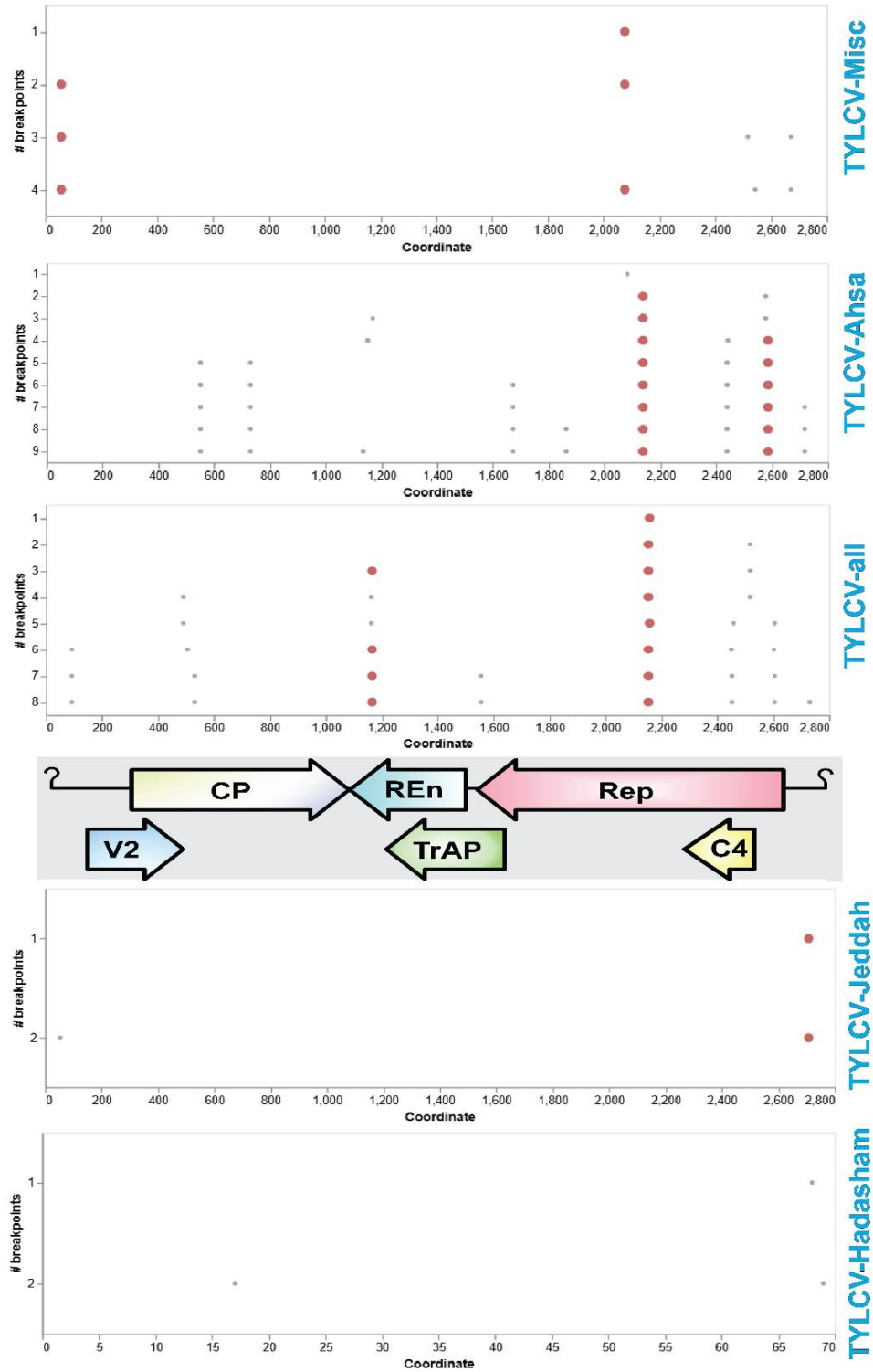




**Fig. S1.** The distribution of recombination breakpoints within different TYLCV datasets from Saudi Arabia. Well-supported breakpoints, identified by high AICc scores, are highlighted as bold red dots. Conversely, breakpoints with lower AICc scores are represented by smaller grey dots. The linear organization of the TYLCV genome is also depicted.

**Table S1.** Multiple recombination events detected by RDP in TYLCV-KSA populations

| Accession number | Recombination event | Breakpoints |      | Parents  |          | Detection Methods <sup>a</sup> | <i>p</i> -value <sup>b</sup> |
|------------------|---------------------|-------------|------|----------|----------|--------------------------------|------------------------------|
|                  |                     | Begin       | End  | Major    | Minor    |                                |                              |
| OR724724         | 1                   | 98          | 1141 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT033715         | 1                   | 74          | 1200 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT355023         | 1                   | 75          | 1201 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| MG571546         | 1                   | 518         | 1141 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT033713         | 1                   | 72          | 1198 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT033709         | 1                   | 516         | 1139 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT033706         | 1                   | 516         | 1139 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| ON756221         | 3                   | 1144        | 2563 | OL416209 | OR724727 | CGM <b>S</b>                   | 1.57×10 <sup>-13</sup>       |
|                  |                     | 2572        | 14   | MN397780 | KF435136 | BCGMRS                         | 1.50×10 <sup>-20</sup>       |
|                  |                     | 2118        | 2403 | ON756218 | OL416216 | BCGMRS                         | 2.03×10 <sup>-27</sup>       |
| ON756220         | 2                   | 2115        | 2525 | OR865126 | ON756219 | GMS <b>3</b>                   | 9.28×10 <sup>-07</sup>       |
|                  |                     | 2526        | 2749 | OL416216 | Unknown  | BCGMRS <b>3</b>                | 3.78×10 <sup>-16</sup>       |
| ON756219         | 1                   | 2609        | 2681 | MN397780 | OR865127 | CGMRS <b>3</b>                 | 4.26×10 <sup>-09</sup>       |
| ON756218         | 1                   | 2564        | 2673 | MN397780 | KF435136 | BCGMRS <b>3</b>                | 1.50×10 <sup>-20</sup>       |
| KU248482         | 1                   | 72          | 1200 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT728752         | 1                   | 69          | 1195 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT728746         | 1                   | 69          | 1195 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT728745         | 1                   | 68          | 1194 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT728744         | 1                   | 515         | 1138 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KT728743         | 1                   | 70          | 1196 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| OR865127         | 2                   | 319         | 469  | OL416209 | Unknown  | CGM <b>R</b> 3                 | 2.90×10 <sup>-12</sup>       |
|                  |                     | 2105        | 74   | OL416216 | KF435136 | BCGMRS <b>3</b>                | 1.45×10 <sup>-34</sup>       |
| OL416210         | 1                   | 1707        | 1892 | OR865127 | MN397780 | BCGM <b>R</b> 3                | 6.12×10 <sup>-07</sup>       |
| OL416209         | 1                   | 1707        | 1863 | OR865127 | MN397780 | BCGM <b>R</b> 3                | 6.12×10 <sup>-07</sup>       |
| MN397780         | 1                   | 2163        | 2432 | ON756218 | OL416216 | BCGMRS <b>3</b>                | 2.03×10 <sup>-27</sup>       |
| MN397779         | 2                   | 523         | 718  | ON756219 | OL416216 | CGM <b>R</b> S3                | 3.51×10 <sup>-14</sup>       |
|                  |                     | 2156        | 2425 | ON756218 | OL416216 | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KF435136         | 2                   | 44          | 1507 | OR724727 | OL416209 | BCGMRS <b>3</b>                | 3.45×10 <sup>-32</sup>       |
|                  |                     | 1554        | 2242 | ON756220 | OR724727 | CGMRS <b>3</b>                 | 1.31×10 <sup>-12</sup>       |
| KF561125         | 1                   | 502         | 1124 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |
| KF435137         | 2                   | 2097        | 2689 | OL416209 | MG571546 | BCGMRS <b>3</b>                | 1.04×10 <sup>-27</sup>       |
|                  |                     | 2507        | 2750 | OR865127 | MG571546 | CMRS <b>3</b>                  | 2.59×10 <sup>-08</sup>       |
| KC845301         | 1                   | 70          | 1196 | OL416209 | Unknown  | BCGMRS <b>3</b>                | 2.23×10 <sup>-37</sup>       |

<sup>a</sup> B, Bootscan; C, Chimaera; G, GeneConv; L, LARD; M, MaxChi; P, Phylpro; R, RDP; S, SisScan; 3, 3SEQ.

<sup>b</sup> The lowest *p*-value corresponds to the recombination program (bold) is mentioned.

**Table S2.** Motifs determined in the population of TYLCV-encoded ORFs

| ORF | Accession # | No. of motifs (protein and DNA) | Motif Number absent in Protein & DNA | Isolated from |      | Seq of protein motif                                                                                                               | Seq of DNA motif                                                                                                                                                                                                                                                                                                                                                                                             |
|-----|-------------|---------------------------------|--------------------------------------|---------------|------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |             |                                 |                                      | Region        | Host |                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                              |
| V2  |             | 3 & 10                          | No (present in all accessions)       | N/A           | N/A  | 1. MWDPILLNDEPESVHGFRCLAIKYLQAVEZTYEPNTLGHDLIRDLISVIR<br>2. DYVEASRRYNHFHARLEGSPKAE LRQPIQPPCCPHCRHKQASIMDVQA<br>3. HVPKAZBIQNVSNP | 1. CATTCCACGCCCCGTCTCGAAGCTTCGCCGAAGGCTGAACCTTCGACAGCC<br>2. TGGGCCACGATTTAATTAGGATCTATWTCGTTRTAAGGGCCCGTGAC<br>3. TTCACGGATTTCGTTGTATGYTAGCYATWAAATATTGCAGGCCGTTGAG<br>4. GCCCCCATTGTCCAGGCAACAACAAGCGTCGATCATGACGTACAGGCC<br>5. CATGTACCGAAAGMCSAGRATATACAGAAATGTATCGAASYC<br>6. ATGTGGATCCACTTCTYAAYGAWTTTCC<br>7. TATGTYGAAGCGWCCCGCGCA<br>8. AACWTAAGAGCCCAAYACTT<br>9. TACAGCAGCCGTGCT<br>10. KGAATCYG |

|    |          |        |                                                          |        |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----|----------|--------|----------------------------------------------------------|--------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CP | MN397780 | 5 & 10 | Motif number 3 absent in protein & motif 4 absent in DNA | Ahsa   | tomato | 1. YSSRAAAPIVQGTNKRRSWTYRPMYRKPRYRMVRTPDVPRGCEGPCKVQ<br>2. SGGQYASKEQCVIRRFYKIYNHVYNNHQEQKYENHTENALLYMACTHA<br>3. LCVSDVTRNGJTHRVGKRFCLKSIYIVGKY<br>4. PVTTPYGFGLFNMYPDNEPSTATIKNDLRDRCQYVKRFTAS<br>5. PGDIISTPVSQVRRRLNFD                                                                                                                                                                                                                                                                                                                                                |
|    | OR724727 |        | Motif number 3 and 4 absent in DNA                       | Riyadh | tomato |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|    |          |        |                                                          |        |        | 1. CATTCCAGCGCCGCTCTCGAAGGTTCCGCCGAAGGCTGAACCTTCGACAGCC<br>2. TACAGAATGTATCGAASYCCTGATGTTCCCGTGATGTGAAGGCCCATG<br>3. TACAGCAGCCGCTGCTGCTGCCCATTTGCCAAGGACAACAAGCGTCG<br>4. GCTTTRTATTGTATATGGCATGTACGCATGCTCTAATCCAGTGATGC<br>5. ATGTWYGATAATGAGCCTWSTACYGCMACYRTKAAGAATGATCTSCGGGA<br>6. ATGTWRYTATAATCATCARGARSMRGSMARTAYGAGAATCATACTGAR<br>7. TAARGTCARTCKTWTGASMARCGSSATGATWTKAAGCATACKGTRWKG<br>8. KTGITWWSWGATGTWACWCGTGGWWMCGGMMTTACYCAYMGWGTKGKA<br>9. GAATCAYACTAAYMMKKKYATGTTYTKGYTKGTYCGKATMGWMGKCKMK<br>10. ARGARATTYMMTGCTASMSTMAKTGCTGTCMATMTGSRWYSAARGARCA |

|             |          |        |                                           |      |        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------|----------|--------|-------------------------------------------|------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rep<br>(C1) | MN397780 | 5 & 10 | Motif<br>number 5<br>absent in<br>protein | Ahsa | tomato | 1. GKTMTWARSLLGPHNYLCGHLDSLPKVYSNDAWYNVIDDVHPHYLKHFEFM<br>2. PPALYISPELSSSFNQYPEELVWVSENVMSAAARPWRPNSIVIEGDSRT<br>3. AHFHPIQGAKSSSDVKS YIDKDGDTIEWGEFQIDGRSARGGQQSANDAY<br>4. AQRDWQSNTRYGKPIQIKGIPTILCNPGPTSSYKEYLDEEKNISLKNW<br>5. ALSQLQNLTNTPVNKL YIKGRELHENGEPHLHVLIIQFEQKYQCTNQRFED<br><br>1. GTMTGGGTGTCCGAGAACGTCATGCTCTKCCGCTGCCGGGCCATGGAGACC<br>2. GAGGGTGATAGCAGRACCGGCARACAATGTGGGCCAGGTCTTAGGCCC<br>3. AATGCAACCTTCATCAGCCCTACGAGCCTGTTCTCAAGTGCCAATCA<br>4. CCCATTCAAATTAAAGSGGAATTCACACTATCTTCCTCTGCAATCCAGG<br>5. TRGTGGACATCTAGACCTRAGTCWAAAGTGTACAGTAAYGAYGCGSTGG<br>6. GRTCCGCTAGAGGGGACACAACATCWGCM AAYGAYGCTTAGGCCSAGGCG<br>7. CGACCTGGTCTCCMCAACCAAGTCAAGACATTCATCCRAACATTCAAG<br>8. YTGACAGARCTTCACGAAATGGGGGAACCRCATCTCCAYGTGCTTATSC<br>9. AAGCACTTYAAAGAATTCATGGRGGCCAGAGGACTGGCAAAAGCAAYAC<br>10. ATTTCTCCMTTTTATCTCTCTTTAATCAAGTTCWGAAGAACTTGA |
|-------------|----------|--------|-------------------------------------------|------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|              |          |        |                                                                                 |        |          |                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------|----------|--------|---------------------------------------------------------------------------------|--------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TrAP<br>(C2) | KF435136 | 5 & 10 | Motif<br>number 5 in<br>protein<br>positioned<br>b/w motif<br>number 1<br>and 2 | Ahsa   | capsicum | 1. AKKKPVRRRRVDLDCGCSYYJHNCINHGFTHRGTHHCSSKEWRFYLG<br>2. ZAIQHEPRRNFBTBPIQSQHQEGVGDSQMFSQLPNLDDLTA<br>3. MQPSSPSTSHCSQVPIKVQHK<br>4. KQSPLFQDHHQ<br>5. RKHKGF | 1. ATGCAACCTTCATCACCCTCTACGAGCCACTGTTCTCAAGTGCCAATCAA<br>2. ATGTTTCTCAACTTCGGAATCTGGAGCAGCTTACRGCTCAGACTGGTC<br>3. CACMTCAACTGCATYAAYCATGGATTGAGGCACAGGGAACTCATCACTG<br>4. GAATGGCGTTTATCTGCGAGATAAACAATCCCTCTATTCAAGATCA<br>5. ATRCARATMMGATTCAATCACAACATCAGGAAGGARVYTGCGATTACAA<br>6. GAAACGARTCAGACGTARGCGAGTRGACCTAGACTGYGCGCTGCTCATACT<br>7. CACGACRASAGGCCATTYMMATGAACMAMGACRTMATTTTC<br>8. TCCAACACACAAGMTAGCCAAGA<br>9. TCTTAAGAGTATTTA<br>10. CTCMTCAGCA |
|              | KT728743 |        | Motif<br>number 5in<br>protein<br>substituted<br>with motif 4                   | Jeddah | cucumber |                                                                                                                                                               | 1. ATG<br>2. TTT<br>3. TCT<br>4. CAA<br>5. CTT<br>6. CCG<br>7. AAT<br>8. CTG<br>9. GAC                                                                                                                                                                                                                                                                                                                                                                            |
| REn<br>(C3)  | OR724727 | 5 & 5  | Motif<br>number 3 in<br>protein                                                 | Riyad  | tomato   | 1. MDS<br>2. RTG<br>3. ELIT<br>4. APQ<br>5. AKN<br>6. GVE                                                                                                     | 1. ATG<br>2. TTT<br>3. TCT<br>4. CAA<br>5. CTT<br>6. CCG<br>7. AAT<br>8. CTG<br>9. GAC                                                                                                                                                                                                                                                                                                                                                                            |

|  |          |  |                                                                        |        |        |  |  |
|--|----------|--|------------------------------------------------------------------------|--------|--------|--|--|
|  |          |  | substituted<br>by motif<br>number 5                                    |        |        |  |  |
|  | KF561125 |  | Motif<br>number 3 in<br>protein<br>substituted<br>by motif<br>number 5 | Qassim | tomato |  |  |

|       |                                                                                                                                                                                                                                                                                           |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       | 1. GTCTCCMCAACCAGGTCAGCACATTCCATCCRAACATTGAGGSAGCTAA<br>2. TTTCAGATCGATGGAAGRTCCCGCTAGAGGGGACAACAATCWGCM AAYGA<br>3. GGGGAACGRCATCTCCAYGTGCTTATSCAATTCGAAGGMAAGTACCAGTG<br>4. GCTTACGCCSAGCGGCTTAACWCWGGAAGTAAGTCGGAGGCTCTTAATGT<br>5. GACGTCAAGTCMTAYATYGACAAGGACGGAGACACCATCGAATGGGCGWA |
|       | 1. MGNRISMCLSNSKESTSAQINDSSTWSPQPGQHISIQTFRZLNPAL.TSSH<br>2. RTETPSNGVSFRSMIEGPLEGDNNQMMML.TPRRL.TLEVSRRL                                                                                                                                                                                 |
|       |                                                                                                                                                                                                                                                                                           |
|       | N/A                                                                                                                                                                                                                                                                                       |
|       | N/A                                                                                                                                                                                                                                                                                       |
|       | No (present in all accessions)                                                                                                                                                                                                                                                            |
| 2 & 5 |                                                                                                                                                                                                                                                                                           |
|       |                                                                                                                                                                                                                                                                                           |
| C4    |                                                                                                                                                                                                                                                                                           |