

Supplementary Information

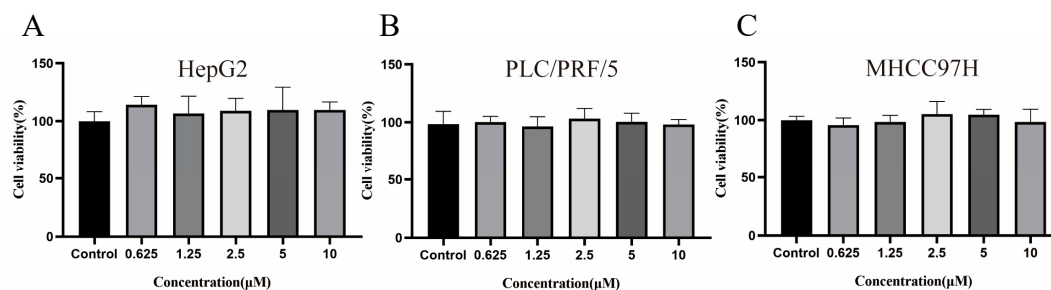


Figure S1. Effects of **1-P** treatment on cell viability in hepatocellular carcinoma cells. (A) HepG2, (B) PLC/PRF/5 and (C) MHCC97H cells were treated with varying concentrations of **1-P** (10, 5, 2.5, 1.25, 0.625 μM) for 4 h, followed by 24 h incubation in the dark.

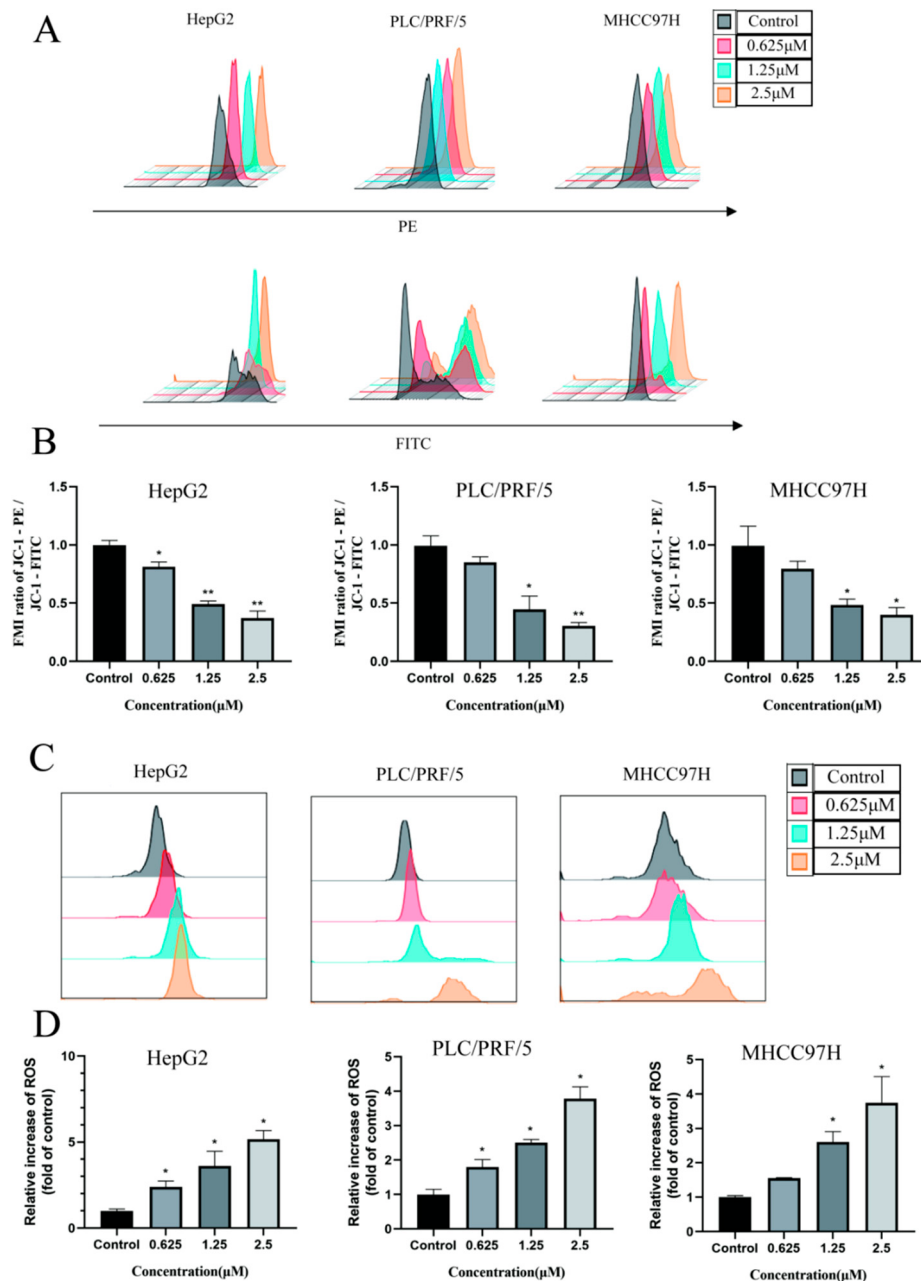


Figure S2. **1-P** induces mitochondrial depolarization and ROS accumulation in hepatocellular carcinoma cells. (A) JC-1 staining (red/green fluorescence) reflecting mitochondrial membrane potential ($\Delta\Psi_m$) in HCC cells treated with **1-P** (0.625, 1.25, 2.5 μM) and 625 nm irradiation. (B) Quantitative analysis of JC-1 red/green fluorescence ratio (PE/FITC), indicating $\Delta\Psi_m$ collapse (* $p < 0.05$, ** $p < 0.01$ vs. control). (C) DCFH-DA fluorescence imaging showing intracellular ROS levels in **1-P**-treated HCC cells. (D) ROS fluorescence intensity quantification (fold change vs. control, mean $\pm$ SD; * $p < 0.05$, ** $p < 0.01$).

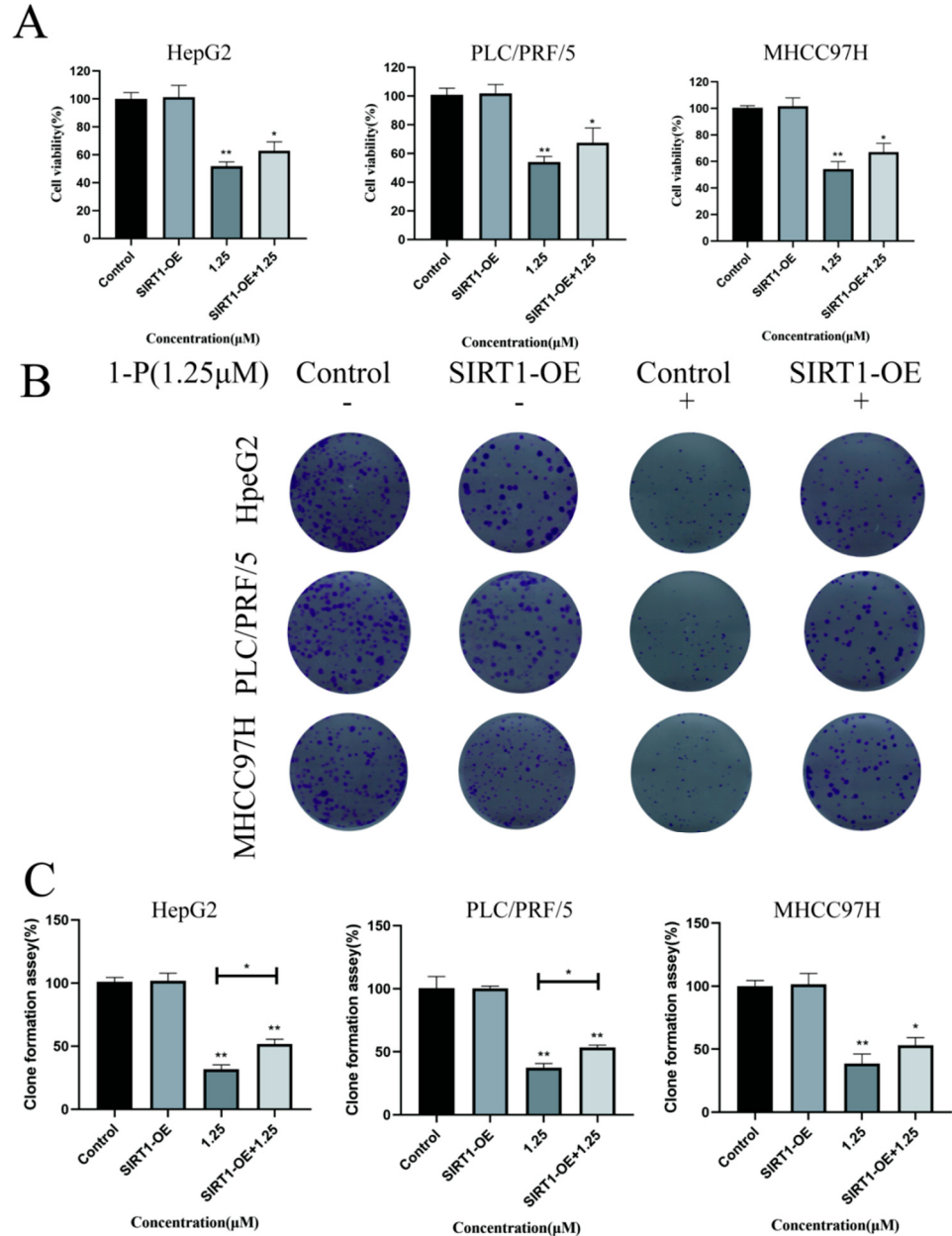


Figure S3. SIRT1 overexpression modulates **1-P**-mediated cytotoxic and anti-proliferative effects in hepatocellular carcinoma cells. (A) Cell viability assessed by MTT assay after transient transfection with SIRT1-overexpressing plasmids (SIRT1-OE), 1.25 μ M **1-P** treatment (4 h with 625 nm light irradiation), and 20 h incubation. (B) and (C) Clonogenic survival analysis under identical treatment conditions. Data represent mean $\pm$ SD (* p < 0.05, ** p < 0.01 vs. control group).

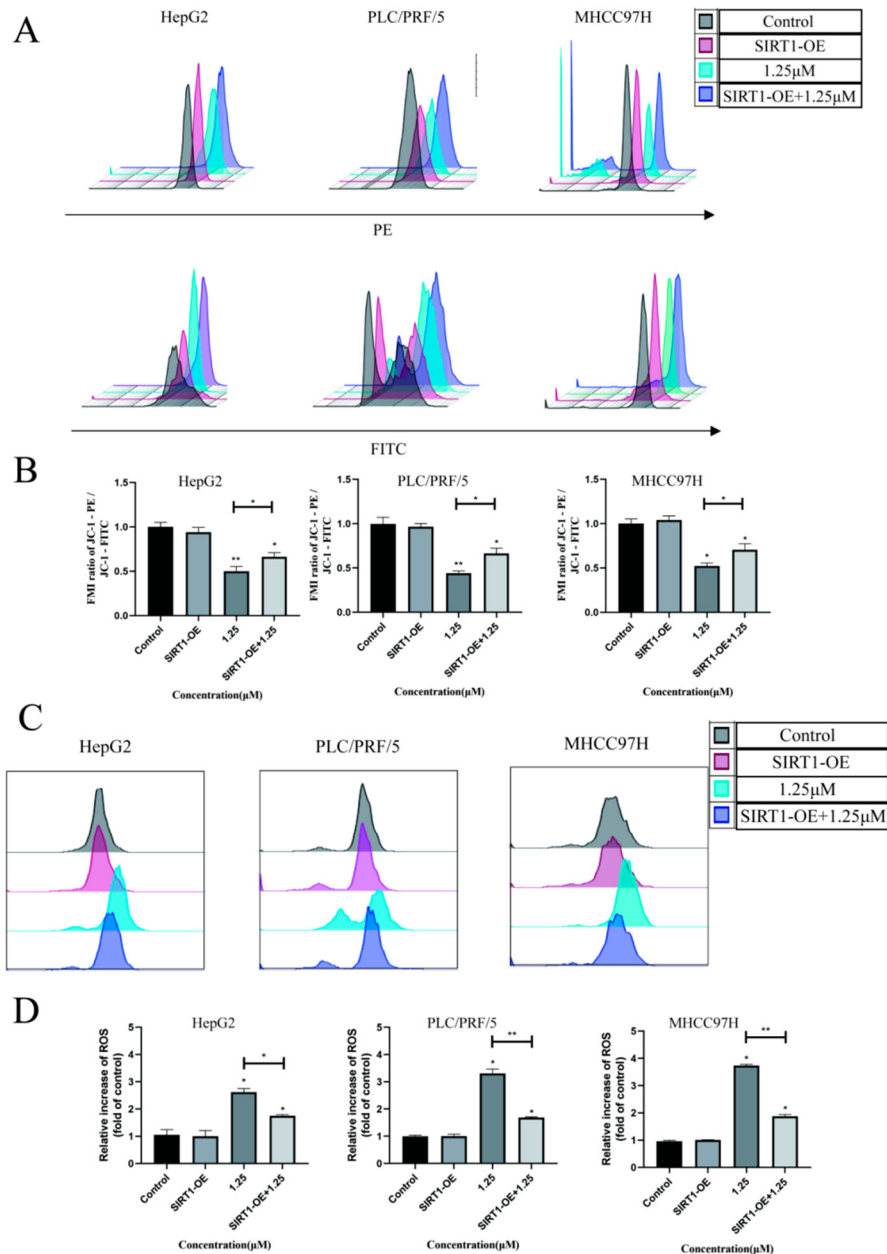


Figure S4. SIRT1 overexpression preserves mitochondrial membrane potential and reduces ROS accumulation in **1-P**-treated hepatocellular carcinoma cells. (A) JC-1 staining (red/green fluorescence) showing mitochondrial membrane potential ($\Delta\Psi_m$) changes in HCC cells transiently transfected with SIRT1-overexpressing plasmids (SIRT1-OE) and treated with 1.25 μM **1-P** (4 h + 625 nm light irradiation). (B) Quantitative analysis of JC-1 red/green fluorescence ratio. (C) DCFH-DA fluorescence imaging of intracellular ROS levels under identical treatment conditions. (D) ROS fluorescence intensity quantification (mean $\pm$ SD; * p < 0.05, ** p < 0.01 vs. control group).

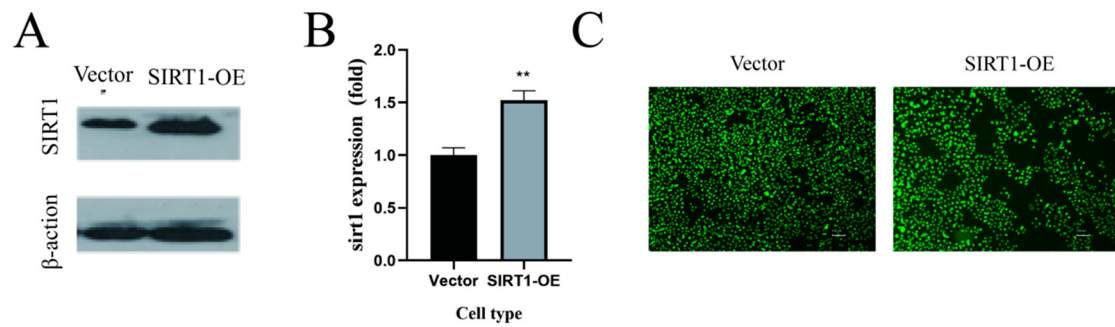


Figure S5. Stable SIRT1-overexpressing HepG2 cell line established via lentiviral transduction. (A) Western blot analysis confirming sustained SIRT1 protein overexpression in stably transduced cells (SIRT1-OE) compared to empty vector controls (Vector). (B) qPCR quantification demonstrating 1.5-fold higher SIRT1 mRNA levels in SIRT1-OE cells ($***p < 0.001$ vs. Vector). (C) Fluorescence microscopy images (20 $\times$) showing GFP-positive populations in stable SIRT1-OE cells (right) versus minimal background signal in vector controls (left).

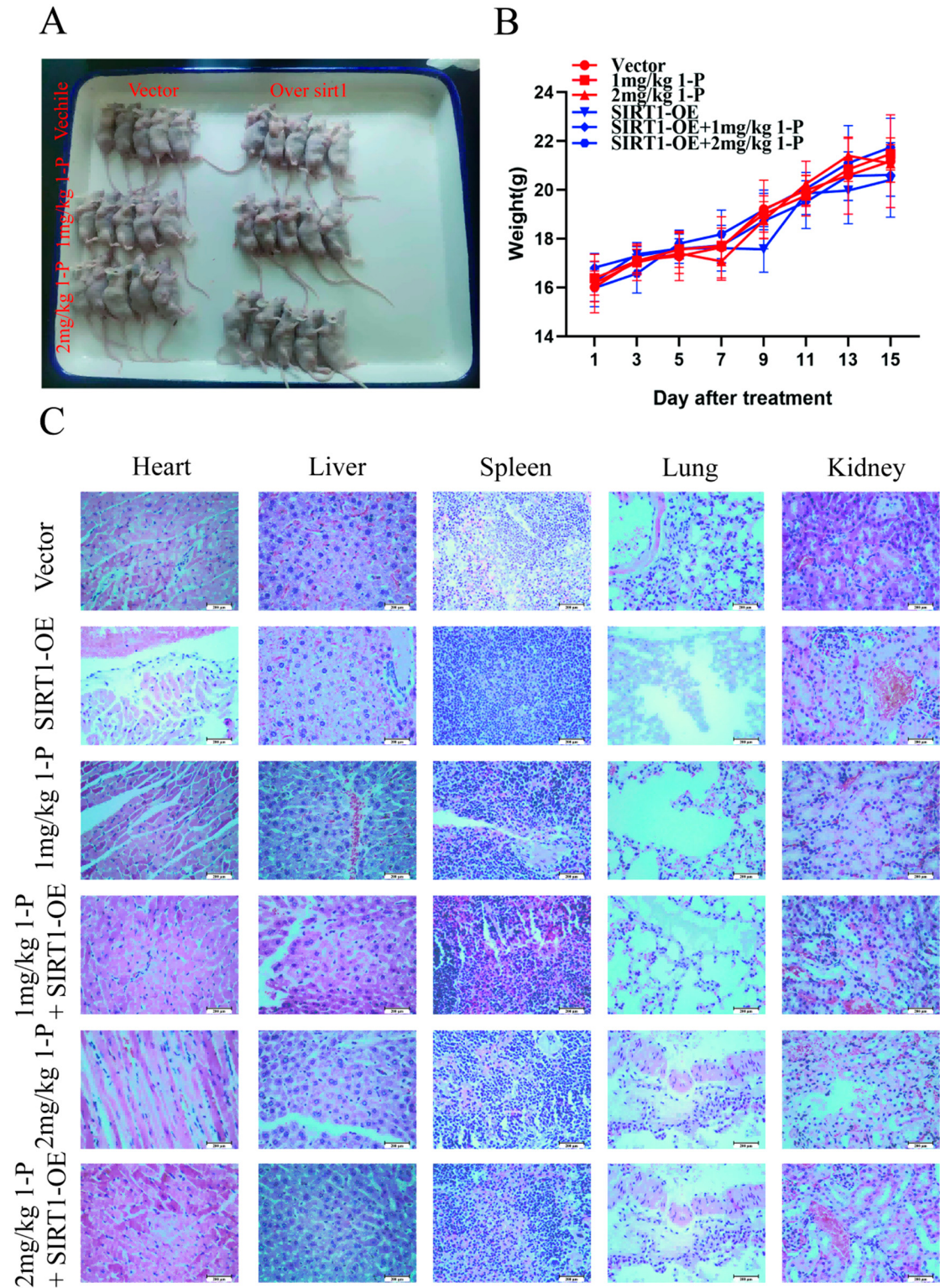


Figure S6. **1-P** exhibits favorable safety profile in tumor-bearing mice. (A) Schematic of experimental timeline and subcutaneous tumor implantation. (B) Body weight dynamics of mice during **1-P** treatment (mean $\pm$ SD, n = 6/group). (C) Representative H&E-stained sections (200 $\times$) of heart, liver, spleen, lung, and kidney tissues from control and **1-P**-treated groups, showing no histopathological abnormalities.