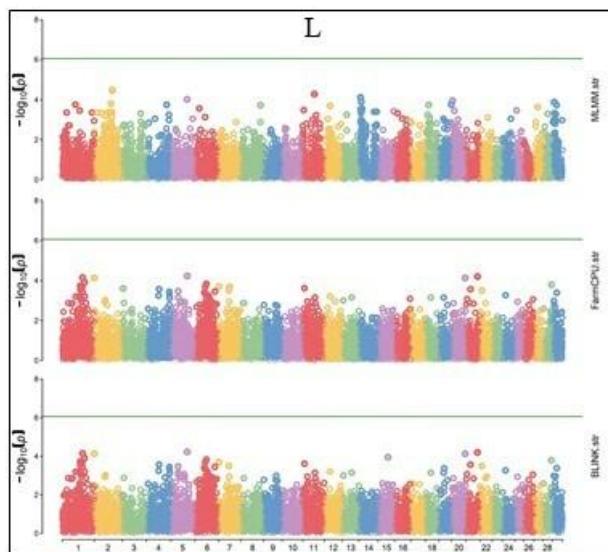
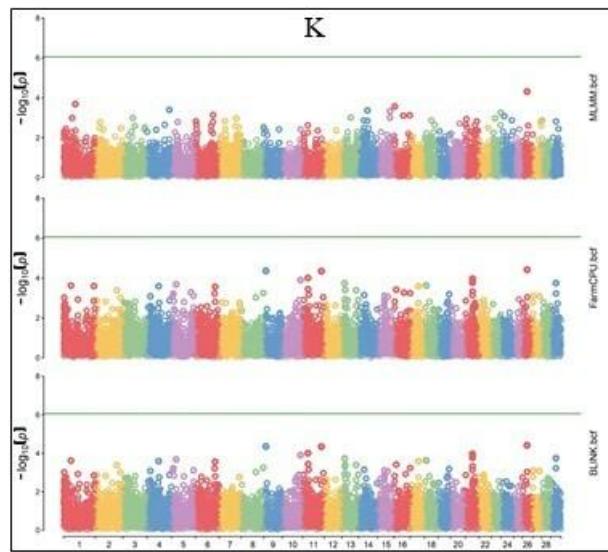
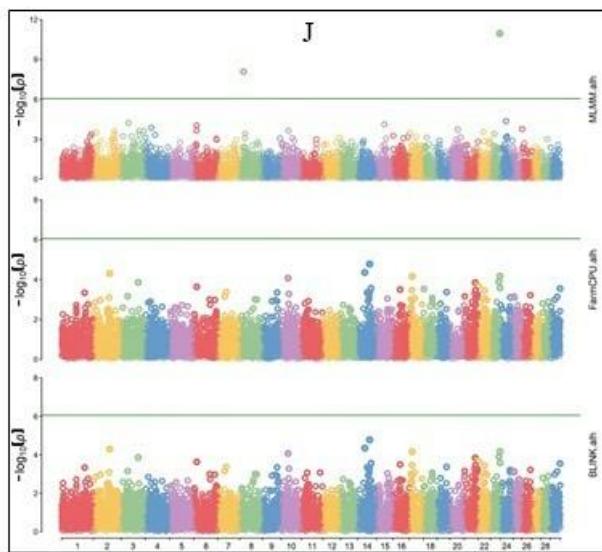
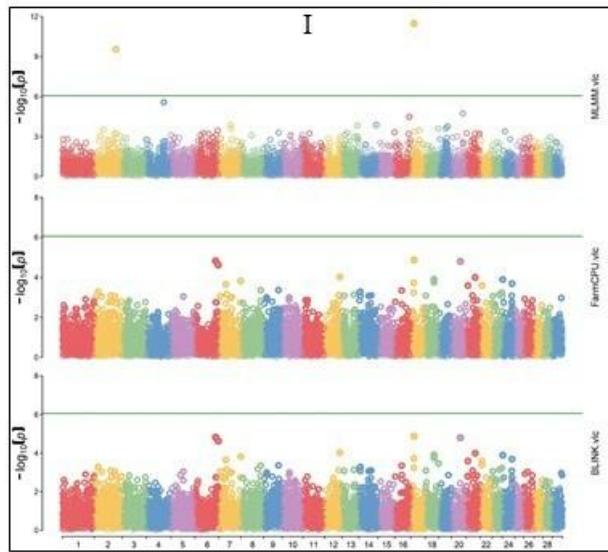
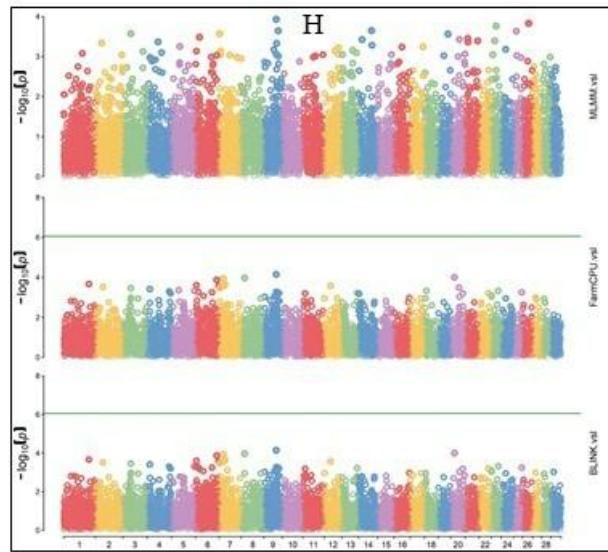
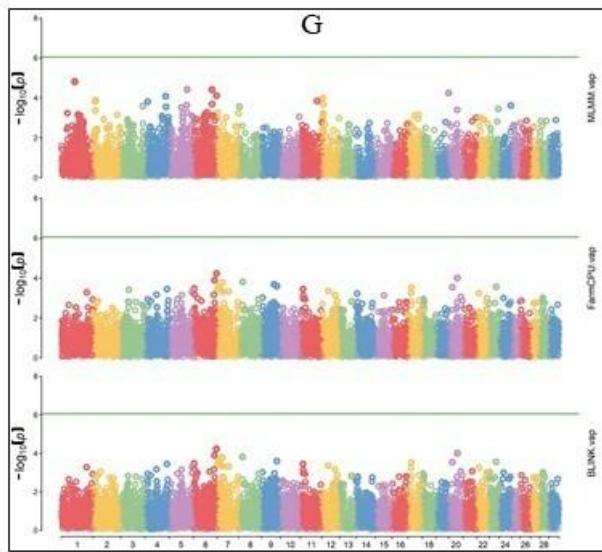
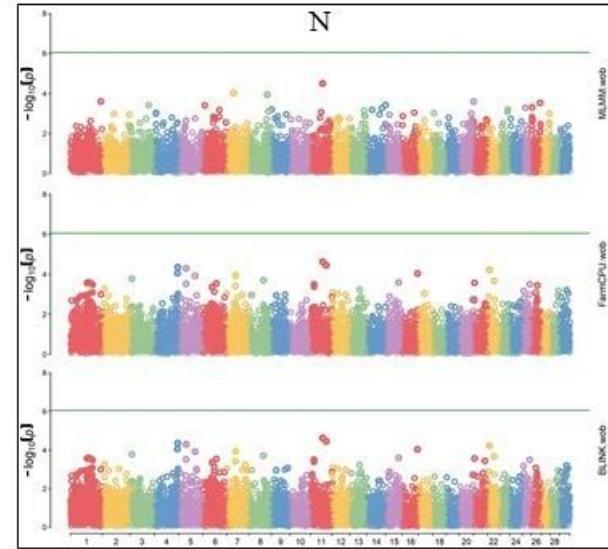
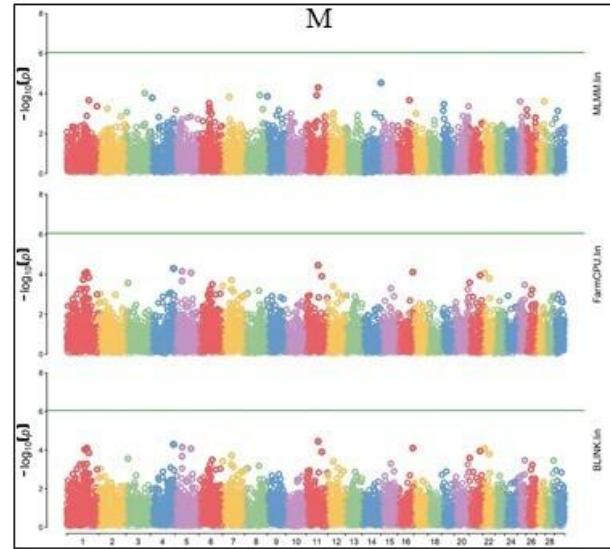


**Additional file 2.** Manhattan plots illustrating QTNs associated with sperm parameters. Manhattan plots displaying the distribution significant of QTNs across chromosomes. The x-axis represents chromosomal positions (Chr 0 indicates SNPs with undetermined genomic coordinates), while the dual y-axes show  $-\log_{10}(p\text{-values})$  (left) for each QTN. The horizontal dashed line represents the significance threshold of  $LOD \geq 6$ . 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.**