D. E. Delaney · S. Nasuda · T. R. Endo · B. S. Gill S. H. Hulbert Cytologically based physical maps of the group 3 chromosomes of wheat

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Abstract Cytologically based physical maps for the group 3 chromosomes of wheat were constructed by mapping 25 *Triticum aestivum* deletion lines with 29 *T. tauschii* and *T. aestivum* RFLP probes. The deletion lines divide chromosomes 3A, 3B, and 3D into 31 discrete intervals, of which 18 were tagged by marker loci. The comparison of the consensus physical map with a consensus RFLP linkage map of the group 3 chromosomes of wheat revealed a fairly even distribution of marker loci on the long arm, and higher recombination in the distal region.

Key words Physical mapping · RFLP · Cereals · *Triticum aestivum*

Kinds of maps

Cytologically based physical maps (CBPMs) are ideograms of wheat chromosomes depicting positions of C-bands, deletion breakpoints, and allocated molecular markers in each deletion interval region (Werner et al. 1992). A CBPM can be aligned colinearly with a genetic linkage map using a common set of markers. The comparison of the two maps reveals important information for analyzing marker concentration and recombination in specific chromosomal regions. Saturation mapping of specific regions can be a starting point for map-based cloning of target genes. In this report, we present CBPMs and compare physical versus genetic linkage maps of the group 3 chromosomes of wheat.

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Markers

The 29 probes used for mapping (Table 1) were kindly provided by K. S. Gill (Gill et al. 1991) (KSU probes), M. D. Gale (Devos et al. 1993) (PSR probes), and K. Tsunewaki (Liu and Tsunewaki 1991) (TAG probes, *Xglk* loci). For 18

 Table 1
 Description of loci mapped with deletion stocks

| Locus | Chromosome location | Number of frag- | Number of scorable fragments | | | Enzyme |
|--------------------|-------------------------|--------------------|------------------------------|---|-----------|---------|
| | | ments | A | В | D | |
| XksuF34 | 38 | 11 | 0 | 0 | 1 | HindIII |
| XksuG13 | 35 | 7 | 1 | 2 | 1 | HindIII |
| XksuG53 XksuH7= | 3S | 2 | 1 | 0 | 1 | HindIII |
| XksuE2 | 3S and 3BL ^a | 6 | 1 | 3 | 1 | HindIII |
| XksuI19 | 35 | 2 | Ô | Õ | ĩ | HindIII |
| XksuI32 | 35 | 9 | 1 | Õ | $\hat{2}$ | HindIII |
| XpsrI23 | 35 | 3 | 1 | 1 | ĩ | HindIII |
| Xpsr598 | 35 | 3 | 1 | 1 | ĩ | HindIII |
| Xpsr689 | 35 | 3 | 1 | 1 | 1 | HindIII |
| Xpsr902 | 35 | 9 | 2 | 3 | 1 | HindIII |
| Xpsr910 | 38 | 4 | 1 | 1 | 1 | HindIII |
| Xpsr926 | 38 | 3 | 1 | 1 | 1 | HindIII |
| Xglk683 | 35 | 2 | 0 | 2 | 0 | HindIII |
| Xglk724 | 35 | 6 | 2 | 2 | 2 | HindIII |
| XksuD19 | 3L | 2 | 1 | 0 | 1 | HindIII |
| XksuE14 | 3L | 9 | 0 | 0 | 1 | HindIII |
| XksuG36 | 3L | 4 | 0 | 2 | 1 | HindIII |
| XksuG48 | 3L | 5 | 0 | 1 | 1 | HindIII |
| XksuG62 | 3L | 15 | 3 | 4 | 5 | HindIII |
| XksuH2 | 3L | 4 | 1 | 1 | 1 | HindIII |
| XksuH15 | 3L | 9 | 2 | 4 | 3 | HindIII |
| Xpsr74 | 3L | 3 | 1 | 1 | 1 | HindIII |
| Xpsr116 | 3L | 3 | 0 | 1 | 0 | HindIII |
| Xpsr156 | 3L | 3 | 1 | 1 | 1 | HindIII |
| Xpsr170 | 3L | 6 | 1 | 1 | 1 | HindIII |
| Xpsr578 | 3L | 3 | 1 | 1 | 1 | HindIII |
| Xpsr931 | 3L | 3 | 1 | 1 | 1 | HindIII |
| Xglk609 | 3L | 3 | 1 | 0 | 0 | HindIII |
| Xglk718 | 3L | 3 | 1 | 1 | 1 | HindIII |

^a 3AS, 3BS, 3BL, and 3DS

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Fig. 1 Physical maps for C-banded group 3 chromosomes of wheat. Fraction length measurements and deletion lines are shown on the *left*, and marker positions on the *right*

of the 29 probes, fragments were mapped on each of the 3A, 3B, and 3D chromosomes. These probes are most useful for analyzing colinearity of marker distribution.

The CBPMs

The 29 probes (Table 1) were used for mapping an array of 25 deletion lines for the group 3 chromosomes to construct CBPMs of chromosomes 3A, 3B, and 3D (Fig. 1). Marker loci were allocated to 18 of the 31 deletion interval regions. The marker coverage of the group 3 long arm is very good. However, for the short arm, no marker that has orthologous loci on all three chromosomes was allocated to the proximal 23% of the arm. Coverage of the distal 25% of the 3BS arm is also poor, as *Xglk683* is the only marker allocated to that region.

Physical versus genetic distances

The consensus group 3 CBPM and consensus group 3 RFLP linkage map (Devos et al. 1993) were aligned at the centromere for comparison of recombinational versus physical distances (Fig. 2). It is clear that the 20 cM linkage distance around the centromere represents approximately 50% of the proximal physical length of each arm. Thus, as is a rule now in wheat, recombination is suppressed in the proximal half of each arm, and this suppression may extend up to 60-75% of the length of the arm. The genetic recombination is very high in the distal ends of group 3 chromosomes (e.g., compare the linkage distance between loci Xpsr170 and Xpsr931 versus the physical distance). The relative distribution of marker loci in each arm can also be calculated. Surprisingly, the middle of 3S appears to be rich in markers. However, marker distribution is fairly uniform along the length of 3L, with the exception of the proximal 20% of the arm, which has only 1 marker. The distribution could also be an artifact of our choice of markers, and may change as more loci are added to the map.

Fig. 2 Comparison of the consensus physical map of the group 3 chromosomes of wheat (*left*) with the consensus genetic linkage map of wheat group 3 chromosomes. The scale in centimorgans (cM) is indicated on the *far right*



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References

- Devos KM, Gale MD (1993) Extended genetic maps of the homoeologous group 3 chromosomes of wheat, rye and barley. Theor Appl Genet 85:649-652
- Gill KS, Lubbers EL, Gill BS, Raupp WJ, Cox TS (1991) A genetic linkage map of *Triticum tauschii* (DD) and its relationship to the D genome of bread wheat (AABBDD). Genome 34:362–374
- Liu YG, Tsunewaki K (1991) Restriction fragment length polymorphism (RFLP) analysis in wheat. II. Linkage maps of the RFLP sites in common wheat. Jpn J Genet 66:617-633
- Werner JE, Endo TR, Gill BS (1992) Toward a cytogenetically based physical map of the wheat genome. Proc Natl Acad Sci USA 89:11307-11311