	5.61
	At 87-358	7.18	5.40	6.81	5.00	6.61	5.22	6.04
	Bg 350	7.49	3.26	5.29	6.82	5.41	6.03	5.72
	Bg 94-1	8.22	5.01	5.10	6.21	6.77	5.92	6.20
	Mean	7.69	4.57	5.77	5.96	6.35	5.82	
Dry	At 85-2	4.73	3.70	5.75	4.69	5.70	4.35	4.82
	At 90-22	5.43	3.76	6.17	4.74	5.18	4.17	5.07
	At 87-358	6.64	5.08	5.09	3.19	5.44	3.19	4.77
	Bg 350	5.43	3.57	5.66	4.21	5.77	5.18	4.97
	Bg 94-1	4.95	4.84	5.17	4.31	4.87	4.95	4.85
	Mean	5.44	4.19	5.57	4.23	5.59	4.37	

seasons (Table 3). The variety term was found to be significant in all situations except under farmer practices in the dry season. With each type of management, the location within variety term (L/V) was found to be significant in both seasons. Thus, adaptability parameters and ranks for the five rice varieties tested in the six locations in farmers' fields under recommended and farmer management practices during the two seasons were estimated. In both seasons, differences in adaptability ranks were observed under both research and farmer management practices (Table 4).

DISCUSSION

The components of location variability are the variability in physical environment, farmer management and any interactions between these two factors. Cooper *et al.* (1996) emphasized the importance of managing the environment in order to

Table 3. Combined analyses of variance performed on plot deviations for five rice varieties grown in six locations under recommended and farmer practices in the wet and dry seasons in Sri Lanka.

		M.S.			
		Recommended practices		Farmer practices	
Source	*d.f.*	Wet season	Dry season	Wet season	Dry season
Total	59				
BKS/Locations (L)	6	2.200	2.013	2.818	1.007
Varieties (V)	4	3.660**	1.504**	1.744**	0.069
L/V	25	1.196**	0.509*	1.537**	0.936**
Pooled error	24	0.406	0.241	0.199	0.216

*,** Indicate significant at 5% and 1% probability levels, respectively.

Table 4. Adaptability parameters of mean varietal deviation (D) and variance in varietal deviation (v^2) and adaptability rank for each of five rice varieties grown in six environments in farmers' fields under recommended and farmer management practices in the wet and dry seasons in Sri Lanka.

		Management					
		Recommended practices			Farmer practices		
Season	Variety	D (t ha^{-1})†	v^2	Rank	D (t ha^{-1})	v^2	Rank
Wet	At 85-2	0.344 a	0.193	1	0.247 a	0.062	1
	At 90-22	0.602 a	1.606*	3	1.196 d	2.954**	3
	At 87-358	0.760 ab	0.536	2	0.774 bc	0.856**	2
	Bg 350	1.296 bc	1.417*	4	1.096 cd	2.504**	3
	Bg 94-1	1.709 c	2.228*	5	0.621 ab	1.374**	2
Dry	At 85-2	0.535 ab	0.220	1	0.771 a	1.146**	2
	At 90-22	0.258 a	0.291	1	0.689 a	0.692*	1
	At 87-358	0.928 c	0.543	2	0.824 a	1.416**	2
	Bg 350	0.725 b	0.672*	3	0.627 a	0.776*	1
	Bg 94-1	1.176 c	0.648*	4	0.748 a	0.646*	1

† 'D's with the same letter within management × season combinations are not significantly different at 5% probability level (Duncan's multiple range test).
*,** Significant at the 5% and 1% probability levels respectively.

achieve environmental differences when genotype × environment (GE) interactions are studied. The present study emphasized farmer management and tried to represent different practices in combination with the differences in physical environment in studying GE interaction as environments are actually managed by farmers.

An interesting observation is that some of the farmer practices were superior to those recommended (Table 2). This was because farmer practices were site-specific representing an improvement on the blanket recommendations to suit local farm conditions. However, the intention was not to show whether farmer practices were inferior or superior to recommended practices, but to compare varietal adaptability under blanket recommended practices with that under varying farmer practices across locations (Table 1). Varietal responses varied accordingly. Any adaptability testing programme in farmers' fields which does not take such variability into account appears

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not to satisfy the objective of on-farm testing of varietal adaptability. Conducting VATs under varying farmer practices implemented by research personnel, the approach adopted to represent farmer management, appeared to be practically feasible as it generated realistic results.

With farmer practices, the location effect was confounded with the management effect because they differed between locations. This increased the variability. The dry season is less favourable for rice cultivation than the wet season because rice cultivation is risky in some areas due to water shortages. In addition, high temperatures and humidities during flowering increase sterility, and high day and night temperatures during the grain-filling period decrease net assimilation in the dry season As a consequence grain yields in the dry season are generally lower than those in the wet season (Table 2). Thus, in the dry season, particularly under farmer practices, varietal differences are less pronounced (Table 3) and the ranking of varieties is less distinct (Table 4). However, in both wet and dry seasons, differential responses by the varieties between locations were observed under both types of management as indicated by the significant L/V term (Table 3), emphasizing the importance of the type of management when the varieties are selected for their adaptability.

Interestingly, during both seasons, the order of adaptability of varieties varied between research and farmer management practices (Table 4). Under the recommended practices, At 85-2 was found to be the most adaptable followed by At 87-358, while Bg 94-1 was found to be the least adaptable in both seasons. The relative adaptability of At 90-22 varied between seasons indicating that this particular variety may be highly sensitive to seasonal changes. In contrast, under farmer practices, although the relative adaptability of varieties changed slightly over the seasons, both At 85-2 and Bg 94-1 were found to be the most adaptable with similar performances when both seasons were considered. Furthermore, Bg 350 behaved similarly to At 90-22, while At 87-358 appeared to be better than these two varieties due to its consistent performance over both seasons under farmer practices. Therefore, varietal recommnedations based on their adaptability over diverse environments under farmer practices was different from that using recommended practices. Bg 94-1 is the most popular variety among farmers and thus, the proposed management approach has the potential to detect varieties with high levels of farmer acceptance as the most adaptable. Under farmer practices, At 85-2 cannot be considered to be a better variety than Bg 94-1. The value of conducting varietal adaptability trials under properly implemented and varying levels of farmer practice is demonstrated. This is direct experimental evidence to show that VATs should be conducted under farmer management practices that vary between locations.

Differences in performances of varieties between recommended and farmer management practices has highlighted the importance of the choice of crop management for VATs conducted in farmers fields. However, the interaction of management practices with genotype is not always accommodated in plant breeding and selection (Hammer *et al.*, 1996). Shorter *et al.* (1991) suggested that one way to integrate physiological understanding and crop improvement was to optimize combinations of genotype and management over the target environment domain.

If variation in management practices occurs within a trial without proper experimental control then it is simply a poorly managed trial. Varying levels of farmer management when implemented by researchers in VATs can detect true varietal differences in their adaptability over diverse farm environments since within-trial uniformity will be maintained. Ceccarelli (1996) evaluated breeding material in farmers' fields by letting farmers manage the crop and concluded that the evaluation was successful. The difference was that he tried to maintain within-trial uniformity, while representing varying levels of farmer management, by selecting only fields with uniform crops. However, achieving representation of the full range of farmer management practices, as well as adequate within-trial uniformity, was questionable using such an approach. Results from the present study have clearly shown that the proposed trial management approach is practically feasible, effective, valid and generates unbiased, objective and realistic information on varietal adaptability over diverse farm environments with scientific merit.

CONCLUSIONS

The present study provided direct experimental evidence to conclude that on-farm VATs should be conducted under farmer management. Implementation of site-specific farmer practices by researchers was able to represent farmer management while keeping within trial uniformity on VATs. This was found to be practically feasible, effective and results-orientated.

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