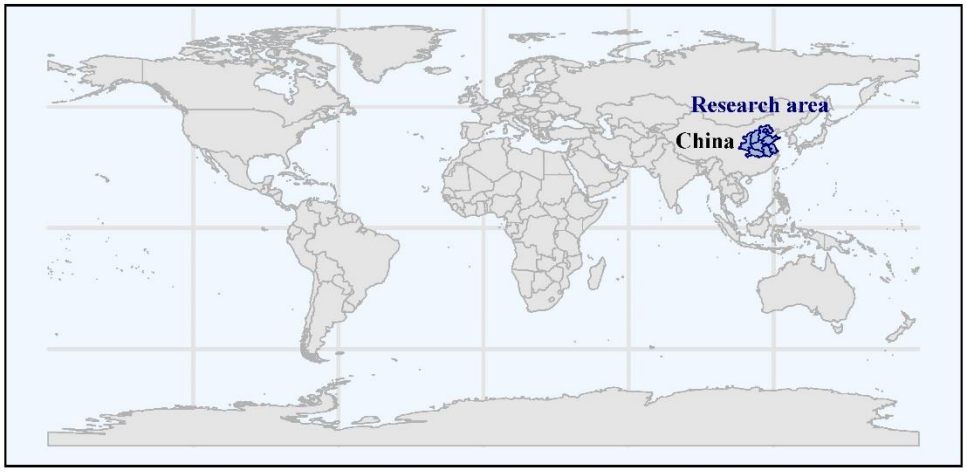


Figure S1 Geographic location of the study area in China within the global context.

Table S1. Matching variables for DiD approach

Variables	Abbreviation	Wheat growth-stage	Definition	Unit
Treatment		HD-HA	County-year in which integrated foliar spraying was applied and HDW exposure ≥ 2 d yr^{-1} during ≥ 1 season after 2004	1
Control		HD-HA	County-year without integrated foliar spraying (or before 2004) regardless of HDW exposure	0
Freezing stress	$Frez_{SW-JT}$	SW-JT	Cumulative hours < 0 °C, divided by degree-hours	°C h
Extreme heat	EH_{JT-HD}	JT-HD	Cumulative hours >31 °C, divided by degree-hours	°C h
Extreme heat	EH_{HD-HA}	HD-HA		
Precipitation	$Prcp_{SW-JT}$	SW-JT	Total rainfall during SW-JT	mm
Precipitation	$Prcp_{JT-HD}$	JT-HD	Total rainfall during JT-HD	mm
Precipitation	$Prcp_{HD-HA}$	HD-HA	Total rainfall during HD-HA	mm
HDW	HDW	HD-HA	HDW events	days
Irrigation fraction	Well-irrigated Poor-irrigated	Whole season	If county irrigation fraction ≥ 0.37 (75th-percentile of the sample). If irrigation fraction < 0.37	%
Soil type	Soil type	Whole season	Dominant WRB 2015 soil group at 250 m resolution (SoilGrids v2), aggregated to county level	Categorical

Growth-stage abbreviations: **SW** = sowing, **JT** = jointing, **HD** = heading, **HA** = harvest.

Table S2. Provincial summary statistics for total HDW hours and HDW_{sd1}, HDW_{sd2}, and HDW_{sd3} during 1981–2020

Province	Metric	Mean ± SD (days)	Q1 (days)	Q3 (days)
Anhui (AH)	HDW	3.03±2.15	1	4
Anhui (AH)	HDW_{sd1}	1.07±1.15	0	2
Anhui (AH)	HDW_{sd2}	1.46±1.33	0	2
Anhui (AH)	HDW_{sd3}	0.49±0.71	0	1
Hebei (HE)	HDW	10.11±7.08	5	14
Hebei (HE)	HDW_{sd1}	4.91±3.69	2	7
Hebei (HE)	HDW_{sd2}	3.88±3.05	2	5
Hebei (HE)	HDW_{sd3}	1.31±1.51	0	2
Henan (HA)	HDW	4.26±3.45	2	6
Henan (HA)	HDW_{sd1}	2.12±2.05	1	3
Henan (HA)	HDW_{sd2}	1.68±1.68	1	2
Henan (HA)	HDW_{sd3}	0.46±0.76	0	1
Hubei (HB)	HDW	2.24±2.07	1	2
Hubei (HB)	HDW_{sd1}	1.28±1.29	0	2
Hubei (HB)	HDW_{sd2}	0.78±0.91	0	1
Hubei (HB)	HDW_{sd3}	0.17±0.47	0	0
Jiangsu (JS)	HDW	3.34±2.57	1	3
Jiangsu (JS)	HDW_{sd1}	1.58±1.43	1	1
Jiangsu (JS)	HDW_{sd2}	1.35±1.44	0	2
Jiangsu (JS)	HDW_{sd3}	0.41±0.67	0	1
Shaanxi (SN)	HDW	3.94±3.49	1	4
Shaanxi (SN)	HDW_{sd1}	2.00±1.94	1	2
Shaanxi (SN)	HDW_{sd2}	1.56±1.70	0	2
Shaanxi (SN)	HDW_{sd3}	0.38±0.66	0	1
Shandong (SD)	HDW	6.40±5.52	2	7
Shandong (SD)	HDW_{sd1}	2.94±2.86	1	3
Shandong (SD)	HDW_{sd2}	2.66±2.48	1	3
Shandong (SD)	HDW_{sd3}	0.81±1.12	0	1
Shanxi (SX)	HDW	4.96±4.01	2	5
Shanxi (SX)	HDW_{sd1}	2.45±2.24	1	3
Shanxi (SX)	HDW_{sd2}	2.00±1.97	1	2
Shanxi (SX)	HDW_{sd3}	0.51±0.82	0	1

Table S3. Annual sample size (number of counties) for treated and control groups in Figure 8

Year	Control	Treatment
2004	287	173
2005	257	200
2006	225	231
2007	216	226
2008	334	116
2009	221	213
2010	316	126
2011	138	291
2012	267	159
2013	242	178
2014	209	202
2015	252	143
2016	319	88
2017	201	217
2018	295	160
2019	174	258
2020	208	216