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Single Tester Triple Test Cross Analysis in Spring Wheat

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Summary. Two experiments, each including the same 30 homozygous varieties of spring wheat plus one separate tester variety, were conducted in order to detect epistasis and to test and estimate the additive and dominance components of genetic variation for five quantitative traits: final plant height, spike length, number of spikelets per spike, 100-kernel weight and grain yield per plant. Epistasis played a significant role in the control of 100-kernel weight and yield per plant. There was a gratifyingly good agreement between the two independent methods ($2\overline{B}_1 i - \overline{F}_{1i} - \overline{P}_i$ and $2\overline{B}_{ci} - \overline{F}_{1i}$) used to test the presence of epistasis. In both experiments, there was a remarkably uniform high dominance ratio for most of the traits studied indicating that this test cross design is equally sensitive to both additive and dominance genetic variation.

Key words: Epistasis – Triple test cross – Spring wheat

Introduction

Kearsey and Jinks (1968) and Jinks et al. (1969) suggested a simplified triple test cross design for investigating true-breeding populations in self-pollinators. If, however, the two testers (L_1 and L_2) do not differ at the loci at which the population of true-breeding lines differ, the analysis provides neither an unambiguous test of epistasis nor an unbiased estimation of D (additive), H (dominance) and F components (Jinks et al. 1969; Virk and Jinks 1977). Jinks and Virk (1977) modified this analysis to test and allow for inadequate testers. However, if the testers prove to be inadequate, most of the advantages which the triple test cross design has over other multiple-mating designs are reduced.

Furthermore, it is not easy to choose adequate testers from the kind of material (a group of homozygous varieties/lines collected from different sources) with which breeders dealing with autogamous crops usually start their breeding programmes. However, Chahal and Jinks (1978) suggested an experimental design and analysis to investigate such materials. The new method requires only one tester and avoids the problems mentioned above (choosing adequate testers and the difficulties created by inadequate testers) and retains most of the advantages of triple test cross design.

Materials and Methods

Experimental Design

The investigation consisted of two experiments, each including the same thirty homozygous varieties (P_i) of spring wheat plus one separate tester. The 30 varieties were 'K65', 'K68', 'C273', 'NP720', 'NP852' and 'NP876' (tall); 'Nortemo 67', 'Raj821', 'Sonalika', 'Safed Lerma' and 'HD1999' (single dwarf); 'HD1981', 'HD2009', 'HD2122', 'HD2177', 'HS13', 'CC60', 'Shera', 'S331', 'UP262', 'WG357', 'WG377', 'WH147', 'WH157' and 'WL711' (double dwarf); and 'Hira', 'Lal Bahadur', 'HD2160', 'UP310' and 'WL212' (triple dwarf). The testers (P_c) were variety 'Kalyan Sona' (double dwarf) in Experiment 1 and the variety 'Moti' (triple dwarf) in Experiment 2. In each experiment, the thirty varieties were crossed to the tester. The thirty F_{1s} thus produced were backcrossed to both their parents (respectively to P_i and P_c) and B_{1i} ($F_{1i} \times P_i$) and the same number of B_{ci} ($F_{1i} \times P_c$) families were obtained. Each experiment (30 P_i, 30 F_{1i}, 30 B_{1i} 30 B_{ci} and P_c) was raised in three randomized blocks in November, 1978. Ten randomly chosen plants from each progeny family in each replication in each of the two experiments were scored for final plant height, spike length, number of spikelets per spike, 100-kernel weight and grain yield per plant.

Statistical Analysis

The analysis of variance for the detection of epistasis and test and estimation of additive and dominance components was carried out according to Chahal and Jinks (1978). The presence of epistasis was detected with the help of two comparisons. $2\overline{B}_{1i} - \overline{F}_{1i} - \overline{P}_i = A_i$ and $2\overline{B}_{ci} - \overline{F}_{1i} = B_i$ + constant for 30 d.f. and 29 d.f., respec-

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tively. Their significance was tested against the errors computed for 180 d.f. (pooled replicate error of the B_{1i}, F_{1i} and P_i family means) and 120 d.f. (pooled replicate error of the B_{ci} and F_{1i} family means), respectively.

Two tests $\bar{B}_{ci} - \bar{B}_{1i} + \bar{P}_i$ and $\bar{B}_{ci} + \bar{B}_{1i} - \bar{P}_i$ were respectively used to test and estimate D and H components, assuming no epistasis. Mean squares due to additive and dominance components were computed each for 29 d.f. and were tested against a pooled replicate error calculated for 180 d.f. The estimates of the two components were obtained so that σ_a^2 (additive) = 1/36 D and σ_d^2 (dominance) = 1/36H.

Results and Discussion

Epistasis

The mean squares for epistatic deviations obtained by two methods ($2\bar{B}_{1i} - \bar{F}_{1i} - \bar{P}_i$ and $2\bar{B}_{ci} - \bar{F}_{1i}$) in two experiments for five quantitative traits in spring wheat are given in Table 1. The epistasis was detected in both experiments by both the methods for 100-kernel weight and yield per plant. Presence of epistasis, though only borderline, was also indicated for final plant height in Experiment 2 by the second method ($2\bar{B}_{ci} - \bar{F}_{1i}$). This was the only discrepancy, relating to epistasis, between the two methods and between the two experiments. The remarkable agreement between the two independent tests for epistasis showed that the two methods were equally sensitive to the presence of epistasis. Similarly, a high consistency between the results of the two experiments indicated that the two testers had done equally well.

Since in the present study the epistatic component could not be partitioned into fixable (i type) and non-fixable (j and 1 type) sub-components, no precise recommendation could be made about its specific utilization in a wheat improvement programme.

Additive and Dominance Components

The D and H components were significant for all five traits in both the experiments (Table 2). An almost uniformly high degree of dominance in all the twenty cases (ranging from 0.66 for number of spikelets per spike in Experiment 1 to 1.06 for yield per plant in Experiment 2) indicated that this method was as sensitive to dominance as to additive genetic variation. The estimates of additive and dominance components for spike length and number of spikelets per spike were unbiased. Since additive gene effects were relatively more important than dominance effects for these two important component traits of grain yield in both the experiments, some improvement in these traits may be expected by following standard selection

Table 1. Mean squares for epistatic deviations ($2\bar{B}_{1i} - \bar{F}_{1i} - \bar{P}_i$ and $2\bar{B}_{ci} - \bar{F}_{ic}$) for five traits in spring wheat

Item	Experiment	d.f.	Plant height	Spike length	Spikelets per spike	100-kernel weight	Yield per plant
$(2\bar{B}_{1i} - \bar{F}_{1i} - \bar{P}_i)$	1	30	18.04	0.78	1.13	1.61[b]	41.54[b]
	2	30	18.33	0.92	1.21	1.47[a]	47.08[c]
Error	1	180	22.25	1.08	2.62	0.68	19.15
	2	180	17.90	1.49	1.86	0.89	11.83
$(2\bar{B}_{ci} - \bar{F}_{1i})$	1	29	20.79	1.10	2.38	1.64[b]	35.23[b]
	2	29	35.10[a]	0.77	1.81	1.69[b]	25.37[b]
Error	1	120	21.56	0.98	3.14	0.75	15.25
	2	120	20.50	0.85	1.50	0.81	12.14

[a] $P = 0.05 - 0.01$; [b] $P = 0.01 - 0.001$; [c] $P < 0.001$

Table 2. Estimates of additive (D) and dominance (H) components and their significance levels for five traits in spring wheat

Components	Experiment	Plant height	Spike length	Spikelets per spike	100-kernel weight	Yield per plant
D	1	81.68[c]	18.20[c]	8.16[b]	4.78[b]	65.22[c]
	2	68.80[c]	16.16[b]	7.80[b]	7.20[b]	46.70[c]
H	1	58.27[c]	12.88[b]	3.52[a]	5.01[b]	59.83[c]
	2	49.45[c]	9.95[b]	4.40[a]	6.77[b]	52.44[c]

[a] $P = 0.05 - 0.01$; [b] $P = 0.01 - 0.001$; [c] $P < 0.001$

procedures. Furthermore, since the two testers have given consistent results relating to the magnitude of D and H components for these traits, the group of homozygous varieties included in the present study seemed to be in linkage equilibrium, particularly for the trait(s) for which the tester used was not an extreme phenotype. Under such a situation, this test cross design, with any arbitrarily chosen inbred line as tester, not only provides information about the kind of gene effects involved in the control of a trait but can also be regarded as a means of supplying unbiased estimates of additive and dominance components.

On the other hand, the estimates of D and H components for 100-kernel weight and yield per plant were biased to an unknown degree by the presence of epistasis. But, since both kinds of estimates were highly significant for these traits in both the experiments, it seemed likely that these traits were controlled by all three kinds of gene effects (epistatic, additive and dominance). Therefore, standard selection procedures should not be used in improving such traits in wheat.

As regards the trait final plant height, since epistasis was significant for this trait at the 5 percent level in only one of the four cases, it is more probable that the trait was governed by additive and dominance gene effects only. Jinks and Perkins (1970), in their backcross data of 1960 and 1961 of the cross 1 × 5 in tobacco and Ketata et al. (1976), in winter wheat, also found this trait controlled by additive and dominance effects only. However, Chapman and McNeal (1971) recorded highly significant epistatic effect for this trait in spring wheat in their 1967 data. This effect disappeared, however, the following year.

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Book Reviews

Herwig, E.; Hübner, S. (eds.): Chancen und Gefahren der Genforschung. Protokolle und Materialien zur Anhörung des Bundesministers für Forschung und Technologie in Bonn, 19. bis 21. September 1979. München, Wien: R. Oldenbourg 1980. XX, 397 pp., 6 figs. Soft bound DM 48,–.

This volume contains the documentation of a hearing of the minister of Research and Technology of the Federal Republic of Germany. The purpose of this hearing was to provide the information required to decide whether recombinant DNA work necessitates special regulations in order to protect the public against potential danger resulting from this work.

The meeting was dedicated to essentially 4 different topics dealing with (a) Application of recombinant DNA techniques in research and in industry. (b) Benefits (c) Risks 1) for the use of E.coli 2) for other host-vector systems, 3) ecological and evolutionary risks. (d) Research, state and society. (e) Guidelines and laws.

Each topic was treated in one or several sections. Prepared statements of invited speakers introduced the particular problem, which then were followed by discussions. Additional material, which could not be presented because of a shortness in time, is supplied in the addendum of the documentation. The speakers include scientists from different countries working in molecular genetics, population genetics, microbiology, cancer research, cell biology, plant physiology and other concerned fields of biology, one theologist, representatives from German workers Unions and of Employer's Unions, representatives from EMBO and the European Community, representatives of the ministry and of the parliaments as well as science journalists.

The active participants of the hearing represent a balanced selection of the various opinions with respect to attitudes against recombinant DNA work. This statement however leads to a first evaluation of the results of this hearing: the entire documentation does not contain anything new. The statements made by the various speakers have been made over and over and can alle be taken from relevant reports from other countries, in particular from the U.S.A. This was to be expected since the speakers invited have been active in this field for years (Szybalski, Chargaff, amongst others). There might in fact be only one point during the entire discussion which has not raised fundamental controversies: In general there appears to be agreement that research should be encouraged which leads to an improvement of risk assessment. All other topics remained controversial.

The majority of experts agreed in the conclusion that recombinant DNA research involves low actual risk, if any at all. Working with pathogenic micro-organisms is generally accepted to be more dangerous, and it was repeatedly pointed out that in this field no regulations comparable to the regulations of recombinant