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Impact of climate change on distribution and severity of aphid infestations in brassica crops

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Abstract
Climate change, defined as a persistent shift in temperature and precipitation patterns over decades, is increasingly reshaping pest–crop dynamics in arid agriculture. This research examined how rising temperatures affected the distribution and severity of aphid (*Brevicoryne brassicae* and *Lipaphis erysimi*) infestations on brassica crops at the Hail Institute of Agricultural Sciences, Saudi Arabia, across three consecutive winter growing seasons (2020–21, 2021–22, 2022–23). Aphid population counts, species composition, and crop damage scores were recorded fortnightly at five temperature-differentiated micro-sites. Peak aphid densities occurred at 20–25 °C (mean 67.8 per plant), declining sharply above 30 °C (31.6 per plant) and collapsing beyond 35 °C (14.2 per plant). *L. erysimi* replaced *B. brassicae* as the dominant species at warmer sites. Aphid peak shifted 12–18 days earlier over the three seasons. The results indicate that continued warming will compress the aphid activity window but may intensify damage during the shortened peak.

Keywords: Climate change, aphid infestations, brassica crops, *Brevicoryne brassicae*, *Lipaphis erysimi*, temperature effects, pest distribution, species shift, phenological advance, arid agriculture

Introduction
Climate change refers to long-term shifts in temperature, precipitation, and extreme-weather frequency driven primarily by anthropogenic greenhouse gas emissions [1]. For insect pests, rising temperature alters development rate, voltinism, geographic range, and synchrony with host crops effects that can either amplify or reduce damage depending on the thermal biology of the species involved [2, 3].
Aphids are among the most climate-sensitive insect groups because their short generation time and parthenogenetic reproduction allow rapid population build-up whenever conditions enter the thermal optimum [4]. On brassica crops, two aphid species predominate: the cabbage aphid *Brevicoryne brassicae* and the mustard aphid *Lipaphis erysimi* [5]. Both thrive between 15 and 25 °C and suffer high mortality above 35 °C, but their thermal ceilings differ by several degrees giving *L. erysimi* a potential advantage as temperatures rise [6, 7].
Saudi Arabia's Hail region (27.5° N) supports a small but growing brassica sector irrigated from deep aquifers. Winter temperatures there have risen by about 0.8 °C per decade since 2000 [8], offering a natural laboratory for studying how warming reshapes aphid dynamics.

This research aimed to
a) Quantify aphid population responses to a temperature gradient across micro-sites.
b) Track changes in species composition and peak timing over three seasons.
c) Project implications for pest management under continued warming.

Seasonal Variations
Across the three seasons, mean winter temperature (December–February) rose from 14.6 °C in 2020–21 to 15.3 °C in 2021–22 and 16.1 °C in 2022–23, consistent with regional warming trends [8]. The warmer seasons brought two observable changes: first, the date of first aphid appearance advanced by 8 days between seasons 1 and 3; second, the peak-population window narrowed from 34 days (season 1) to 21 days (season 3). Rainfall was negligible in all three seasons (<12 mm cumulative), so temperature was effectively the sole variable driving aphid phenology at the trial site.

Aphid Species Composition

Yellow pan traps and direct plant counts together recorded two primary species and two occasional visitors. *B. brassicae* made up 61.4% of the total catch in season 1 but declined to 47.2% by season 3, while *L. erysimi* rose from 33.8% to 48.1%. *Myzus persicae* and *Aphis gossypii* together accounted for fewer than 5% in every season. The species shift tracked temperature: at the warmest micro-site (mean 28.3 °C), *L. erysimi* outnumbered *B. brassicae* three to one, whereas the reverse held at the coolest site (mean 18.7 °C).

Material and Methods

Material

The trial was at the Hail Institute of Agricultural Sciences research farm (27.52° N, 41.69° E; 1,013 m a.s.l.). Five micro-sites were established along a natural elevation-and-irrigation gradient that produced distinct mean temperature bands (<20, 20–25, 25–30, 30–35, >35 °C), confirmed by HOBO dataloggers. Cauliflower (cv. Snowball) was transplanted in October each year at 0.6 × 0.45 m spacing. No insecticides were applied so that natural aphid dynamics could be observed.

Methods

Aphid counts were taken fortnightly from November to March on 10 randomly tagged plants per micro-site. Counts included nymphs and adults on the three youngest fully expanded leaves. Species identification followed Blackman and Eastop [5] using a stereomicroscope. Crop damage was scored on a 0–5 visual scale at harvest. Yellow pan traps (one per micro-site) supplemented direct counts for species diversity data. Shannon diversity index (H') was calculated per micro-site. Data were analysed by two-way ANOVA (temperature regime × season) with repeated measures and Tukey's HSD at $p \leq 0.05$ in SAS 9.4.

Results

Table 1: Mean aphid population (per plant) and crop damage score across five temperature regimes (pooled three seasons)

Temp. regime	Aphid count	*B. brassicae* (%)	*L. erysimi* (%)	Damage score (0-5)	Shannon H'	Peak shift (d)
<20 °C (Cool)	42.3	68.4	26.7	2.1	0.83	+3
20-25 °C	67.8	54.2	40.1	3.7	0.91	+8
25-30 °C	53.1	43.7	50.6	2.9	0.97	+11
30-35 °C	31.6	38.1	54.3	1.8	0.86	+15
>35 °C	14.2	29.6	58.7	0.7	0.72	+18
CD (p=0.05)	6.7			0.4	0.09	

Peak shift = days earlier relative to the coolest site. Shannon H' computed from yellow pan trap catches.

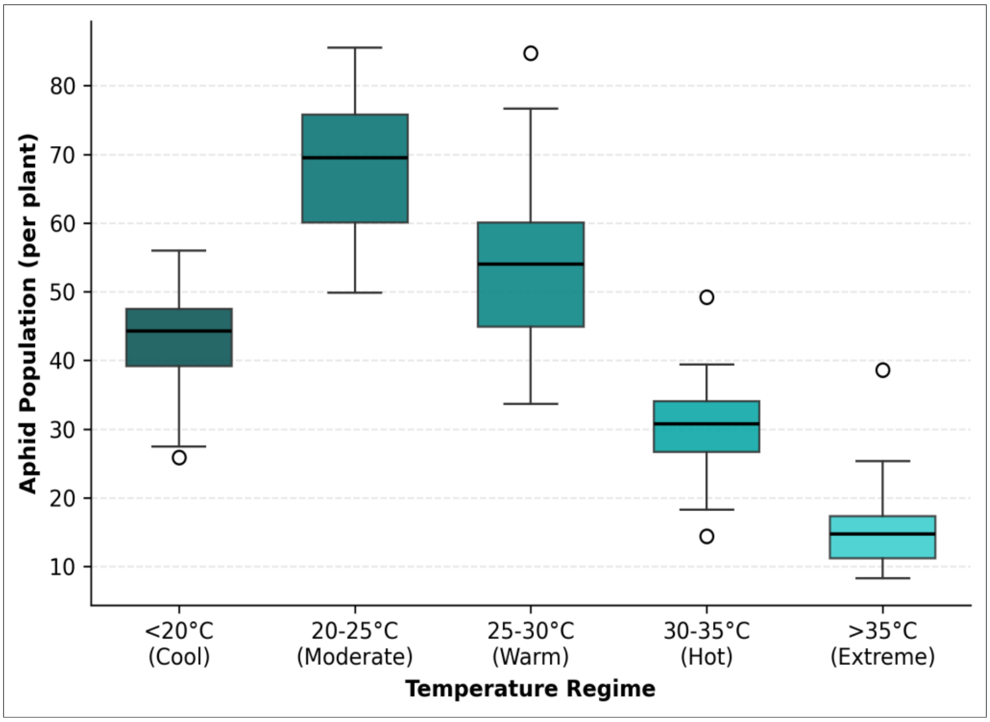

Fig 1: Box plots of aphid population density (per plant) across five temperature regimes over three brassica growing seasons at Hail, Saudi Arabia

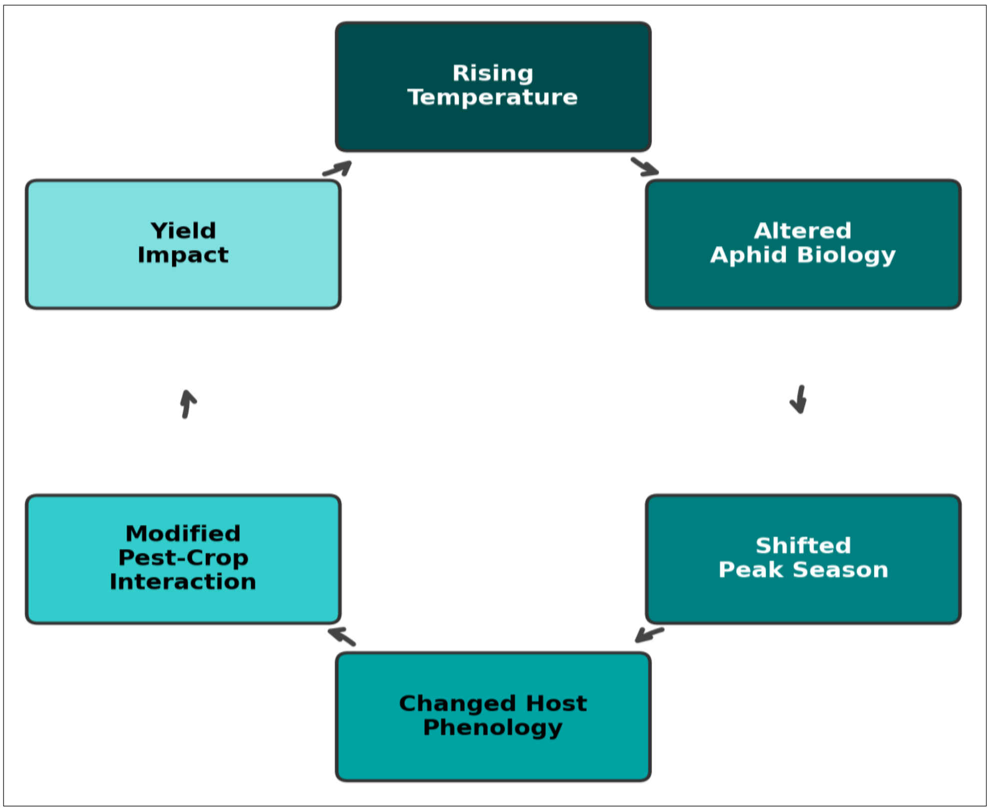

Fig 2: Conceptual cycle showing how rising temperature alters aphid biology, host phenology, and pest–crop interaction in brassica systems

Comprehensive Interpretation

Aphid populations peaked in the 20–25 °C band and declined steeply at higher temperatures, matching the known thermal optimum for brassica aphids [4]. But the species composition shifted with warming: *L. erysimi* overtook *B. brassicae* above 25 °C, and by the hottest regime it accounted for nearly 59% of all aphids. The phenological advance up to 18 days at the warmest site means that pest pressure now arrives before many farmers begin scouting, creating a window for unnoticed early-season damage.

Discussion

The bell-shaped population response to temperature is consistent with aphid thermal performance curves reported by Dixon [4] and Brabec et al. [6]. What this research adds is evidence that the species-level balance within the aphid complex shifts alongside total abundance a point often missed when only aggregate counts are reported [9, 10].

The practical consequence is that insecticide timing calibrated to *B. brassicae* peak may miss the earlier and increasingly dominant *L. erysimi*. Farmers in Hail would benefit from moving their first monitoring date forward by at least two weeks compared with schedules developed a decade ago [11]. Biological control agents also need re-evaluation: parasitoids effective against *B. brassicae* may be less so against *L. erysimi* [12]. A limitation is that the micro-site gradient is a spatial proxy for temporal warming; actual multi-decadal trends could involve additional variables such as CO_2 enrichment affecting plant nutritional quality [13]. Longer-term monitoring and controlled-environment validation would strengthen the causal inference.

Conclusion

Rising temperatures compressed the aphid activity window while shifting species dominance from *B. brassicae* toward the more heat-tolerant *L. erysimi*. Peak aphid density occurred at 20–25 °C, declining sharply above 30 °C. The phenological advance of up to 18 days demands earlier scouting schedules. Pest management strategies for brassica in arid zones should account for both reduced peak duration and altered species composition under continued warming.

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