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A method to verify the continuance of check varieties in multilocation yield trials – A case study in wheat

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Abstract

Three statistical tools, namely relative yield, yield responsiveness and Eberhart and Russel's parameters, were used for assessing the performance of three wheat check varieties used for evaluation of coordinated multilocation yield trials. Relative yield indices over locations and over years revealed that the check HD2687 was the most stable one, while PBW343 showed above optimum performance and HD2329 showed below optimum performance. In responsiveness for yield, HD2687 showed stable responsiveness, while PBW343 showed higher responsiveness and HD2329 recorded low responsiveness. The study revealed that among the three check cultivars, HD2329 may be removed as a check due to its low yield performance, while HD2687, showing desirable features of responsiveness along with yield stability and PBW343 having high responsive attributes, should be continued as checks in the years to come. The continuance of check cultivars for multilocation yield testing should be based on the relative yield stability and responsiveness characteristics.

Key words: Check varieties, relative yield, responsiveness, yield stability

Introduction

The evaluation and release of crop cultivars for commercial cultivation in India is done through a set process and norms. The performance of new genotypes is generally tested through a coordinated system of multilocation evaluation trials where assessment is made for yield and agronomic, pathological and quality parameters. The results of the multilocation trials are statistically analyzed and the performance of test lines is compared with respect to the performance of check varieties used in the evaluation trials. The performance of the check cultivars is regarded as an index for evaluating the performance of the test lines. Generally a cultivar of long-standing, best performing variety and a recently identified/released variety are selected as checks. This system for selecting check cultivars is also followed in wheat coordinated trials. The period for which a particular check variety should be used in multilocation varietal evaluation trials is often a matter for debate among the breeders. When check cultivars produce lower yields due to disease susceptibility or other factors, they are replaced with new ones. However, certain checks continue to yield well for long periods. In such a situation, the need for a method to test the usefulness of check cultivars for prolonged periods has always been felt. In this paper three check cultivars were analyzed for their continuance to test newly developed lines of wheat in North Western Plains Zone (NWPZ) on the basis of some statistical tools.

Materials and methods

The All India Coordinated Wheat and Barley Improvement Project provides the platform for conducting multilocation evaluation trials to test the performance of newly developed wheat genotypes before they can qualify for identification and release as variety for commercial use. In the present study, the experimental results of cultivar evaluation in Advanced Varietal Trial (AVT) conducted under timely-sown condition in NWPZ (comprising the states of Punjab, Haryana, Delhi and districts falling in northern Rajasthan, western Uttar Pradesh, and plains of Himachal Pradesh and Uttarakhand) were utilized for analysis. In AVT, the entries are evaluated for two years and they are conducted in a gross plot size of 6m x 2.76m (12 rows spaced 23cm apart) and sown during a window of 5-20th November at various locations. A seed rate of 100 kgha^{-1} and fertilizer dose of 120:60:40 kgha^{-1} NPK is uniformly applied with 4-5 irrigations provided at various stages of crop growth to raise a

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good crop. The grain yield is recorded from a net plot size of 5m x 2.3m. As the test entries are changed after every one or two years in AVT, the data of check entries, which include a long-term check HD2329 and best performing checks PBW343 and HD2687, were considered for evaluation of their performance at 10 locations (Delhi, Karnal, Hisar, Gurdaspur, Ludhiana, Durgapura, Sriganganagar, Bulandshahar, Pantnagar and Modipuram), which served as representative sites for the major states of the zone, over a period of 6 years from 1998-99 to 2003-04 crop seasons.

The performance of the three check cultivars during the above period was tested for stability over locations and over years following the approach enunciated by Eberhart and Russell [1]. This analysis of stability was further supplemented with two additional statistical tools, relative yield and yield responsiveness, which are calculated as given below.

(1) Relative Yield (RY) = $Y\ AY^{-1}$

where, Y is the yield of a particular cultivar and AY is the average yield of all cultivars evaluated at the experimental site.

Relative yield was used by Yau and Hamblin [2] as an index to measure the performance of genotypes against the mean of all entries tested at various locations. The entries having RY values <1 yields less than the site average and are not stable, the entries having RY values >1 yields more showing responsive behaviour, while the entries having RY values equal to 1 shows stable performance.

(2) Yield Responsiveness, the coefficient of the regression of the relationship between yield and environmental index, the AY of all cultivars evaluated in each experiment [3]. The yield was regressed with environmental index using 'STATISTICA' statistical package. A slope >1 indicates responsiveness, i.e., genetic improvement with increasing yield leads to decreas in the yield stability.

Results and discussion

Testing new genotypes for yield stability over different locations in an agroclimatic zone is among the main objectives of coordinated varietal evaluation programme which leads to release of new varieties for commercial cultivation. In this regard, multilocation testing gives an opportunity to know whether the cultivars have the potential to maintain competitive yields with the checks at various sites and also tests their response to favourable conditions or higher inputs. The testing of genotypes in multilocation trials for evaluation as cultivars is although more for adaptability, but stability across various locations is also required because development and replacement with new cultivars is a time taking process. Undoubtedly, stability for yield becomes a necessary criterion in development and testing of cultivars.

While evaluating the test genotypes in multilocation trials, it also becomes imperative to observe the performance of check cultivars over a period of time. One of the commonly used methods to assess the performance of a genotype over a period of time is the stability analysis. The stability analysis is not free from bias; the high-yielding locations (treatments) affect the overall results. A usually observed consequence of breeding for higher yield is the phenomenon of yield responsiveness, i.e., higher capacity to respond to better environments. The genotypes that have been bred for higher yielding environments tend to yield poorly whenever there is a fall in standard cultural practices. It has been rightly observed that the new cultivars are undoubtedly higher yielding than their predecessors, but are correspondingly less stable over environments [3-5]. Thus, the yield responsiveness behaviour is reciprocal to yield stability. Nevertheless, the reduction in stability among higher yielding genotypes should also be seen as a success of genetic improvement for yield in wheat. Yield responsiveness should be measured to assess the yield enhancing capability of new genotypes.

The stability statistic, relative yield, has several advantages among which the prime ones are: (i) conversion of simple entry variance across sites to a practical, agronomic stability measure and removal of the bias accorded to high-yielding sites, (ii) giving of equal weight to each site when calculating means across sites, and (iii) ease in comparing large number of entries tested in different experiments at the same site (no limitation in number of entries and locations) for estimating genotype x environment interactions [2]. Koemel *et al*. [6] have used the relative yield method to analyze the stability among hybrids and purelines of wheat.

The check varieties HD2329, PBW343 and HD2687 are used to evaluate the performance of test genotypes in the AVT. The three varieties used in this study have contributed significantly to increase the yield level and production in the NWPZ. The long-term check

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HD2329 was an extremely popular cultivar for over a decade during the late 1980s till mid-1990s, occupying almost 50% of the area, and was responsible for significantly boosting the production and yield. The best performing check PBW343 has been yielding extremely well from the mid-1990s and it is presently occupying more than 50% of the area in NWPZ, while HD2687 is also a popular cultivar in limited areas. The mean yield performance of these check varieties at ten locations over a period of six years is given in Table 1. The mean yield of HD2329 (4289 kgha^{-1}) was lowest in comparison to PBW343 (5092 kgha^{-1}) and HD2687 (4735 kgha^{-1}). The average yield of all entries across sites (environmental index) during the six year period was 4722 kgha^{-1}. PBW343 achieved the highest mean yield among the 3 check cultivars across sites and it is one reason for its great popularity in the NWPZ. The main cause for low yield of HD2329 was its susceptibility to leaf and stripe rusts leading to its replacement by new cultivars.

Table 1. Yield (mean, range) of wheat varieties tested over a period of 6 years at 10 locations.

Varieties	Yield (kgha^{-1})	
	Mean	Range
HD 2329	4289	2500 - 6620
PBW 343	5092	2920 - 7250
HD 2687	4735	3110 - 7250

Table 2. Stability of check varieties over locations and years

Varieties	Over Locations		Over Years	
	b_i	S_d^2	b_i	S_d^2
HD2329	1.025	5.617	0.986	1.574
PBW343	0.944	8.421	1.035	0.769
HD2687	1.031	1.932	0.979	1.234

The stability of the three wheat varieties was tested over locations and over years. When stability of the varieties was estimated over the 10 locations, it was observed that variety HD2687 was the most stable followed by HD2329 and PBW343. However, when stability was estimated over the 6 years' period, the b_i values were observed to be near to optimum for all the three varieties and PBW343 showed least deviations (S_d^2) followed by HD2687 and HD2329. The overall stability estimations revealed that variety HD2687 gave a more stable performance followed by HD2329 and PBW343 (Table 2).

The values of relative yield indices over locations and over years revealed that the variety HD2687 was the most stable one, while the cultivar PBW343 showed above optimum performance and HD2329 showed below optimum performance (Tables 3 & 4). The yield responsiveness behaviour of the three cultivars over locations and years revealed that HD2687 showed stable responsiveness, while PBW343 showed higher responsiveness and HD2329 recorded low responsiveness (Table 5).

Table 3. Relative yield of check varieties over locations

Varieties	Locations*										
	1	2	3	4	5	6	7	8	9	10	Mean
HD2329	1.058	0.842	0.960	0.877	0.803	0.923	0.946	0.909	0.833	0.908	0.906
PBW343	1.055	1.115	1.056	1.097	1.129	1.044	1.108	1.034	1.078	1.062	1.078
HD2687	1.073	1.022	1.023	1.049	0.872	1.033	1.008	0.976	0.952	1.025	1.003

*Locations 1-10: Delhi, Karnal, Hisar, Gurdaspur, Ludhiana, Durgapura, Sriganganagar, Bulandshahar, Pantnagar, Modipuram

Table 4. Relative yield of check varieties over years

Varieties	Years						
	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	Mean
HD2329	0.942	0.940	0.925	0.895	0.844	0.890	0.906
PBW343	1.135	1.078	1.083	1.078	1.081	1.013	1.078
HD2687	1.082	1.029	0.987	0.956	1.011	0.954	1.003

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Table 5. Responsiveness of check varieties over locations and years

Variety	Over locations	Over years
HD2329	0.979	1.100
PBW343	1.166	1.127
HD2687	1.053	0.973

In order to assess the relative merit of the two stability statistics, relative yield and yield responsiveness, their comparison with the estimations of stability parameters becomes essential. On comparing stability *vs* relative yield over locations (Tables 2 & 3), HD2687 showed similar results, while HD2687 and PBW343 showed a similar observation with respect to years (Tables 2 & 4). Comparing stability *vs* responsiveness (Tables 2 & 5) revealed that HD2687 and HD2329 showed similar results both over locations and years. The values for relative yield *vs* responsiveness (Tables 3, 4 & 5) were comparable only for HD2687 over locations and years.

These observations reveal that among the three varieties tested, HD2687 was found to exhibit a greater stable performance over locations and years as a check cultivar in multilocation testing in the NWPZ. The cultivar PBW343 was giving less stable performance that indicated its high responsiveness attribute while HD2329 showed low responsiveness.

Current wheat varieties are both input responsive and input efficient. Such varieties undoubtedly allow farmers to derive benefit over a wide range of input levels, but under adverse conditions the losses are great due to erosion of stability in these high yielding varieties. It can be, therefore, construed that the development of high yielding genotypes has resulted in a concomitant reduction in their stability as in higher yielding systems there is very less variation between environments. Though yield responsiveness is a desirable attribute for enhancing production, its outcome leads to instability. Increased genetic gains in yield have come from narrowing of the adaptation and sacrificing the stability [4, 7]. Such a situation is bound to happen as yield potential and stability are negatively correlated [7]. One reason for the increased genotype-environment interaction and narrowing adaptation may be due to an increase in genetic diversity amongst elite lines [4]. Rajaram [8] and Ozgen [9] have stated that use of paramount germplasm and special genetic stocks have been responsible for providing continuing breakthrough in yield potential.

It can be concluded that among the three check varieties, HD2329 may be removed from the list of checks due to its low yield performance. HD2687, showing desirable features of responsiveness along with yield stability, is capable for continuance as a check cultivar in the years to come while, PBW343 should be continued as a check to observe genotypes having responsive attributes. Further, the results reveal that the two statistical tools, relative yield and responsiveness, give comparable findings and these methods can be preferred to derive conclusions with regard to yield stability of cultivars. Furthermore, among the three methods used for assessing stability, the relative yield method can be given preference as it is easy to estimate and also that it precisely gives the same conclusions as other methods for stability that are in vogue.

Thus, it becomes quite evident that the continuance of check cultivars for evaluation of new genotypes in multilocation yield evaluation trials should be based on their yield stability and responsiveness attributes. However, high susceptibility to diseases always overrides these considerations for continuance of cultivars as checks and such varieties may be discontinued.

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