Supporting Information

Green Biosynthesis of Silver Nanoflowers Using Tithonia diversifolia Leaf Extract: In Vitro Anticancer Activity, Antimetastatic Effects, and Crystal Violet Photodegradation

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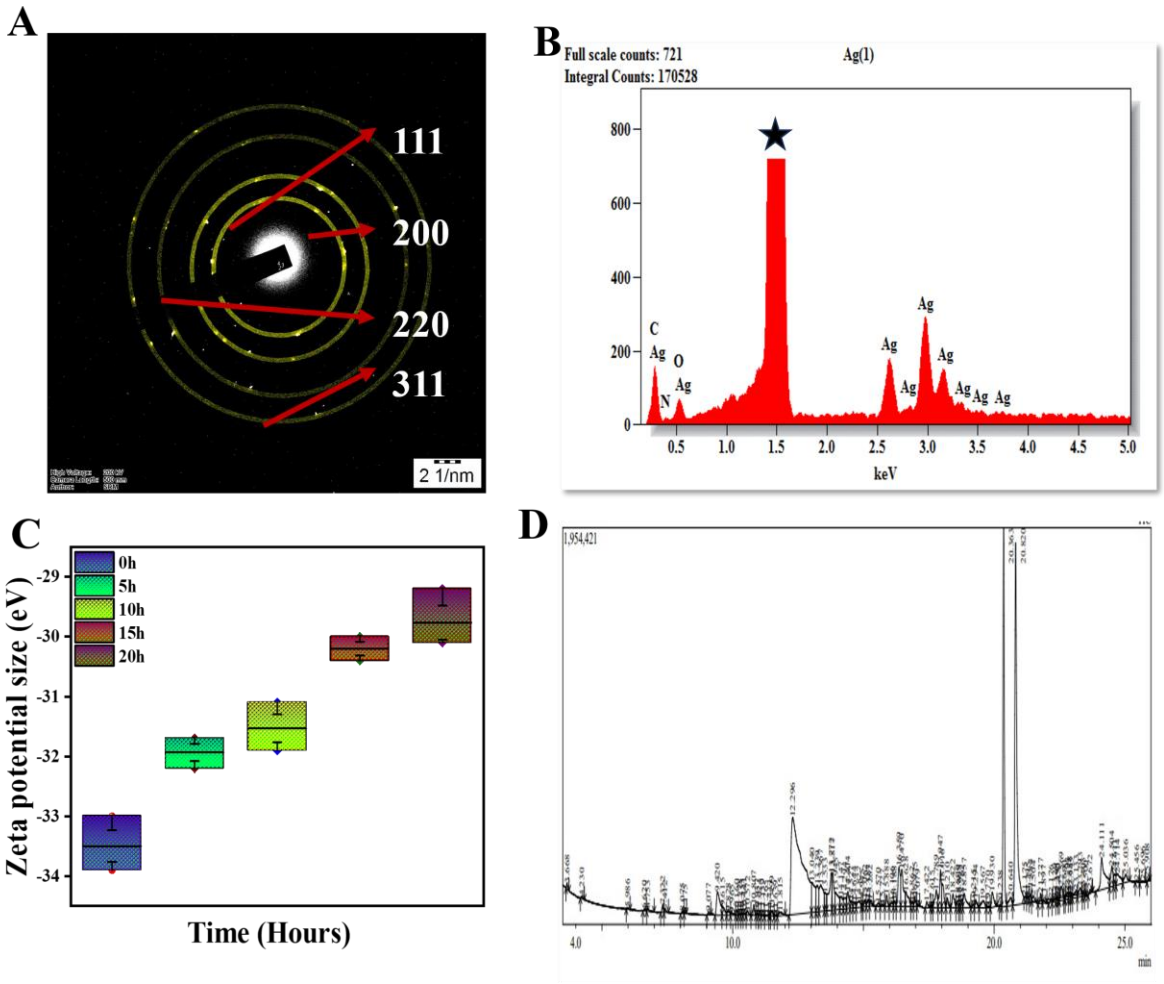
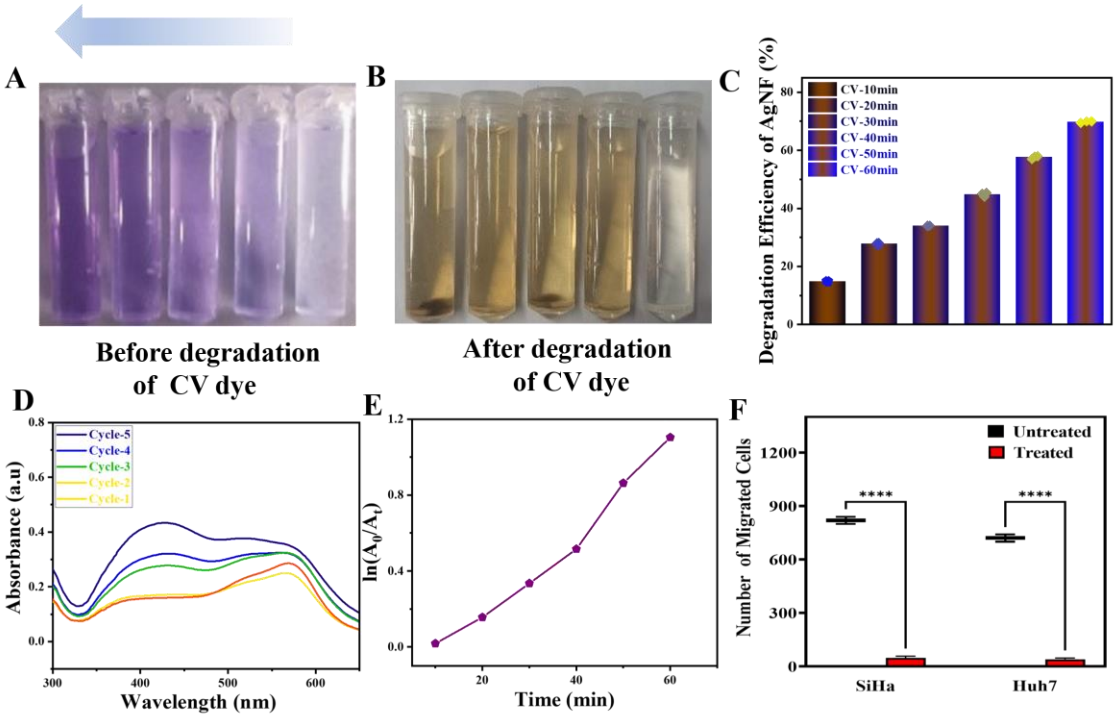
Supporting Fig. 1. Green synthesis of silver nanoflowers (AgNFs) using *Tithonia diversifolia* leaf extract (TDLE). (A) Preparation of plant precursor: *T. diversifolia* leaves were sun-dried and milled to a fine powder. (B) Synthesis scheme: the leaf powder was boiled in water for 10 min and filtered through Whatman paper to obtain TDLE; the extract was mixed with aqueous $AgNO_3$ for 30 min to reduce Ag^+, producing a brown suspension; the product was collected by centrifugation and washing, then dried at 60 °C for 4 h to yield TD-AgNFs.



Supporting Fig. 2. Additional characterization of TD-AgNFs. (A) Selected area electron diffraction (SAED) pattern of TD-AgNFs, showing diffraction rings indexed to the crystalline Ag planes. **(B)** Energy-dispersive X-ray (EDX) spectrum of TD-AgNFs, confirming the elemental presence of silver. **(C)** Time-dependent zeta potential measurements of TD-AgNFs. **(D)** GC–MS chromatogram of *Tithonia diversifolia* leaf extract (TDLE).



Supporting Fig. 3. Additional evidence for crystal violet (CV) photocatalytic degradation and anti-migratory activity of TD-AgNFs. (A) Photographic images of CV solutions before degradation, showing the characteristic violet color across increasing dye concentrations. **(B)** Corresponding images after TD-AgNF-mediated photocatalytic treatment, showing progressive decolorization. **(C)** Time-dependent CV degradation efficiency in the presence of TD-AgNFs (10–60 min). **(D)** UV–Vis absorbance spectra recorded over successive reuse cycles (Cycles 1–5) for evaluating TD-AgNF reusability. **(E)** Kinetic plot of CV degradation expressed as $\ln(A_0/A_t)$ versus irradiation time (0–60 min). **(F)** Quantification of Transwell migration in SiHa and Huh7 cells, showing reduced numbers of migrated cells in TD-AgNF-treated groups relative to untreated controls.

Table S1. Comparison of the present TD-AgNFs system with recently reported green-synthesized Ag-based nanoparticles/nanostructures.

No.	Nanoparticle / composition	Reported structure / morphology	Plant / green source used	Applications evaluated	Key performance / highlights	Ref
1	**TD-AgNFs, present study**	Hierarchical flower-like Ag nanoflowers; petal-like Ag plates; mesoporous structure	*Tithonia diversifolia* leaf extract	Anticancer, in vitro anti-migratory activity, antimicrobial/antifungal activity, antioxidant/ROS response, crystal violet decolorization	BET surface area **36.7 $m^2 g^{-1}$**; IC_{50} values **0.16, 0.23, and 0.26 mg mL^{-1}** for Huh7, THP-1, and SiHa; **migration inhibition** at 50 µg mL^{-1}; **crystal violet decolorization; hierarchical AgNF platform; multi-application validation; BET-supported mesoporosity; biomedical–environmental integration**	Present work
2	AgNFs	Flower-like Ag nanostructures	*Kalanchoe daigremontiana* leaf extract	Photocatalytic and antibacterial activity	Green-synthesized Ag nanoflowers showed enhanced antibacterial activity against *E. coli* and *S. aureus* and photocatalytic performance; limited biological scope; no anticancer/anti-migratory evaluation	[1]
3	AgNPs	Ag nanoparticles	*Magnolia alba* leaf extract	Antimicrobial, antifungal, antiviral, anticancer, antioxidant, photocatalytic activity	Evaluated against multiple bacterial strains, *Candida albicans*, HCT-116 colon cancer cells, DPPH/FRAP-based antioxidant activity, and methyl orange dye photocatalysis; AgNP morphology; no nanoflower architecture; no migration assay	[2]
4	AgNPs	Irregular/rugged spherical nanoparticles	*Stachys tibetica* extract	Antioxidant, antimicrobial, photocatalytic activity	Rhodamine B degraded under sunlight within **1 h**; rate constant **0.066 min^{-1}**; active against *Bacillus cereus*, *Pseudomonas*, *E. coli*, and *S. aureus;* no anticancer evaluation; no anti-migratory study	[3]

5	AgNPs	Cluster-like/agglomerated; mostly spherical/oval particles, **16–22 nm** by HR-TEM	*Momordica cymbalaria* leaf extract	Antioxidant, cytotoxicity, antibacterial, photocatalytic activity	DPPH inhibition **67.77% at 1000 µg mL⁻¹**; IC_{50} **54.89 µg mL⁻¹** for MCF-7 and **160.74 µg mL⁻¹** for Vero cells; maximum antibacterial zone **17.33 mm** against *E. coli;* clustered AgNPs; no nanoflower/BET/migration correlation	[4]
6	Ag/AgCl NPs	Spherical and rod-shaped particles; **~20 and 75 nm**	*Durio zibethinus* seed extract	Antibacterial, cytotoxicity, photocatalytic activity	SPR at **420 nm**; zeta potential **−15.41 mV**; sunlight-assisted synthesis optimized at **4000 ± 200 lux**; evaluated for methylene blue degradation; Ag/AgCl mixed phase; no anti-migratory validation	[5]
7	AgNPs	Spherical/oval nanoparticles; average size **28.32 nm**	*Myrsine africana* leaf extract	Antibacterial, antioxidant, phytotoxic activity	UV–Vis peak at **438 nm**; highest antioxidant activity **57.7% at 40 µg mL⁻¹**; DPPH IC_{50} **77.56 µg mL⁻¹**; stronger antibacterial activity against *E. coli;* phytotoxic focus; no anticancer/photocatalytic integration	[6]
8	Ag-TiO_2 bimetallic NPs	Bimetallic nanoparticles; **10–60 nm**	*Pluchea indica* leaf extract	Anticancer, antibacterial, antioxidant activity	IC_{50} **33.5 µg mL⁻¹** against MCF-7; IC_{50} **169.6 µg mL⁻¹** against Wi-38 normal cells; MIC **31.25–62.5 µg mL⁻¹**; antioxidant IC_{50} **225 µg mL⁻¹**, bimetallic system; no dye-degradation/migration study	[7]
9	AgNPs	Ag nanoparticles	*Cucumis prophetarum* aqueous leaf extract	Antibacterial and antiproliferative activity	Antibacterial and antiproliferative activity against cancer cell lines; limited application window; no photocatalytic or anti-migratory assessment	[8]

10	AgNPs	Ag nanoparticles	*Carissa carandas* leaf extract	Antioxidant and antibacterial activity	First report of *C. carandas* leaf-mediated AgNP synthesis for antioxidant and antibacterial activity; two-application scope; no anticancer/dye-degradation study	[9]
11	AgNPs	Ag nanoparticles	*Conocarpus lancifolius* fruit/plant extract	Antimicrobial and anticancer activity	Plant extract used to synthesize AgNPs for antimicrobial and anticancer evaluation against drug-resistant infection-related concerns; no nanoflower structure; no photocatalytic remediation	[10]
12	AgNPs	Small-sized AgNPs	*Viburnum grandiflorum* leaf extract	Antibacterial, antioxidant, anticancer activity	Biosynthesized AgNPs described as cost-effective and environmentally friendly, with antimicrobial and anticancer properties; no anti-migratory or dye-degradation validation	[11]
13	AgNPs	Predominantly spherical; average diameter **~20 nm** by TEM	*Brassica oleracea* leaf extract	Antibacterial, antioxidant, anticancer activity	Maximum antibacterial zones: **14.33 ± 0.57 mm** against *S. epidermidis* and **12.0 ± 0.20 mm** against *P. aeruginosa*; MCF-7 IC_{50} **55 µg mL^{-1}**; DPPH IC_{50} **~50.37 µg mL^{-1}**; spherical AgNPs; no AgNF morphology; no environmental remediation	[12]
14	AgNPs	Ag nanoparticles	*Pandanus dubius* extract	Antioxidant, antibacterial, anticancer activity	UV–Vis absorption peak **458 nm**; FTIR identified functional groups involved in reduction/stabilization; limited mechanistic/functional integration; no anti-migratory or dye-degradation study	[13]
15	AgNPs	Ag nanoparticles	*Ammi visnaga* extract	Antibacterial, antibiofilm, anticancer,	**99% inhibition** against biofilm/bacteria; anticancer IC_{50} **17.1 ± 0.6 µg mL^{-1}**; Eosin Y photodegradation	[14]

				Eosin Y photodegradation	up to **50%**; AgNP system; no nanoflower/BET-supported architecture; no migration assay	
16	AgNPs	Ag nanoparticles	*Aegle marmelos* leaf extract	Antimicrobial, antioxidant, anticancer, photocatalytic degradation	Integrated antimicrobial, antioxidant, anticancer, and photocatalytic degradation activity; conventional AgNPs; no hierarchical AgNF structure; no anti-migratory study	[15]
17	AgNPs	Ag nanoparticles	*Acer oblongifolium* plant extract	Antibacterial, antioxidant, antiproliferative activity	Reported IC_{50} values against MCF-7 and HeLa after 48–72 h, with values listed as **9.43 and 6.22 µg mL^{-1}** in the accessible text; antiproliferative focus; no photocatalytic/migration integration	[16]
18	AgNPs	Round AgNPs; **50–90 nm**	*Lantana camara* leaf extract	Antibacterial and anticancer activity	IC_{50} **49.52 µg mL^{-1}** against A549 and **46.67 µg mL^{-1}** against MCF-7; round AgNPs; antibacterial–anticancer only; no dye-degradation study	[17]
19	AgNPs	Ag nanoparticles	*Justicia brandegeana* aqueous extract	Antibacterial, antioxidant, anticancer activity	Reported as a green-synthesized AgNP system for combined antibacterial, antioxidant, and anticancer evaluation; no nanoflower morphology; no anti-migratory/photocatalytic validation	[18]
20	AgNPs	Ag nanoparticles	*Odontosoria chinensis* leaves	Antibacterial, antioxidant, anticancer activity	Synergistic antibacterial effects, antioxidant potential, and anticancer activity; AgNP structure; no environmental remediation or migration assay	[19]
21	AgNPs	Ag nanoparticles; **50–110 nm**, average **~70 nm**	*Elaeocarpus serratus* / Ceylon olive extract	Antibacterial activity	AgNPs in the 50–110 nm range; proteins, phenols, and flavonoids involved in reduction/capping;	[20]

					antibacterial-only scope; no multifunctional biological–environmental testing	
22	AgNPs	Ag nanoparticles	*Melaleuca alternifolia* leaf extract	Antibacterial, antifungal, antioxidant, anticancer activity	Tea-tree-leaf-mediated AgNPs with antibacterial, antifungal, antioxidant, and anticancer activities; no photocatalytic dye decolorization; no anti-migratory assessment	[21]
23	AgNPs	Ag nanoparticles	*Barleria gibsonii* extract	Antibacterial, antioxidant, cytotoxic, catalytic activity	*B. gibsonii*-AgNPs with antibacterial, antioxidant, cytotoxic, and catalytic activities; conventional AgNPs; no AgNF morphology; no CV decolorization/migration integration	[22]
24	Ag_2O NPs	Silver oxide nanoparticles	*Eruca sativa* extract	Biological activities	*E. sativa*-mediated Ag_2O nanoparticles with biological activity; silver oxide phase; no metallic AgNF architecture; no biomedical–photocatalytic integration	[23]
25	AgNPs	Ag nanoparticles	*Alcea rosea* leaf aqueous extract	Biological activities	*Alcea rosea*-mediated AgNPs with biological activity; conventional AgNPs; no AgNF morphology; no BET/migration/CV-decolorization study	[24]

Table S2. Structural parameters calculated from XRD peaks of TD-AgNFs

Plane (hkl)	2 theta (deg)	FWHM (2theta)	FWHM (rad)	d-spacing (Å)	Crystalline size (nm)	Lattice parameter (Å)	Micro strain (ε)	Dislocation density (m^{-2})
(111)	37.98	0.6927	0.01209	2.3835	12.1	4.10	8.86×10^{-3}	6.83×10^{15}
(200)	44.17	0.5196	0.00907	2.0482	16.8	4.09	5.6×10^{-3}	3.5×10^{15}
(220)	64.35	0.5196	0.00907	1.4477	18.7	4.08	3.5×10^{-3}	2.9×10^{15}
(311)	77.32	0.5196	0.00907	1.2346	20.4	4.11	2.8×10^{-3}	2.4×10^{15}

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