Supplementary materials

Table S1. Primers used in this study

	Forward primer	Reverse Primer
MdCo4	TTAGTGCTCCTTGCTGCC	TCAAATTCCTAACAATTCTGGAATTTCC
MdCo6	CGACTGCTTCAGGGT	TTAGTTGAGAAAGTCCTTCATTGG
MdCo9	ATGAATGCTATTGAAGAAGTTTACAGAA	CTACACAACTGGAACTGTCCTGTTG
MdCo10	CTGCAATGTCTTTCAGAGGGC	TCAATGGGCACGGTCTCTGAGCA
MdCo11	ATGACGTCCTTTTCGCTTG	TCAATATCTTTGAGAATAATTATCAGTACC
MdCo26	AGACATTAGATCAGAATCTT	TTAGCTACTCGAGAGGCTTAAA
MdCo28	ATGATGTTCGGTAGGTTGAAGGGTG	CTATGGCTTTATTTCCGGAGTTTCTGG
MdCo32	ATGTTGCAGTTAATGAGCTGTGGC	CTACTCATTACTAGTTAATATAGTTTGCTCT
MdCo33	ATGAGGCAAAGAGAGATGCTGGAA	TCAACACCAACCTTGAGGCCAC
MdCo37	ATGGCATCAGATTCAGCAGCT	TAAACTTAATAAAATATTAAAATAAGTATTTAAAG
MdCo38	AAGACGAATCCTCGTATTACG	TTAGGCTAATTTAAAATGAGAAAGGGCA
MdCo41	ATGTCAACTGTTGTTTCGGCTTGTG	TTAAAAACTGCACCACCATAACTCAGAGTC
MdCo44	TGGACGTGTTGGATCA	CTAAAGTTTGTAACGTTTCATGTATTCTC
qNtGRF1	ATAAACAGAGGTCGCCATCG	GTTGACAAGCTGCTCAGTGG
qNtGRF3	CAGAGCCAGGGAGATGTAGG	CACCACTAGCATGGCCACTA
qNtGRF5	CTCTGCGAGGTTCTTCCATC	TGCTGCTTCCAGTAGCATTG
qRT-MdCo41	AGAAGAAGGCCGCAAGAGATT	GCTCGCAGCCACCTAACAAT
qNtMAX4	ATTTATTAAAGGCTGAGCCCACA	ATCCTCGCCGTTGAATGACC
qNtCCD7	TGCTTGTGGGAAGGTGGTGA	ATCCTCTGCGTTGCATGACG
qNtCCD8	GGCTTAGGTACTTCGGAAAA	AGAAATGGCCCAGGACAATG
qPCR-NtIPT	AACGCAAAGGTATCCCTCA	CATCAACCCAAATAAAGCAAC
qPCR-Co38	GTTCCTCATTCATCCACCAC	CCACTCCATCTTCACCTCC

qRT-GA20ox	CATAGGCGATACATTTATGGCG	CAGCTCTGTAATGCTTTTGTGT
qRT-NtGA2ox	GTGCTGGAAATGATAGCAGAAG	AAAAGGAGTAGTGATCAGGTGG
qRT-NtIPT	AACGCAAAGGTATCCCTCA	CATCAACCCAAATAAAGCAAC
qRT-NtPIN1	ATTAGGAACCCGAACACTTA	ACACCCATTGAGAAAGCAG
qRT-NtPIN2	TATTCTGTTCAATCGTCCCG	CCCGCTCATACTCCTACCTC
qRT-Ntactin	AGAGGTTCCGTTGCCCAGAAGT	GCTAGGAGCCAAAGCCGTGATT
qRT-MdACTIN	GGATTTGCTGGTGATGATGCT	AGTTGCTCACTATGCCGTGC

Table S2. Sequence alignments of 11 candidate genes in 'McIntosh'

Genes name	'McIntosh' sequence
Co4	ATGGTTAGTGCTCCTTGCTGCCAGAAGATGGGGTTGAAGAAAGGGCCTTGGACTGCAGAAGAAG ATCACATACTTGTCACTTACATTCAGCAGCATGGCCATGGAAACTGGAGAGCTCTCCCAAAACT AGCTGGTTTGTTACGGTGTGGAAAGAGTTGTAGACTCAGATGGACAAACTACTTGAGGCCAGAT ATCAAAAGAGGGAATTTTAGCAGGGAAGAAGAAGACGCCATCATCAACTTACATCAAATGTTA GGAAATAGATGGTCACAAATCGCAGCGAGATTGCCTGGTCGCACAGACAATGAAATAAAAAAT GTATGGCACACCCATTTAAAAAAAAAGCTGAAATCGAACCACACCGAACCAAATTCTAGGGCA CGTTTCTACTCTAGAAAATCGGAGCAAGAGCTAGAGCCCATTGATGATTCTTCATATTGTGCAAA ATCTGATAGCTTGGATTGTGTGCCTGTTTCGCCGGCTCGATGTACTTCAAATAACACGTCATCTGT CACGACCAACGACTACGACAACAACAACAATAGTAACAATGTATGTGTGACATTTGACGATTAC CAAGCAAATTTACCAGAACCGGATGATAGTTTTTGGTCGGAAGTTTTGTCAACTGAGTATTATGA AGAGACGGTGAATGAGTTTCAGGCATTTGGTGGTGACCCACAAGTGAATATGGGGCCTACTGAT GGTGGTTTTAGTTTAGACATGTACAATGACAACAACATGGACTTTTGGTTTAATATATTCTCAGG AGCTGAGGAAATTCCAGAATTGTTAGGAATTTGA
Co6	ATGGCGACTGCTTCAGGGTCATTCAAATCTAGGGAAGACCATCGTAAGCAAATGGAATTGGAAG AAGCGCGTAAAGCTGGGCTTGCGCCAGCTGAACTGGACGAGGATGGAAAGGAGATTAATCCTC ATATTCCCCAATATATGTCATCTGCGCCTTGGTATCTCAAACACGAGAGGCCTAGCTTGAAACAT CAAAGGAAATGGAAATCAGATCCAAATTACACAACATCATGGTATGACAGAGGTGCAAAGATA TTCCAGGCTGATAAATATAGGAAGGGTGCATGTGAGAACTGTGGTGCCAGTACACACGACTCAA AGTCATGCATGGATAGGCCCAGGAAAGTGGGAGCAAAGTGGACTAACACGCACATTGCTCCTG ATGAAAAGATAGAGACTTTTGAGCTTGACTATGATGGAAAACGGGACCGCTGGAATGGATATGA TGCAACGAGCTATGCTTTGGTAGTTGAAAGATATGAATCAAGAGATGAAGCTCGAAAGAAATTC TTAAAGGAACAGCAACTAAAGAAGTTAGAGGAGAAAAATAATAACCCAAATGGTGAGGACAA GGTTAGTGATGTGGATGAGGATGAGGATGAGGATGAGGATGATTTGAGGGTAGATGAAGCCAA GGTTGATGAAAGCAAACAAATGGACTTCGCAAAGGTTGAGAAGCGTGTACGTACAACTGGTGG TGGAAGCACAGGAACTGTCAGGAATTTGCGTATTCGTGAGGATACTGCAAAATATCTCTTAAAC CTTGATGTCAACTCTGCACATTATGACCCCAAAACCCGATCCATGCGTGAGGACCCTCTTCCAGA TGCTGATCCGAATGAGAAGTTTTACGGGGGTGATAATCGATATAGAAATAGTGGTCAAGCCATG GAGTTCAAGGAGCTCAATATCCATGCTTGGGAAGCATTTGAGAAGGGACAAGATATCCACATGC AAGCAGCGCCATCCCAAGCTGAGTTGCTGTATAAGAATTATCAGGTGATCAAGGAGAATTTGAA GTCAAAAACAAAGGACACTGTTCTGGAGAAGTATGGCAATGCAGCTAATGAAGAAGAATTTCC TAGGGAGCTTCTACTGGGACAAAGTGAAAGAGAAGTTGAATATGATCGTGCTGGGAGAATCATC AAGGGCCAGGATATAGCACTTCCCAGAAGCAAGTATGAAGAAGACGTCTATGTCAATAACCAC ACCACTGTATGGGGTTCGTGGTGGAAGGATCATCAATGGGGCTACAGGTGTTGTAAGCAGGTTA CTCGTAATAGCTATTGCACAGGTGCTGCTGGAATTGAGGCTGCTGAGGCTGCAGCTGATCTTATG AAGGCTAACATTGCTCGCAAAGAGGCCAATGGTGATATCCCTGCACCAGTGGAGGAGAAAAGA CCCGCTACTTGGGGAACTGATATACCAGATGATTTGGTTTTAGATGAGAAATTACTTGCTGAAGC TCTTAAAAAGGAGGATGGAAGAAAGAGAGAAGAGAGAGATGAGAGGAAGCGTAAATACAATG TTAAATGGAATGATGATGTTACTGCAGAGGATATGGAGGCTTATAGGATGAAGAAAGTCCACCA TGATGATCCAATGAAGGACTTTCTCAACTAA
Co9	ATGAATGCTATTGAAGAAGTTTACAGAATCGCAAGGGCGCAAACTCTTATTGCATTGTGCAGTA CTGTCCCGGGCTACTGGTTTACGGTAGCTCTCATTGACAGGATTGGAAGATTTGCAATTCAGTTG ATGGGATTCTTCTTCATGACAGTGTTCATGTTTGCACTGGCTATTCCCTACGAACATTGGACTCAC AAGGACAACCGAATTGGGTTCGTAGTGATCTACTCATTGACCTTCTTTTTTGCGAACTTCGGTCCT AATGCAACCACATTTGTTGTGCCGGCTGAGATTTTCCCAGCTAGGTTCCGGTCTACGTGTCATGG AATCTCAGCTGCGTCCGGGAAGCTTGGCGCCATAGTTGGTGCATTCGGGTTCTTGTACTTGGCTC AGAACAAAGATAAGAACAAGACAGATGCAGGGTACCCTCCAGGCATCGGGGTTAAAAACTCGC TCCTTGTGTTGGGTGTGGTCAACTTCTTGGGGATATTGTTCACTTTCTTGGTGCCTGAATCGAATG GGAGGTCGTTGGAGGAGATGTCGGGTGAGAACGAAGAAGAAAGCGAAACCGGGACAGTGGAG TTGGAGCAATCAAGCTATAACAACAGGACAGTTCCAGTTGTGTAG
Co10	ATGGCTGCAATGTCTTTCAGAGGGCTCAGTCGGCCAAATGCTTCATGTGCCATGGGGGTTTCTGA TGAGAGCAAGAACACTTTCATGGAGCTACAGAGAAAGAAGGTTCACCGCTATGTGATATTCAAG

GTTGAGGAGAAGAAGAGGGAGGTCGTAGTTGAAAAGATTGGTGGTCCGGCGGAGAGCTATGAT
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Co11
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Co32
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GAAGTTGTATATCATGGTCCGCATGGTTCATAATGCAGGCAATCACACTGAAGAAATATCCTGC
ACAACTGTCACTAACCACATGGATAAATTGTATTGGGGCAGCACAATCGGCTGTTTTCACAGTA
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AGAAGTATCTCAGGCTCAACACGATACGAACGCGCGATGAGATCTTCCCGGCTAAGGATGATGA
Co33
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ACGATGGATACTGCTACACTGGGTTGGAATTCGAAGAAGTCGTGGTTTCCTCGAATGGATCCGA
AAAAGAGGTGGCCTCAAGGTTGGTGTTGA

Co37	ATGGCATCAGATTCAGCAGCTCGAACCCCGCAACTGAGGAAAGACTCGGTGACGAAGCGGTGG GTGATATTCTCACCCGCCAGAGCCAGGCGACCTTCCAACTTCAAATCCAAGTCCCCCATCAACC CCAACTCCGACCAACAACAACAGTGCCCCTTCTGCATCAGCCACGAGCACGAGTGCGCTCCCGA AATCTTCCGGCTCCTGCCCGATAACGCCGACTGGACAATCCGGGTCATCCAGAACCTCTACCCC GCCCTCAGCAGAGACATGGAAGTCGTCTCTGCTCAAGACCCGTTACACCAGAACTCCGATTGGG TGATGGGGGATGGGGGAAGGCGTGGGAGGGTGGGCACGGGTGGGGATCTGTGTTTTTTTTTTTT TTTTACTTTTCTTTAAATACTTATTTTAATATTTTATTAAGTTTATAG
Co38	ATGGAAGACGAATCCTCGTATTACGACAGAACCAAGGAAGTGAAAGAGTTTGATGAAACGAAA GCCGGAGTTAAGGGCCTTGTGGACTCAGGGATCACAAAAGTCCCCAAGTTCCTCATTCATCCAC CACATAGCCTTTCAAATTCAGAAACAACAAATGTAGACTTCAAGGTTCCTGTCATAGACTTTTAC GGCTTTGATCAAGATTTCCGGCGAGCGCAGATTGTGAAGGAGATTTGTGAAGCATCCGAAACGT GGGGGTTCTTTCAAATGGTTAATCATGGAGTTCCAGAGAGAGTGATTGAGAATATGTTGGAAGG GATTCGAGGGTTTCATGAGCAGCCGAAGGAGGTGAAGATGGAGTGGTATTCTCGTGACTCGAAA CATAGAGTGAGATACTACTGCAATGGAGATCTGTTGGTGTCGAAAACAGCGAATTGGAGAGAC ACGATAGGGTTTGATTTCCAGGACGGTCCATTGGACCCCGAGACATTTCCCTTCGTTTGCAGAGA GGCAGTGCAGGAGTACATCGATCACTTAAAGAACTTGAGGGAGATGCTATCAGGTTTGTTGTCC GAGGCCTTGGGGCTCAGCACTGACTACCTGGAAAACATAGAGTGCATGGAGACTGAAAATCTG GTGTGCCATTACTACCCGAGCTGTCCAGAACCGGAGCTGACCCTTGGCACAACCAAGCATTCGG ATCCTTCCTCTTTAACTGTACTCTTGCAGGATAATCTCGGCGGCCTGCAAGTCCTCCATCAAGGTC ACTGGGTTGATGTTCCTCCAACTCCTGGAGCTCTTGTGGCGAATGTCGGTGATCTTATGCAACTTA TCACCAATGACAAGTTCAGAAGCGTCGAGCATAGAGTACTGGCTAGAAGAGTGGGGCCCAGGA TCTCAGCTGCATGTTTTTTCTATCCAAGTGCTACGCAAAGATTCAAACCCTATGGCCCCATCAAG GAGTTTCTATCGGACAACCTACCGATATACAGGGAAACACACTTTGGGGAGTATCTTGCTTATTA CAGATCAAAGGGGTTAGATGGTAATTCTGCCCTTTCTCATTTTAAATTAGCCTAA
Co41	ATGGAAGTGCTCGGAGTTCACGGATATGCAAATGAAGCAACAGCAATGGTCTGCAAGATGGAG AGAGAGAAGATCAAGCCAAATGGGGTTACTTTTGAAAGTGTTTTAAGTGCCTGCACTCATTCAG GATTTGTAGAAGAAGGCCGCAAGAGATTTTCAAGCACGATCCTGGACTATTCCATCCGCCCCAA AGTTGAGCAATATGGATGCATGGTGGATCTGTTGAGCAAAGCCGGCCTGCTTGAAAATGCTCTA GGGTTGATAAGAAGCATGGAGTTTGAACCGAACTCTGGTATATGGGGTGCATTGTTAGGTGGCT GCGAGCTTCGTAAAAACTTGAAGATTGCTCAAGTTTGTGTCAAGGAATTGATGTTGTTGGAGCCA AATAATTGTGGGTGTTTCAACCTTTTGGTGAACATGTGTGTGGATGCAAAACGATGGGGAGAAGT TGCGGATATTCGAGCAACCATGAAGGAACTTGGAGTTGAAAAGGGATGTCCTGTGTCCAGTTGG ATTGAAATGGAGAGGAAAGTTCATCAGCTTGCAGCGTCTGATGAATCTCATTCAGCTTCTGATGT AATTTACTCATTGCTGGTGGAATTATATGTGCAGCTGAAACTTGACGTTTATGTTCCTGAACTTGA CTCTGAGTTATGGTGGTGCAGTTTTTAA
Co44	ATGGTGGACGTGTTGGATCATGAGCTGGAGGAGGAACTGAAACAGTTCGACGAAACCAAAGCT GGTGTGAAAGGGCTTGTAGATTCTGGGGTGACCAAGCTCCCAAGAATGTTCAAACACCCTCCGG AGTGTCTACCATCCCCGAACCAAAACAATGGAATTCACGACCTGCAAGTTCCTGTCATTGATCTG AAAGATGCGGAGAACAATGAAAGGAGAAGCGAAATCATCAGTAACCTCCGCAAAGCAGCTGA AGAATGGGGTTTCTTTCAAATTGTGAATCATCCCATTCCACTTGACGTCATGGATGATGTGCTGA AAGGTGTTCGGCGGTTTCATGAGCAGCCCCAGGAAGCCAAGGAGGAGTGGTATTCGCGTGATTT CACGAAGAAGGTCAACTTCTTCAGCAATGGAGAATTGAAGGTAGACACTCCAGCTGACTGGAG AGACACCTTGTCGTGCAAAGTCCTCGAAGATGAACGAAACTTTGAAGAAATCCCTGAAGTCTGC AGAACGGAAATACGTGAGTATATGAAATACATCGTTCAAGTGAAGGAGAAGCTATCCGGATTAT TTTCGGAAGCTTTAGGCCTAAGCAGGGATTACCTTGAAAATCTAAGGTGCTTCAAATCTAGGTCA TTGGCATGCCACTACTACCCGGTATGCCCGGAGCCCCATTTAACCCTAGGAGGAACCAAACACT CCGATCTCGGCTTTCTAACCTTGCTCTTGCAAGATAGTGCTGGCCTACAAGTTCTTCATCAAAATA TTTGGATTGATGTTCCCCCAGTGGAGGGAGCTTTGCTCATCAATCTTGCCGACATGCTGCAGTTTA TTACTAATGGCAAGTTCAAGAGTGTACAGCACAGAGTACTGATGCCACTGTCGACCCTCGAGCC CCGTACGTCAATTGCATGTTTTGTTGGCACGGACGACCTCCAAAAACCTTACGGTCCGTTAAAGG AGCTCGTCTCCAAAAACAATCCGGCAAAATACGAAGATGTCTGTTTTGGAGAATACATGAAACG TTACAAACTTTAG

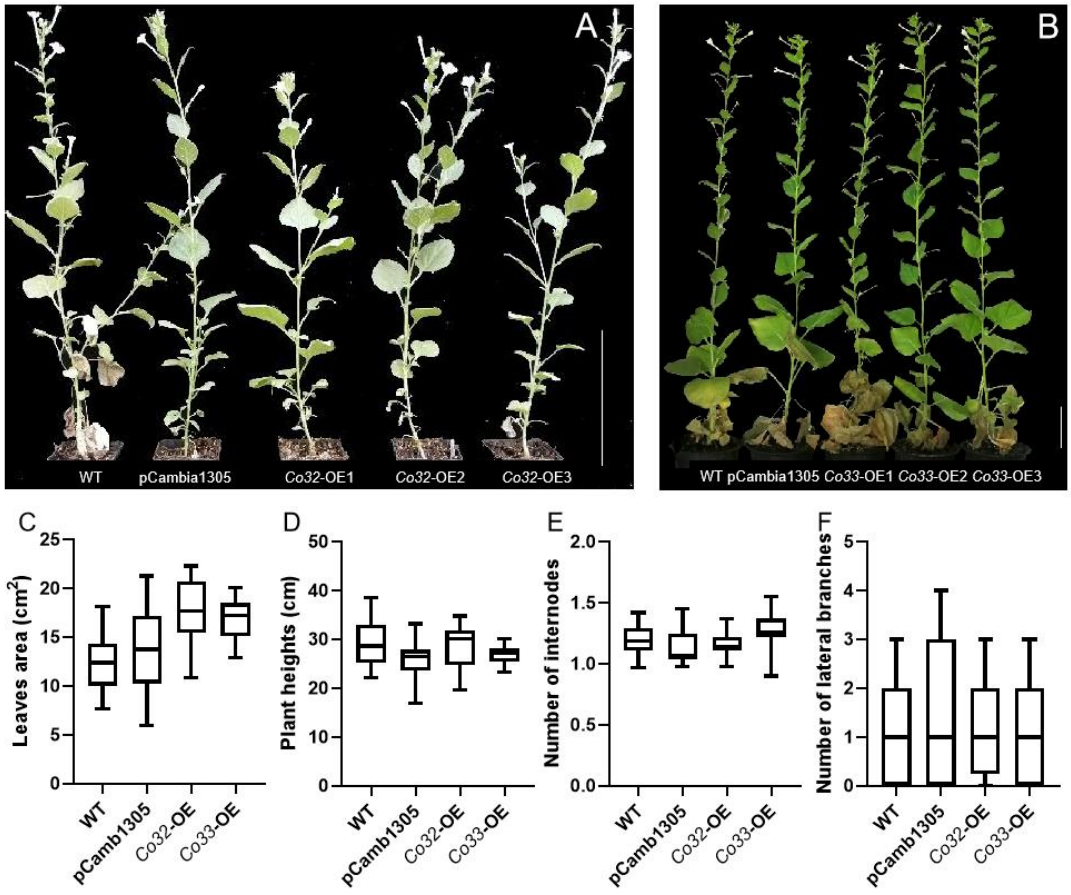

Figure S1 Phenotypes of transgenic tobacco by overexpressing *Co32* (A) and *Co33* (B), and analysis of several growth parameters (C~F)

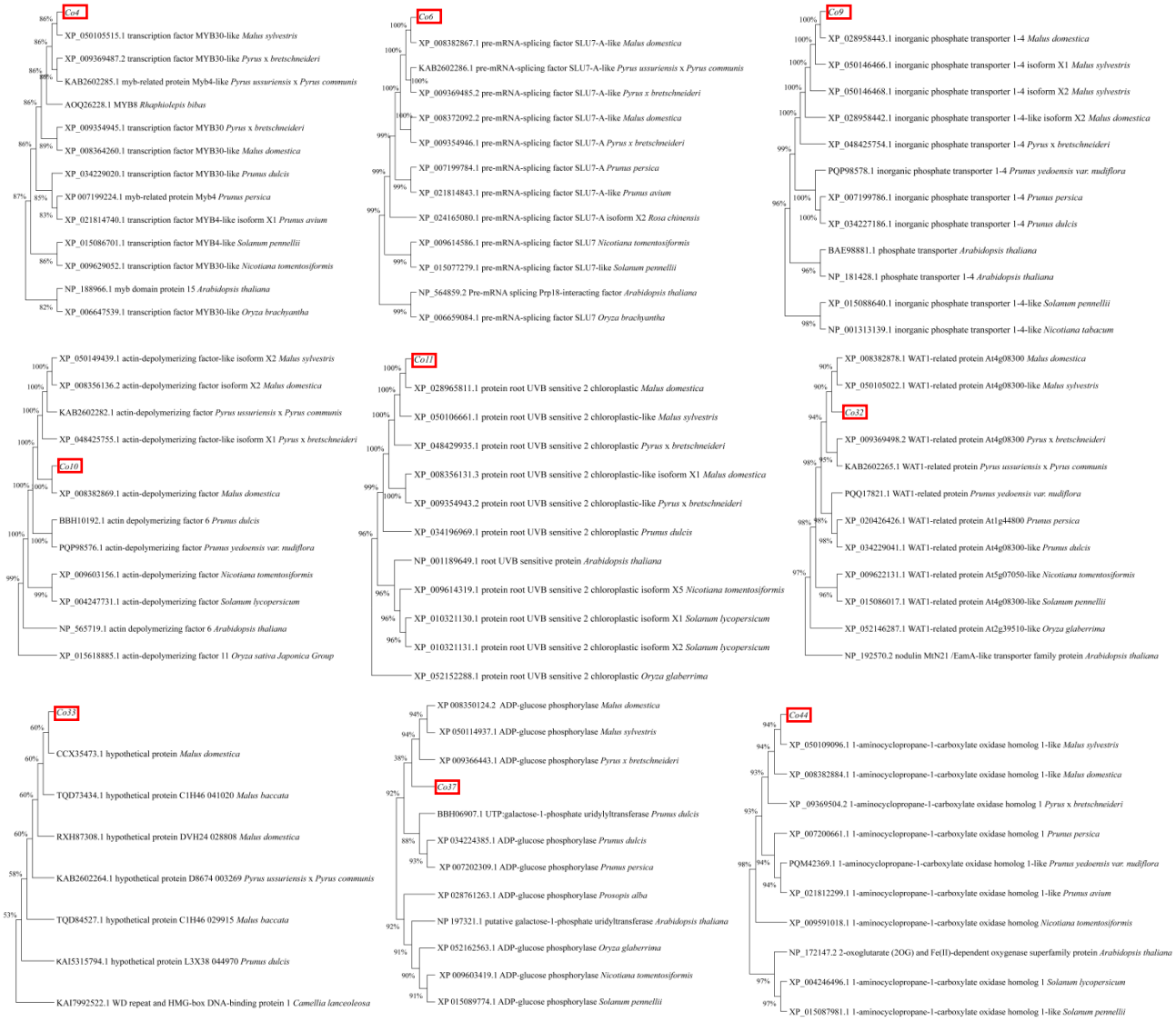

Figure S2 Phylogenetic analysis of individual gene at the *Co* locus mentioned in study

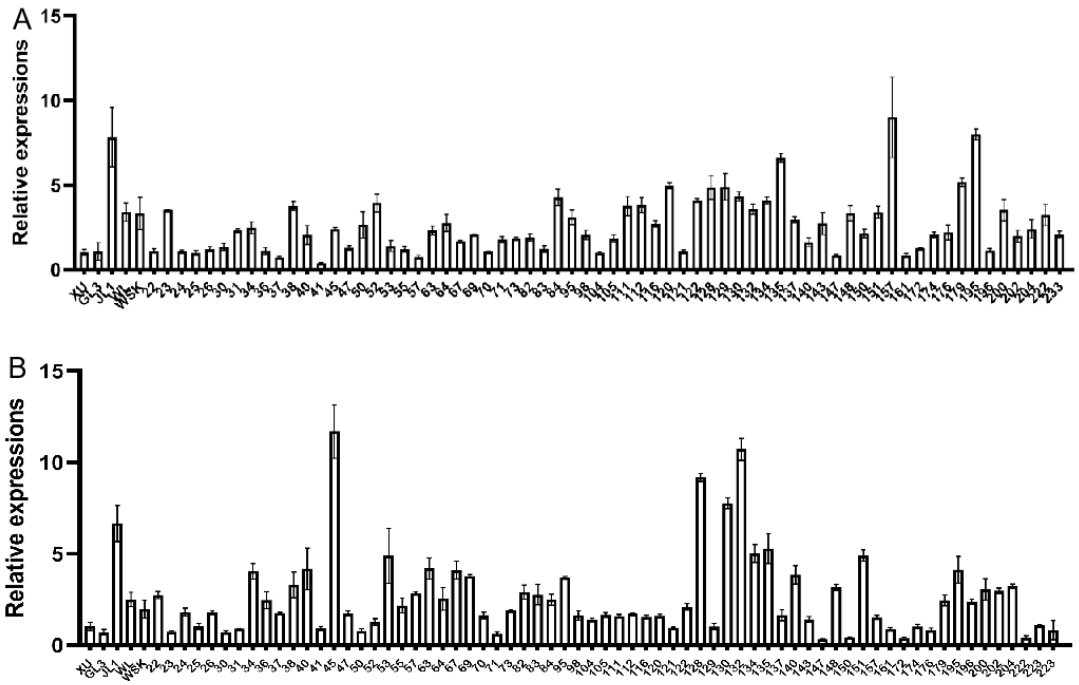

Figure S3 Expression analysis of *MdCo38* (A) and *MdCo41* (B) in apple cultivars and F1 population of 'Jinlei No.1' × 'Maypole'. (XU, GL3, JL1, WL, and WSK represented 'McIntosh', 'Gala 3', 'Jin-Lei No.1', 'Tuscan', and 'Wijcik', respectively)