Article type: Research article

***TaAPO-A1*, an ortholog of rice *ABERRANT PANICLE ORGANIZATION 1*, is associated with total spikelet number per spike in elite European hexaploid winter wheat (*Triticum aestivum* L.) varieties**

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Supplementary figures

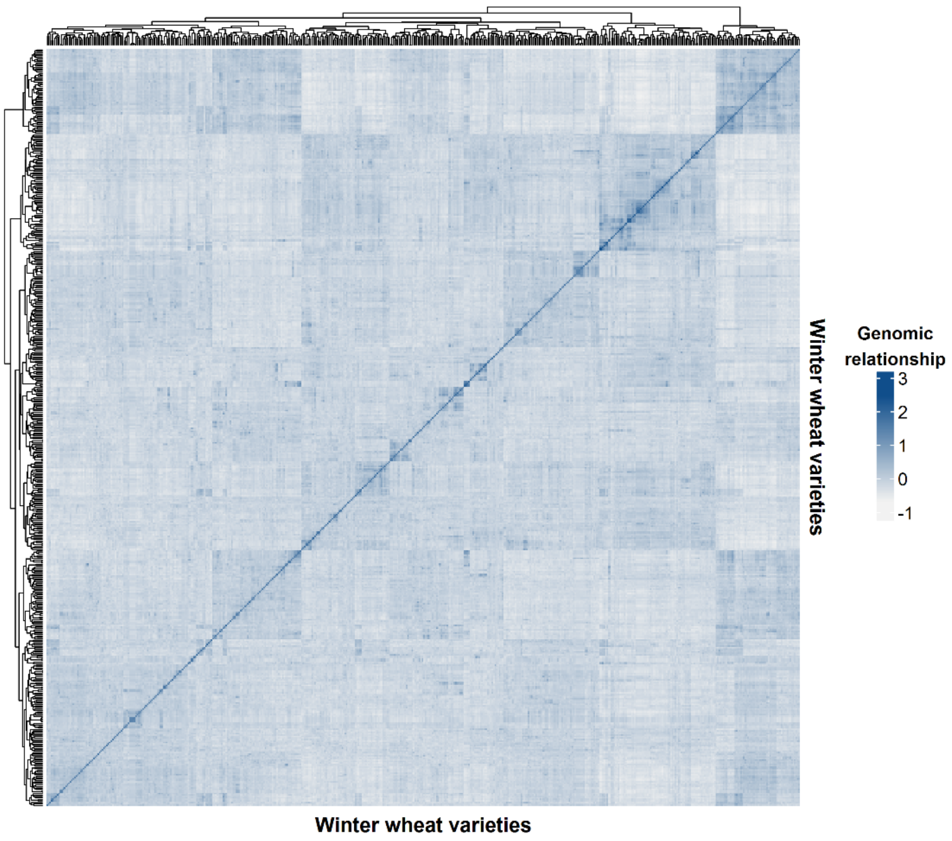
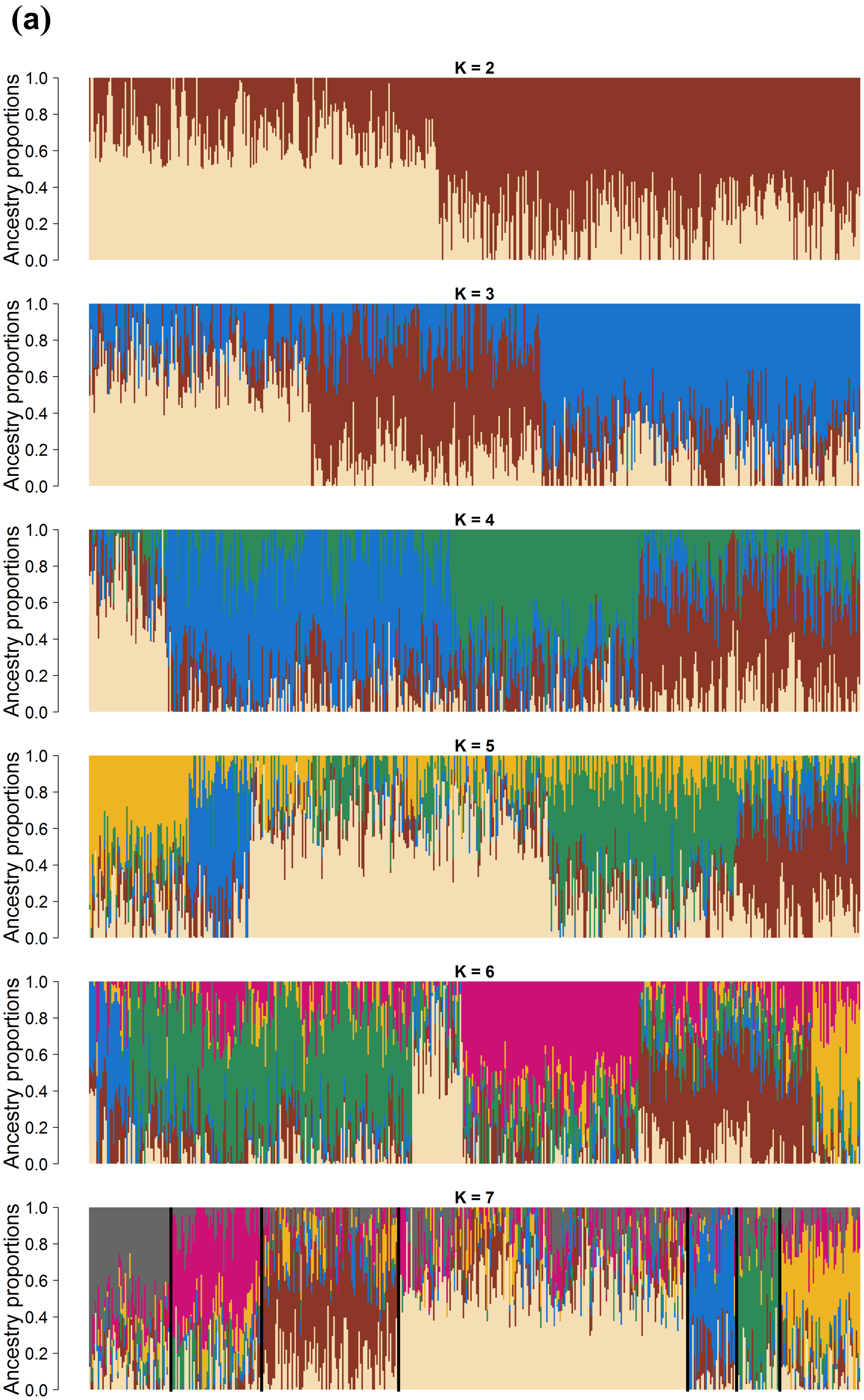


Figure S1. Heat map of the genomic relationships among 518 elite European winter wheat varieties based on 39,908 marker genotypes. The varieties are ordered according to hierarchical cluster analysis. The scale of genomic relationships is given in the figure.


(a)
K = 2
K = 3
K = 4
K = 5
K = 6
K = 7
Ancestry proportions
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0.2
0.4
0.6
0.8
1.0

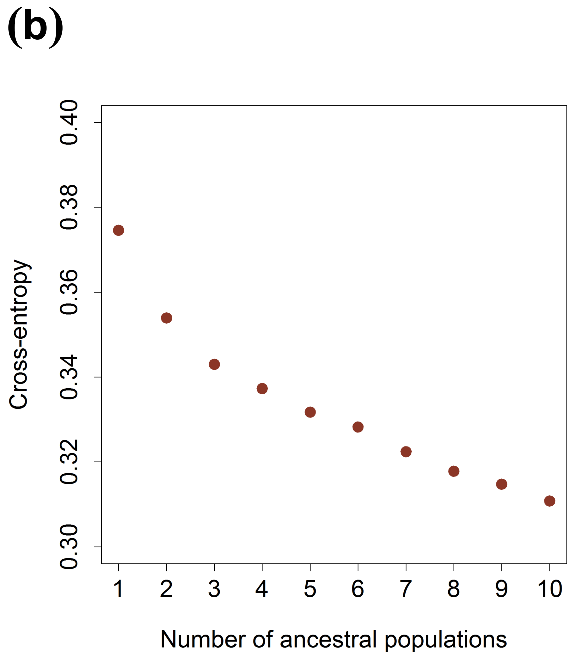


Figure S2. Population structure analysis of the 518 elite European winter wheat varieties based on 39,809 marker genotypes. (a) Bar plots show the existence of admixed sub-populations, (b) The cross-entropy plot shows that there exists a minimal sub-structuring in the panel.

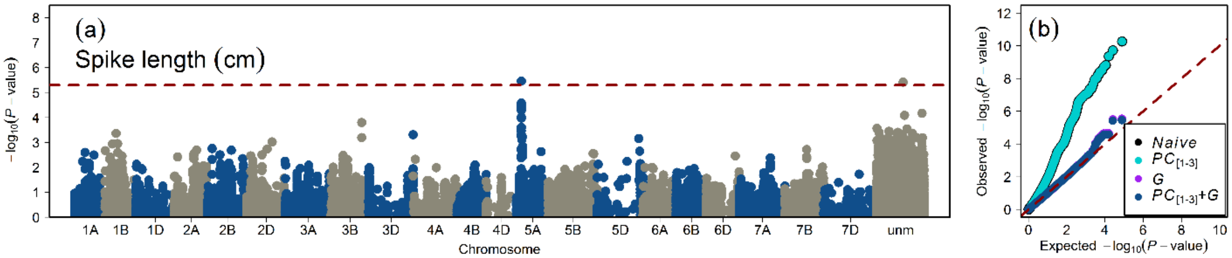


Figure S3. Summary of the genome-wide association studies (GWAS) of spike length in the population of 518 elite European winter wheat varieties. (a) Manhattan plot shows the distribution of markers significance $-\log_{10}(P-\text{value})$ along the chromosomes. The correction for population stratification and familial relatedness was performed by using the first three principal components ($PC_{[1-3]}$) and an additive genomic relationship matrix (*G*) in a linear mixed-effect model. The red dashed line marks the multiple testing criteria of false discovery rate (FDR) <0.10, **(b) Quantile-quantile plot showing the distribution of observed versus expected (red dashed line) $-\log_{10}(P-\text{value})$.** The naïve model represents the GWAS without the correction of population structure, the $PC_{[1-3]}$ model represents the population structure corrected with the first three *PCs*, the *G* model represents the familial relatedness corrected with a genomic relationship matrix, and the $PC_{[1-3]}+G$ model represents the population structure and familial relatedness corrected with the *PCs* and the *G* matrix. The color code for different models is given in the figure legend.

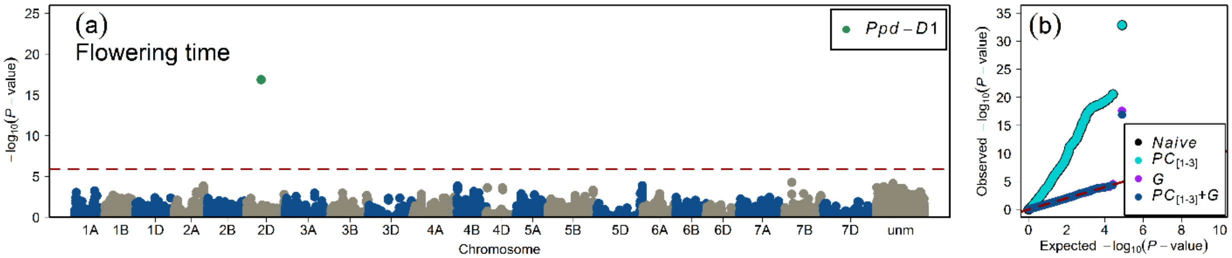


Figure S4: Summary of the genome-wide association studies (GWAS) of flowering time in the population of 518 elite European winter wheat varieties. (a) Manhattan plot shows the distribution of markers significance $-\log_{10}(P-\text{value})$ along the chromosomes. The correction for population stratification and familial relatedness was performed by using the first three principal components ($PC_{[1-3]}$) and an additive genomic relationship matrix (*G*) in a linear mixed-effect model. The red dashed line marks the multiple testing criteria of false discovery rate (FDR) <0.05, **(b) Quantile-quantile plot showing the distribution of observed versus expected (red dashed line) $-\log_{10}(P-\text{value})$.** The naïve model represents the GWAS without the correction of population structure, the $PC_{[1-3]}$ model represents the population structure corrected with the first three *PCs*, the *G* model represents the familial relatedness corrected with a genomic relationship matrix, and the $PC_{[1-3]}+G$ model represents the population structure and familial relatedness corrected with the *PCs* and the *G* matrix. The color code for different models is given in the figure legend.

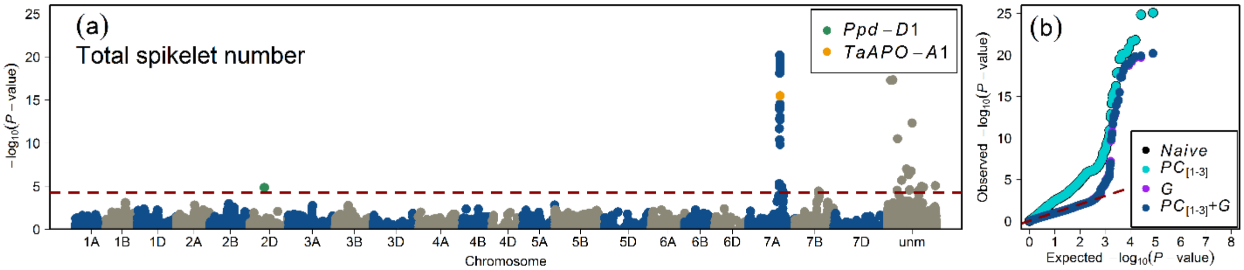
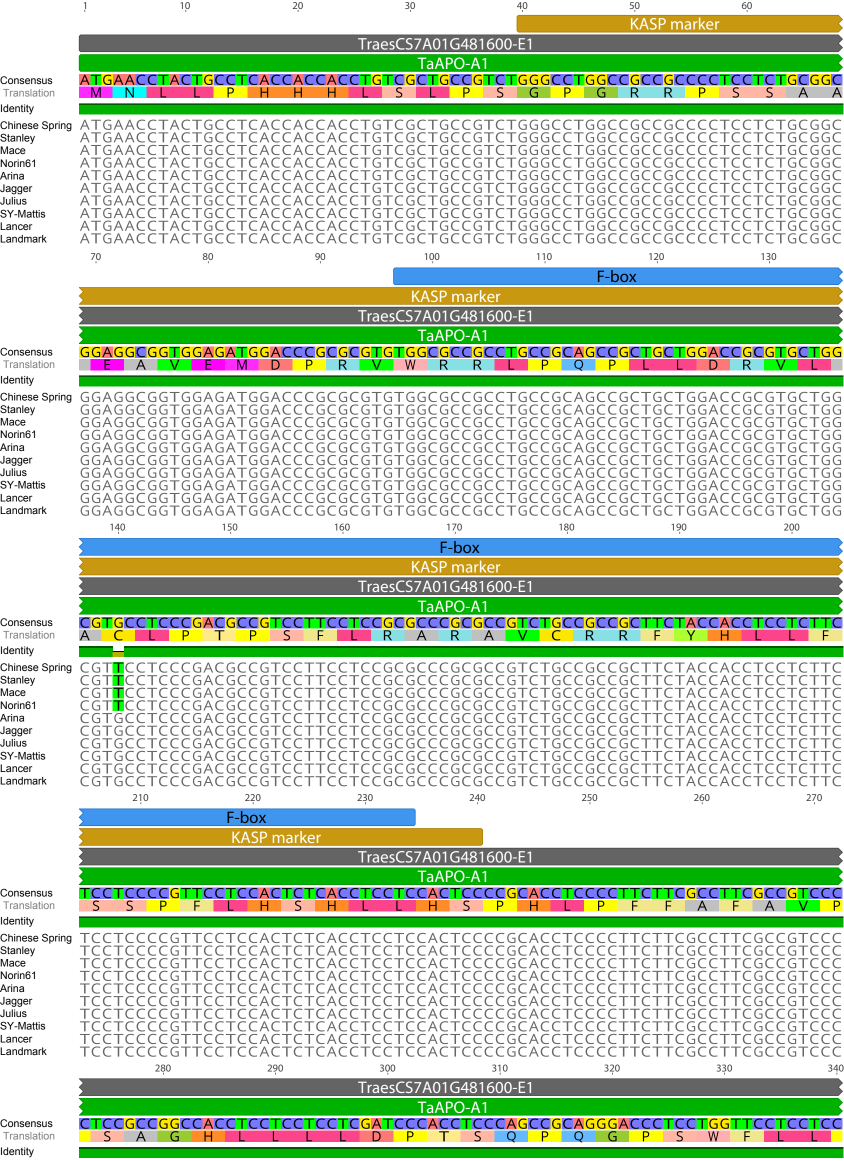
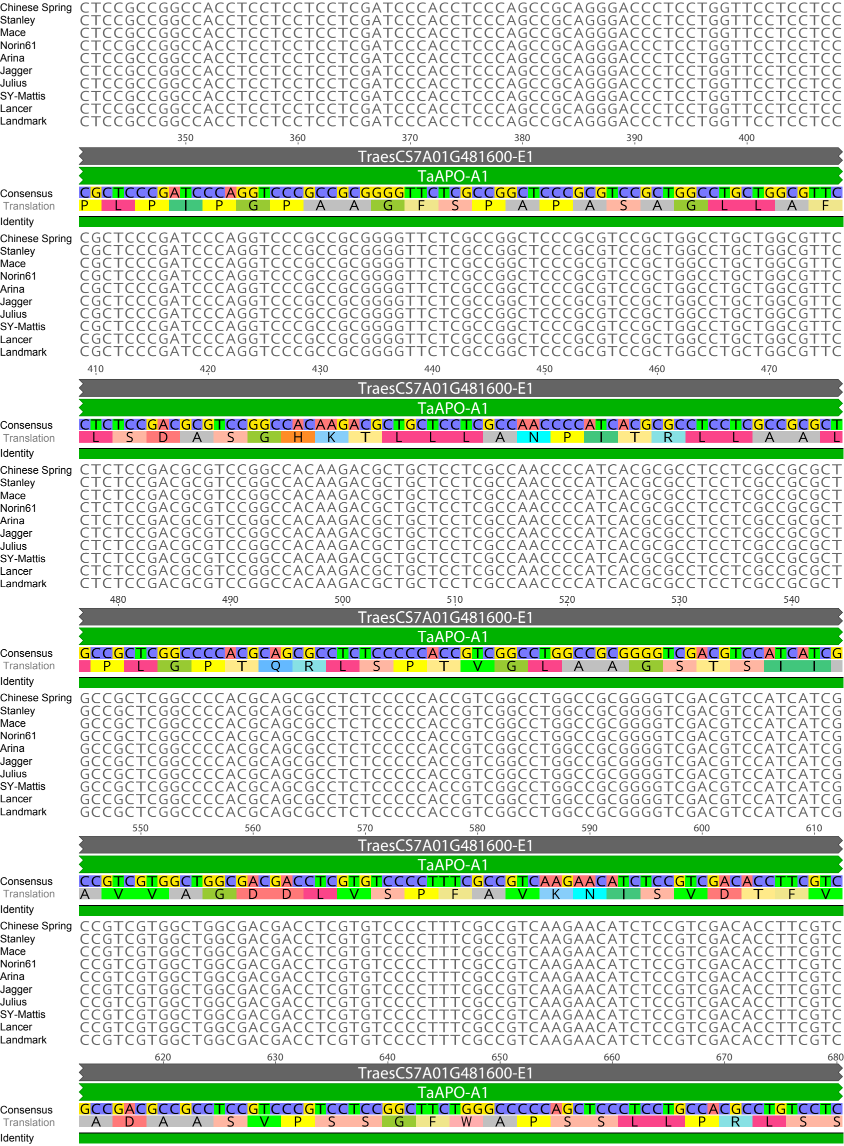


Figure S5. Summary of the genome-wide association studies (GWAS) of total spikelet number per spike in the population of 518 elite European winter wheat varieties. (a) Manhattan plot shows the distribution of markers significance $-\log_{10}(P-\text{value})$ along the chromosomes. The correction for population stratification and familial relatedness was performed by using the first three principal components (*PC*$_{[1\text{-}3]}$) and an additive genomic relationship matrix (*G*) in a linear mixed-effect model. The red dashed line marks the multiple testing criteria of false discovery rate (FDR) <0.05, **(b) Quantile-quantile plot showing the distribution of observed versus expected (red dashed line) $-\log_{10}(P-\text{value})$.** The naïve model represents the GWAS without the correction of population structure, the *PC*$_{[1\text{-}3]}$ model represents the population structure corrected with the first three *PCs*, the *G* model represents the familial relatedness corrected with a genomic relationship matrix, and the *PC*$_{[1\text{-}3]}$+*G* model represents the population structure and familial relatedness corrected with the *PCs* and the *G* matrix. The color code for different models is given in the figure legend.





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Stanley         CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Mace            CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Norin61         CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Arina           CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Jagger          CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Julius          CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
SY-Mattis       CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Lancer          CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC
Landmark        CTCCGCCGGCACCTCCTCCTCCTCGATCCCACCTCCCAGCCGCAGGGACCCTCCTGGTTCCTCCTCC

                        350       360       370       380       390       400
                                  TraesCS7A01G481600-E1
                                       TaAPO-A1
Consensus       CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Translation     P  L  P  I  P  G  P  A  A  G  F  S  P  A  P  A  S  A  G  L  L  A  F
Identity
Chinese Spring  CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Stanley         CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Mace            CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Norin61         CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Arina           CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Jagger          CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Julius          CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
SY-Mattis       CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Lancer          CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC
Landmark        CGCTCCCGATCCCAGGTCCCGCCGCGGGGTTCTCGCCGGCTCCCGCGTCCGCTGGCCTGCTGGCGTTC

                  410       420       430       440       450       460       470
                                  TraesCS7A01G481600-E1
                                       TaAPO-A1
Consensus       CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Translation       L  S  D  A  S  G  H  K  T  L  L  L  A  N  P  I  T  R  L  L  A  A  L
Identity
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Stanley         CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Mace            CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Norin61         CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Arina           CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Jagger          CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Julius          CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
SY-Mattis       CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Lancer          CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT
Landmark        CTCTCCGACGCGTCCGGCCACAAGACGCTGCTCCTCGCCAACCCCATCACGCGCCTCCTCGCCGCGCT

                    480       490       500       510       520       530       540
                                  TraesCS7A01G481600-E1
                                       TaAPO-A1
Consensus       GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Translation        P  L  G  P  T  Q  R  L  S  P  T  V  G  L  A  A  G  S  T  S  I  I
Identity
Chinese Spring  GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Stanley         GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Mace            GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Norin61         GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
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Jagger          GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Julius          GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
SY-Mattis       GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Lancer          GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG
Landmark        GCCGCTCGGCCCCACGCAGCGCCTCTCCCCCACCGTCGGCCTGGCCGCGGGGTCGACGTCCATCATCG

                     550       560       570       580       590       600       610
                                  TraesCS7A01G481600-E1
                                       TaAPO-A1
Consensus       CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Translation     A  V  V  A  G  D  D  L  V  S  P  F  A  V  K  N  I  S  V  D  T  F  V
Identity
Chinese Spring  CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Stanley         CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Mace            CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Norin61         CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Arina           CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Jagger          CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Julius          CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
SY-Mattis       CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Lancer          CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC
Landmark        CCGTCGTGGCTGGCGACGACCTCGTGTCCCCTTTCGCCGTCAAGAACATCTCCGTCGACACCTTCGTC

                      620       630       640       650       660       670       680
                                  TraesCS7A01G481600-E1
                                       TaAPO-A1
Consensus       GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
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Identity
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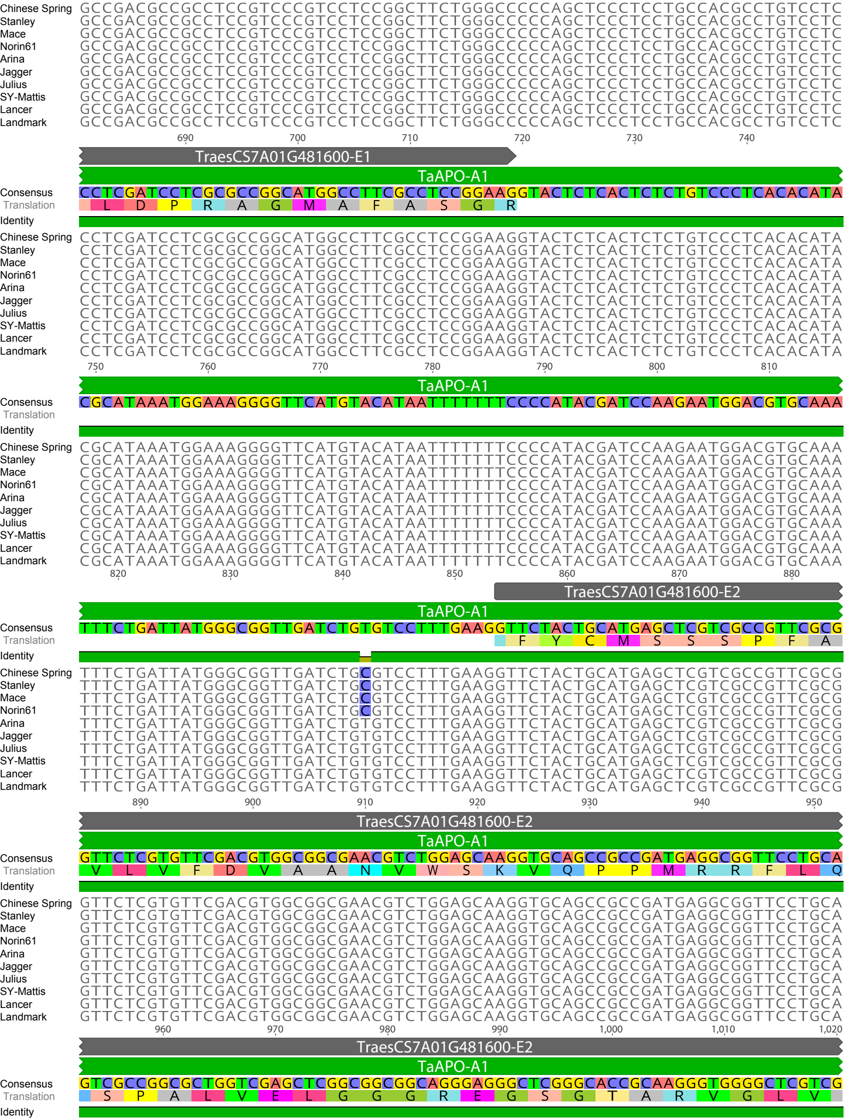

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Stanley        GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Mace           GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Norin61        GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Arina          GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Jagger         GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Julius         GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
SY-Mattis      GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Lancer         GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
Landmark       GCCGACGCCGCCTCCGTCCCGTCCTCCGGCTTCTGGCCCCCAGCTCCCTCCTGCCACGCCTGTCCTC
                        690       700       710       720       730       740

               TraesCS7A01G481600-E1
               TaAPO-A1
Consensus      CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Translation     L  D  P  R  A  G  M  A  F  A  S  G  R
Identity
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Stanley        CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Mace           CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Norin61        CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Arina          CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Jagger         CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Julius         CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
SY-Mattis      CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Lancer         CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
Landmark       CCTCGATCCTCGCGCCGGCATGGCCTTCGCCTCCGGAAGGTACTCTCACTCTCTGTCCCTCACACATA
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               TaAPO-A1
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Translation
Identity
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Mace           CGCATAAATGGAAAGGGGTTCATGTACATAATTTTTTTCCCCATACGATCCAAGAATGGACGTGCAAA
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Arina          CGCATAAATGGAAAGGGGTTCATGTACATAATTTTTTTCCCCATACGATCCAAGAATGGACGTGCAAA
Jagger         CGCATAAATGGAAAGGGGTTCATGTACATAATTTTTTTCCCCATACGATCCAAGAATGGACGTGCAAA
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SY-Mattis      CGCATAAATGGAAAGGGGTTCATGTACATAATTTTTTTCCCCATACGATCCAAGAATGGACGTGCAAA
Lancer         CGCATAAATGGAAAGGGGTTCATGTACATAATTTTTTTCCCCATACGATCCAAGAATGGACGTGCAAA
Landmark       CGCATAAATGGAAAGGGGTTCATGTACATAATTTTTTTCCCCATACGATCCAAGAATGGACGTGCAAA
                 820       830       840       850       860       870       880

                                                     TraesCS7A01G481600-E2
               TaAPO-A1
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Translation                                             F  Y  C  M  S  S  S  P  F  A
Identity
Chinese Spring TTTCTGATTATGGGCGGTTGATCTGCGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Stanley        TTTCTGATTATGGGCGGTTGATCTGCGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Mace           TTTCTGATTATGGGCGGTTGATCTGCGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Norin61        TTTCTGATTATGGGCGGTTGATCTGCGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Arina          TTTCTGATTATGGGCGGTTGATCTGTGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Jagger         TTTCTGATTATGGGCGGTTGATCTGTGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Julius         TTTCTGATTATGGGCGGTTGATCTGTGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
SY-Mattis      TTTCTGATTATGGGCGGTTGATCTGTGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Lancer         TTTCTGATTATGGGCGGTTGATCTGTGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
Landmark       TTTCTGATTATGGGCGGTTGATCTGTGTCCTTTGAAGGTTCTACTGCATGAGCTCGTCGCCGTTCGCG
                    890       900       910       920       930       940       950

               TraesCS7A01G481600-E2
               TaAPO-A1
Consensus      GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Translation     V  L  V  F  D  V  A  A  N  V  W  S  K  V  Q  P  P  M  R  R  F  L  Q
Identity
Chinese Spring GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Stanley        GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Mace           GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Norin61        GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Arina          GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Jagger         GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Julius         GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
SY-Mattis      GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Lancer         GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
Landmark       GTTCTCGTGTTCGACGTGGCGGCGAACGTCTGGAGCAAGGTGCAGCCGCCGATGAGGCGGTTCCTGCA
                    960       970       980       990       1,000     1,010     1,020

               TraesCS7A01G481600-E2
               TaAPO-A1
Consensus      GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGGTGGGGCTCGTCG
Translation      S  P  A  L  V  E  L  G  G  G  R  E  G  S  G  T  A  R  V  G  L  V
Identity
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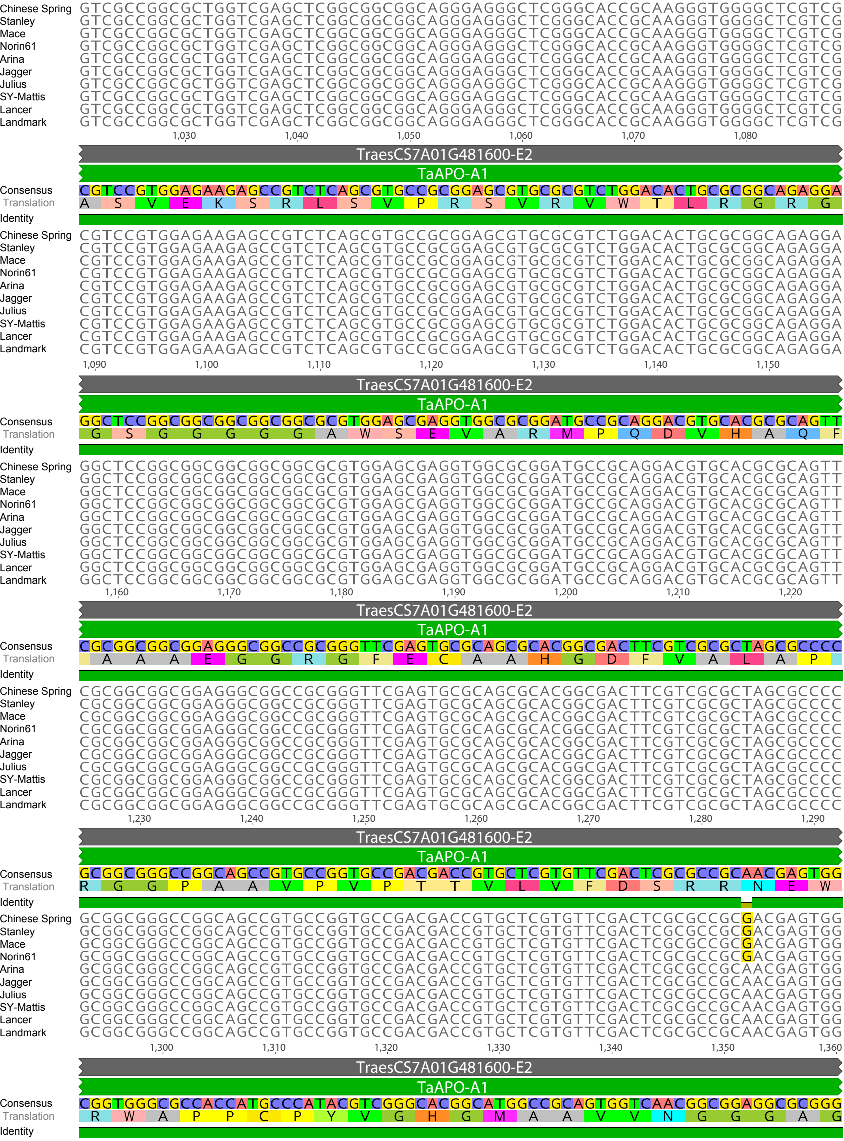

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Stanley         GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Mace            GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Norin61         GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Arina           GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Jagger          GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Julius          GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
SY-Mattis       GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Lancer          GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
Landmark        GTCGCCGGCGCTGGTCGAGCTCGGCGGCGGCAGGGAGGGCTCGGGCACCGCAAGGTGGGGCTCGTCG
                1,030  1,040  1,050  1,060  1,070  1,080

TraesCS7A01G481600-E2
TaAPO-A1
Consensus       CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Translation     A S V E K S R L S V P R S V R V W T L R G R G
Identity
Chinese Spring  CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Stanley         CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Mace            CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Norin61         CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Arina           CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Jagger          CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Julius          CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
SY-Mattis       CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Lancer          CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
Landmark        CGTCCGTGGAGAAGAGCCGTCTCAGCGTGCCGCGGAGCGTGCGCGTCTGGACACTGCGCGGCAGAGGA
                1,090  1,100  1,110  1,120  1,130  1,140  1,150

TraesCS7A01G481600-E2
TaAPO-A1
Consensus       GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Translation     G S G G G G G A W S E V A R M P Q D V H A Q F
Identity
Chinese Spring  GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Stanley         GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Mace            GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Norin61         GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Arina           GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Jagger          GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Julius          GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
SY-Mattis       GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Lancer          GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
Landmark        GGCTCCGGCGGCGGCGGCGGCGCGTGGAGCGAGGTGGCGCGGATGCCGCAGGACGTGCACGCGCAGTT
                1,160  1,170  1,180  1,190  1,200  1,210  1,220

TraesCS7A01G481600-E2
TaAPO-A1
Consensus       CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Translation     A A A E G G R G F E C A A H G D F V A L A P
Identity
Chinese Spring  CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Stanley         CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Mace            CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Norin61         CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Arina           CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Jagger          CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Julius          CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
SY-Mattis       CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Lancer          CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
Landmark        CGCGGCGGCGGAGGGCGGCCGCGGGTTCGAGTGCGCAGCGCACGGCGACTTCGTCGCGCTAGCGCCCC
                1,230  1,240  1,250  1,260  1,270  1,280  1,290

TraesCS7A01G481600-E2
TaAPO-A1
Consensus       GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
Translation     R G G P A A V P V P T T V L V F D S R R N E W
Identity
Chinese Spring  GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCGACGAGTGG
Stanley         GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCGACGAGTGG
Mace            GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCGACGAGTGG
Norin61         GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCGACGAGTGG
Arina           GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
Jagger          GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
Julius          GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
SY-Mattis       GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
Lancer          GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
Landmark        GCGGCGGGCCGGCAGCCGTGCCGGTGCCGACGACCGTGCTCGTGTTCGACTCGCGCCGCAACGAGTGG
                1,300  1,310  1,320  1,330  1,340  1,350  1,360

TraesCS7A01G481600-E2
TaAPO-A1
Consensus       CGGTGGGCGCCACCATGCCCATACGTCGGGCACGGCATGGCCGCAGTGGTCAACGGCGGAGGCGCGGG
Translation     R W A P P C P Y V G H G M A A V V N G G G A G
Identity
```

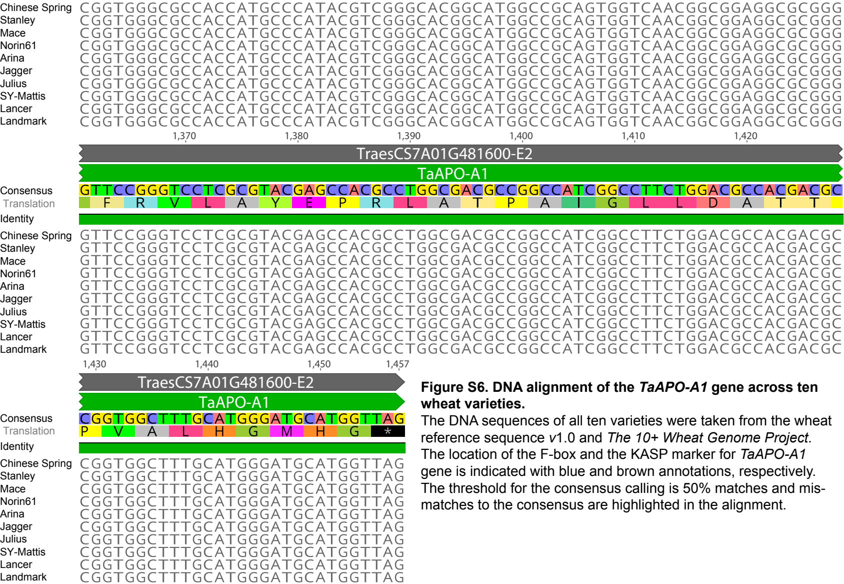

Figure S6. DNA alignment of the *TaAPO-A1* gene across ten wheat varieties. The DNA sequences of all ten varieties were taken from the wheat reference sequence *v*1.0 and *The 10+ Wheat Genome Project*. The location of the F-box and the KASP marker for *TaAPO-A1* gene is indicated with blue and brown annotations, respectively. The threshold for the consensus calling is 50% matches and mismatches to the consensus are highlighted in the alignment.

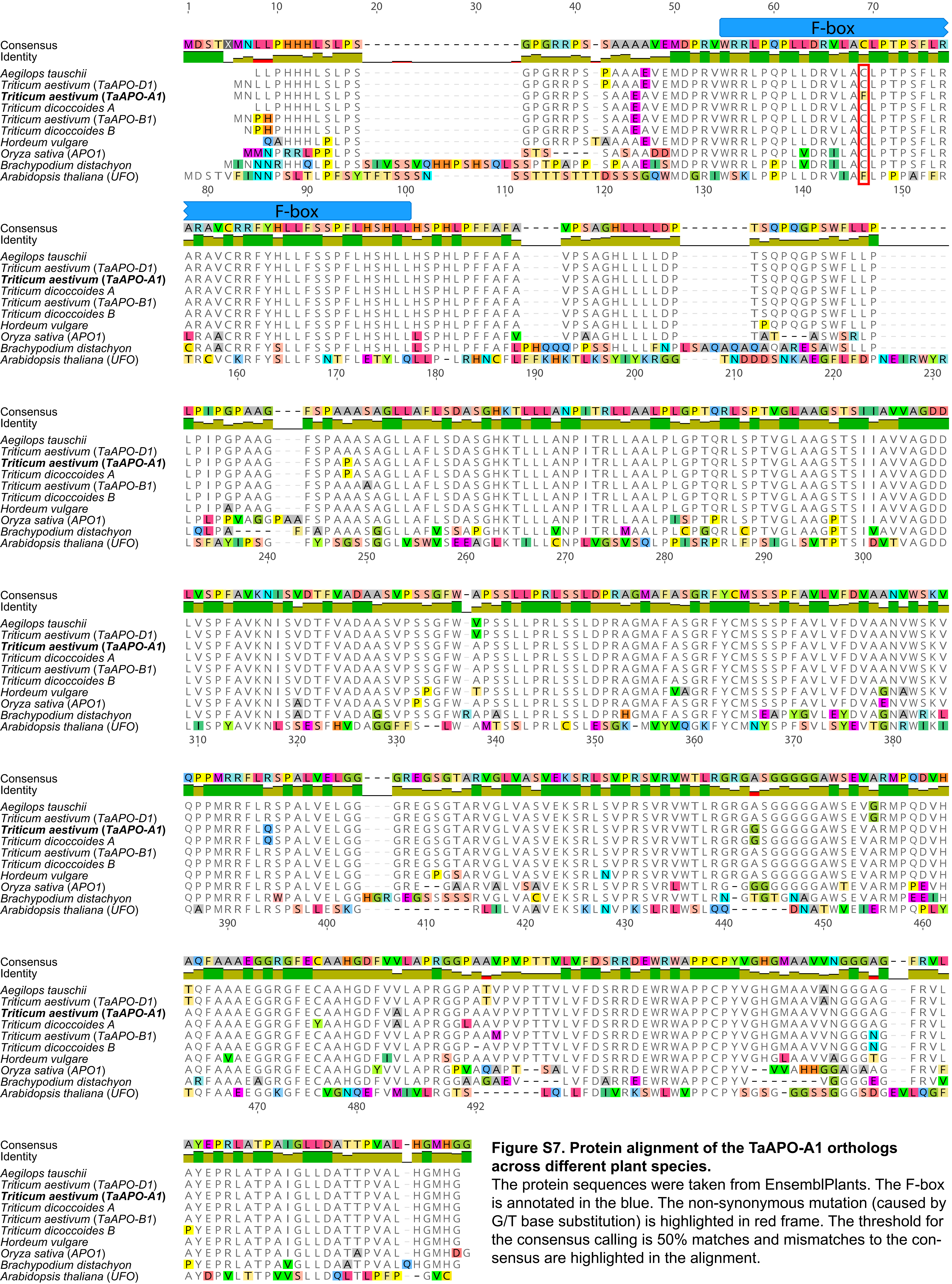

Figure S7. Protein alignment of the TaAPO-A1 orthologs across different plant species.
The protein sequences were taken from EnsemblPlants. The F-box is annotated in the blue. The non-synonymous mutation (caused by G/T base substitution) is highlighted in red frame. The threshold for the consensus calling is 50% matches and mismatches to the consensus are highlighted in the alignment.