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Terpenes have various applications as fragrances, cosmetics and fuels. One of the most prominent examples is the sesquiterpene farnesene, which can be used as a diesel substitute in its hydrogenated form farnesane. Recent metabolic engineering efforts have enabled efficient production of several terpenes in Saccharomyces cerevisiae and Escherichia coli. Plant terpene synthases take on an essential function for sesquiterpene production as they catalyze the specific conversion of the universal precursor farnesyl diphosphate (FPP) to the sesquiterpene of interest and thereby impose limitations on the overall productivity. Using farnesene as a case study, we chose three terpene synthases with distinct plant origins and compared their applicability for farnesene production in the yeast S. cerevisiae. Differences regarding the efficiency of these enzymes were observed in shake flask cultivation with maximal final titers of 4 mg/L using α-farnesene synthase from Malus domestica. By employing two existing platform strains optimized for sesquiterpene production, final titers could be raised up to 170 mg/L in fed-batch fermentations with RQ-controlled exponential feeding. Based on these experiments, the difference between the selected synthases was not significant. Lastly, the same fermentation setup was used to compare these results to production of the fragrance sesquiterpene santalene, and almost equivalent titers were obtained with 163 mg/L, using the highest producing strain expressing a santalene synthase from Clausena lansium. However, a reduction of the product yield on biomass by 50% could indicate a higher catalytic efficiency of the farnesene synthase.