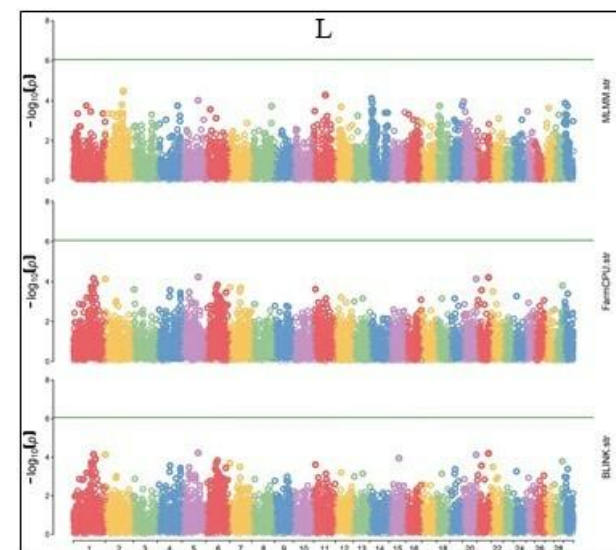
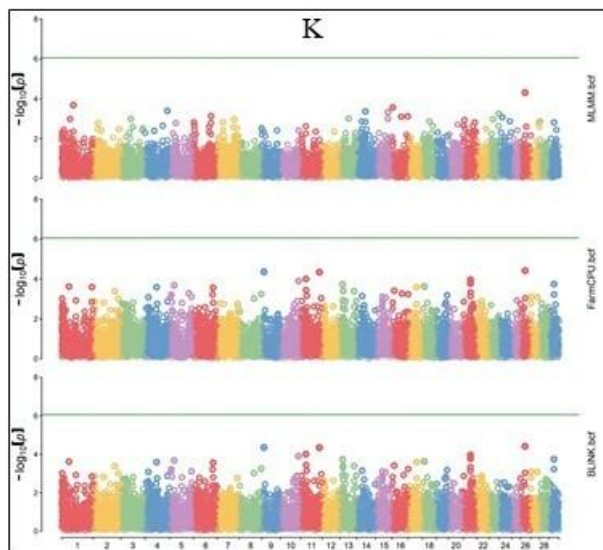
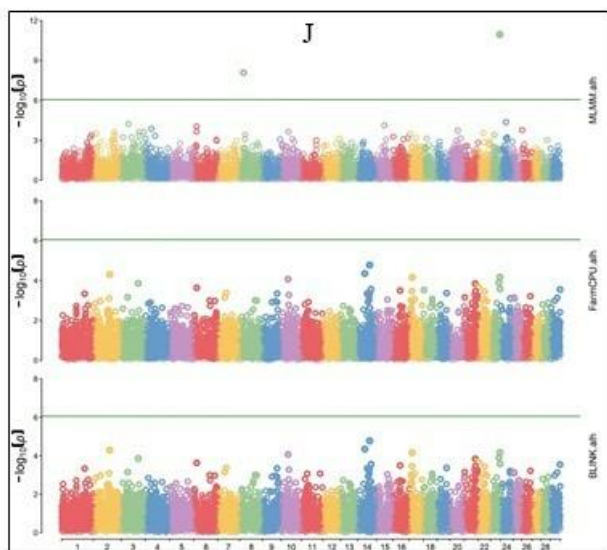
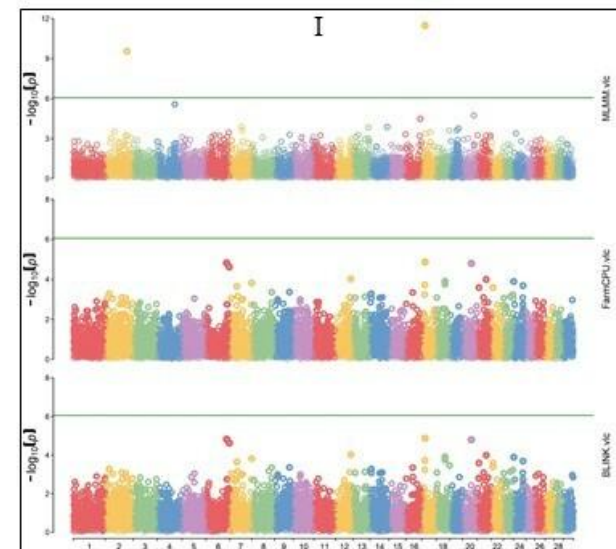
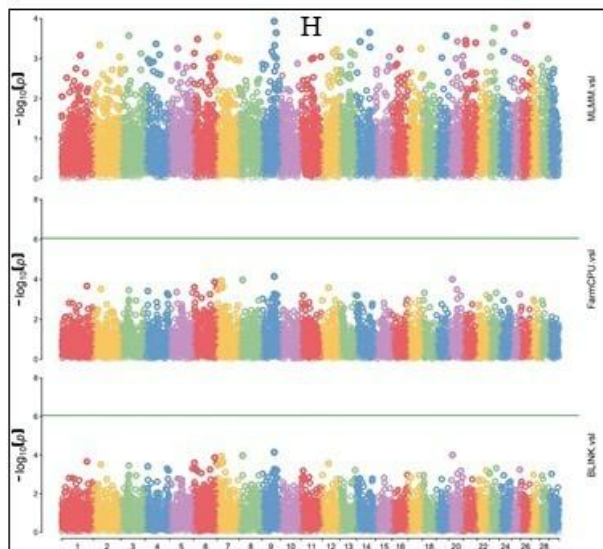
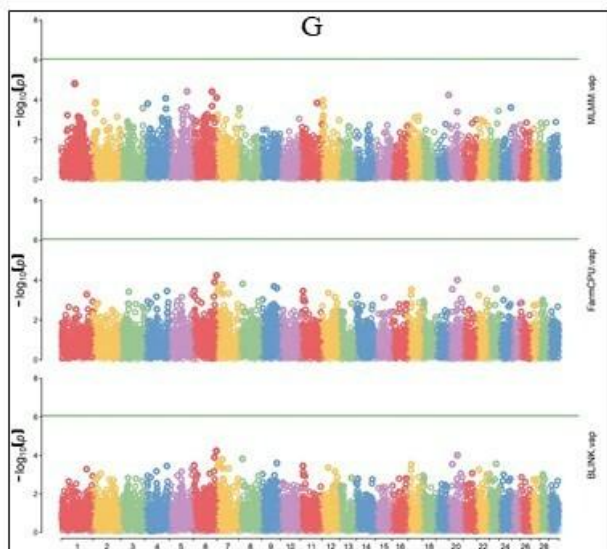
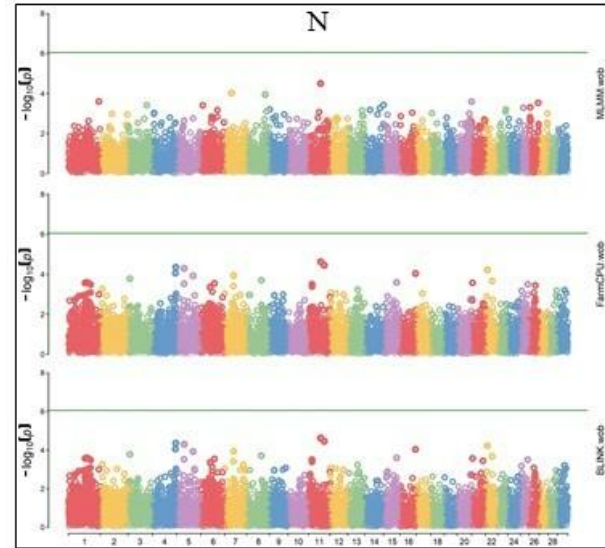
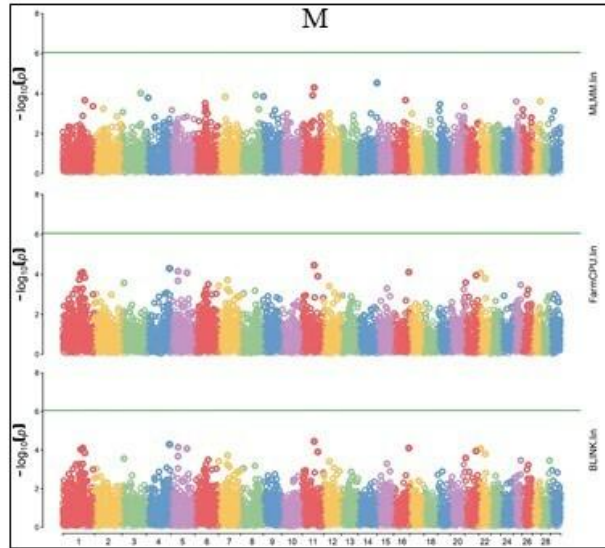


Additional file 2. Manhattan plots illustrating QTNs associated with sperm parameters. Manhattan plots displaying the distribution significant of QTNs across chromosomes. The x-axis represents chromosomal positions (Chr 0 indicates SNPs with undetermined genomic coordinates), while the dual y-axes show $-\log_{10}(p\text{-values})$ (left) for each QTN. The horizontal dashed line represents the significance threshold of $\text{LOD} \geq 6$. Each plot consists of three panels: the top panel presents data obtained using the MLMM method, the middle panel shows results from the FarmCPU method, and the bottom panel displays data from the BLINK method. **A:** Semen volume; **B:** Mass activity; **C:** Concentration; **D:** Total sperm count per ejaculation; **E:** Total motility; and **F:** Progressive motility.



Additional file 2 (continued). G: VAP; H: VSL; I: VCL; J: ALH; K: BCF; and L: STR.



Additional file 2 (continued). M. LIN and N: WOB.