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COMPARATIVE EFFICACY OF BIOPESTICIDES AND SYNTHETIC INSECTICIDES FOR SUSTAINABLE MANAGEMENT OF WHEAT APHID *(DIURAPHIS NOXIA)*

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ABSTRACT

WHEAT APHID (Diuraphis noxia) reduces crop productivity through sap feeding, honeydew deposition and virus transmission. A field experiment was conducted at the Hazara Agriculture Research Station, Haripur, to compare synthetic insecticides and biopesticides against the *WHEAT APHID (Diuraphis noxia)* complex. The trial was laid out in a randomized complete block design with three replications. Seven treatments were evaluated: imidacloprid 0.006%, methyl-o-demeton 0.025%, thiamethoxam 0.0075%, azadirachtin 0.001%, neem oil 2%, Beauveria bassiana and an untreated control. Aphid counts were recorded before application and at 24, 48, 72 and 168 hours after treatment. Natural enemy abundance, treatment persistence, yield and economic return were also assessed. Synthetic insecticides gave the strongest immediate aphid suppression, with imidacloprid and methyl-o-demeton producing 92.1% and 90.5% reduction at 72 hours, respectively. Thiamethoxam was also effective but caused greater reduction in natural enemy abundance than botanical treatments. Among biopesticides, azadirachtin gave moderate efficacy and maintained higher coccinellid and chrysopid abundance. Beauveria bassiana showed slower action but improved relative performance by 168 hours. Methyl-o-demeton produced the highest cost-benefit ratio, while imidacloprid provided the highest aphid reduction and yield response. Minimum temperature and morning relative humidity were positively associated with aphid abundance, while rainfall was negatively associated. The results suggest that synthetic insecticides remain useful for rapid knockdown under severe aphid pressure, but botanicals and microbial agents are better suited for predator-compatible IPM programs. A rotational strategy using economic thresholds, selective products and natural enemy conservation is recommended.

Keywords: Triticum aestivum; *WHEAT APHID (Diuraphis noxia)*; Rhopalosiphum padi; Schizaphis graminum; azadirachtin; Beauveria bassiana; imidacloprid; IPM

1. Introduction

Wheat (Triticum aestivum L.) is the leading staple cereal in Pakistan and a major contributor to food security. Global production statistics underline the continuing

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importance of wheat within cereal systems (FAO, 2025). However, the crop is attacked by several sucking pests, among which aphids are particularly important during the vegetative and heading stages. The major *WHEAT APHID (Diuraphis noxia)* species include Rhopalosiphum padi, Schizaphis graminum and Sitobion avenae, although species composition varies by location, cultivar, sowing date and seasonal weather. Aphids are damaging because they remove phloem sap, reduce photosynthetic efficiency, promote honeydew and sooty mold formation and transmit plant viruses (Blackman & Eastop, 2000; van Emden & Harrington, 2017).

Aphid ecology is strongly linked to temperature, humidity, host quality and natural enemies. Dixon (1998) explained that aphid population growth is driven by rapid parthenogenetic reproduction and close synchronization with host plant condition. *WHEAT APHID (Diuraphis noxia)* populations in Pakistan have been reported to fluctuate across the season, with species such as S. graminum and R. padi occurring in wheat fields of Lahore and other wheat-growing regions (Akhtar et al., 2002). Screening of Pakistani wheat germplasm also confirms the need to combine host resistance and pest monitoring in *WHEAT APHID (Diuraphis noxia)* management (Khalique et al., 2021).

Synthetic insecticides, especially systemic neonicotinoids and organophosphates, are widely used because they provide rapid aphid suppression. Neonicotinoids such as imidacloprid and thiamethoxam act on nicotinic acetylcholine receptors and have become important tools against sucking pests (Jeschke et al., 2011). Their use must nevertheless be balanced against resistance risk, resurgence potential and non-target effects. Resistance to neonicotinoids is now a global concern in several insect systems (Bass et al., 2015), and neonicotinoids and broad-spectrum insecticides can affect non-target invertebrates and beneficial arthropods (Pisa et al., 2015; Desneux et al., 2007).

Biopesticides provide an alternative or complementary approach in IPM. Botanical insecticides such as azadirachtin and neem oil contain bioactive compounds that can reduce feeding, growth and reproduction in target pests while often being less persistent than synthetic insecticides (Isman, 2006; Isman, 2020). Microbial agents such as Beauveria bassiana infect insects through the cuticle and can contribute to aphid suppression, although field performance depends on humidity, temperature, formulation and application timing (Faria & Wraight, 2007; Meyling & Eilenberg, 2007; Lacey et al., 2015). Biopesticides are not always as fast as synthetic products, but they may fit better into predator-conserving wheat IPM systems (Copping & Menn, 2000).

A field comparison under local conditions is necessary because efficacy, persistence and economics can differ substantially across agro-ecological zones. The present study evaluated synthetic insecticides and biopesticides against the *Wheat aphid (Diuraphis noxia)* complex at HARS, Haripur. The specific objectives were to compare aphid reduction over time, measure treatment persistence, assess effects on natural enemies, estimate economic returns and relate aphid abundance to abiotic weather factors.

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2. Materials and methods

The experiment was conducted during the 2024-2025 rabi season (November 2024 to April 2025) at the Hazara Agriculture Research Station, Haripur, Khyber Pakhtunkhwa, Pakistan, located in the Hazara division at approximately 33.99°N, 72.93°E at an elevation of 520 m above sea level, using the wheat variety Pirsabak-2013 sown under standard agronomic practices in plots measuring 5 m × 4 m with 20 cm row spacing, while recommended fertilizer, irrigation, and weed control practices were uniformly applied across all plots and crop stages interpreted using the decimal cereal growth-stage concept (Zadoks et al., 1974). The trial was laid out in a randomized complete block design with three replications, comparing seven treatments: imidacloprid 0.006%, methyl-o-demeton 0.025%, thiamethoxam 0.0075%, azadirachtin 0.001%, neem oil 2%, Beauveria bassiana, and an untreated control; treatments were applied when aphid populations reached the local economic threshold of approximately 5 to 8 aphids per tiller, with spray volume and application method kept uniform to ensure that differences reflected treatment performance rather than application bias. Aphid monitoring was conducted by randomly selecting ten tillers per plot, with pre-treatment counts taken immediately before application, followed by post-treatment counts recorded at 24, 48, 72, and 168 hours; percent reduction was calculated using Abbott's formula (1925) for control adjustment, while the Henderson-Tilton correction (1955) was applied where both treated and control populations changed between pre- and post-treatment counts, alongside simultaneous counting of key natural enemies including coccinellids, chrysopids, and syrphid larvae from ten plants per plot after treatment to assess compatibility with biological control. Persistence was expressed as the number of days during which treatment efficacy remained biologically effective relative to the untreated control; at harvest, conducted during April 2025, grain yield was recorded and converted to kg ha^{-1}, while net return over control and cost-benefit ratio were calculated from treatment cost, yield advantage, and local grain price, with the cost-benefit ratio interpreted as net return divided by treatment cost to highlight economic gain attributable to pest management. Weather data—including maximum and minimum temperature, morning and evening relative humidity, sunshine hours, and rainfall—were obtained from the HARS weather station, and Pearson correlation coefficients were calculated between aphid population and weather variables, while all treatment data were subjected to analysis of variance (ANOVA) with treatment means separated using LSD at $p \leq 0.05$ following standard agricultural statistical procedures (Gomez & Gomez, 1984; Steel et al., 1997), thereby ensuring that the experiment generated robust, reproducible, and economically interpretable findings for sustainable *WHEAT APHID (Diuraphis noxia)* management in the Hazara region.

3. Results

3.1 Aphid reduction after treatment application

Synthetic insecticides produced the highest and fastest aphid suppression. Imidacloprid reduced aphid population by 68.5% at 24 hours and 92.1% at 72 hours. Methyl-o-demeton followed closely, with 65.3% reduction at 24 hours and 90.5% at 72 hours. Thiamethoxam produced 88.4% reduction at 72 hours. Biopesticides showed lower early efficacy. Azadirachtin reached 62.5% reduction at 72 hours, neem oil reached 55.8%, and B. bassiana reached 52.3%. The microbial treatment showed a slower effect, with reduction increasing to 60.5% by 168 hours.

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Table 1. Percent reduction of *WHEAT APHID (Diuraphis noxia)* population at different intervals after treatment

Treatment	24 h	48 h	72 h	168 h
Imidacloprid 0.006%	68.5a	85.2a	92.1a	84.6a
Methyl-o-demeton 0.025%	65.3ab	82.4ab	90.5ab	82.3ab
Thiamethoxam 0.0075%	60.2b	78.6b	88.4b	78.5b
Azadirachtin 0.001%	35.4c	48.2c	62.5c	55.8c
Neem oil 2%	28.6c	42.5c	55.8c	48.3c
Beauveria bassiana	22.4d	38.7d	52.3d	60.5d
Untreated control	5.2e	8.5e	10.2e	12.6e

Note. Means followed by different letters within a column are significantly different at p <= 0.05.

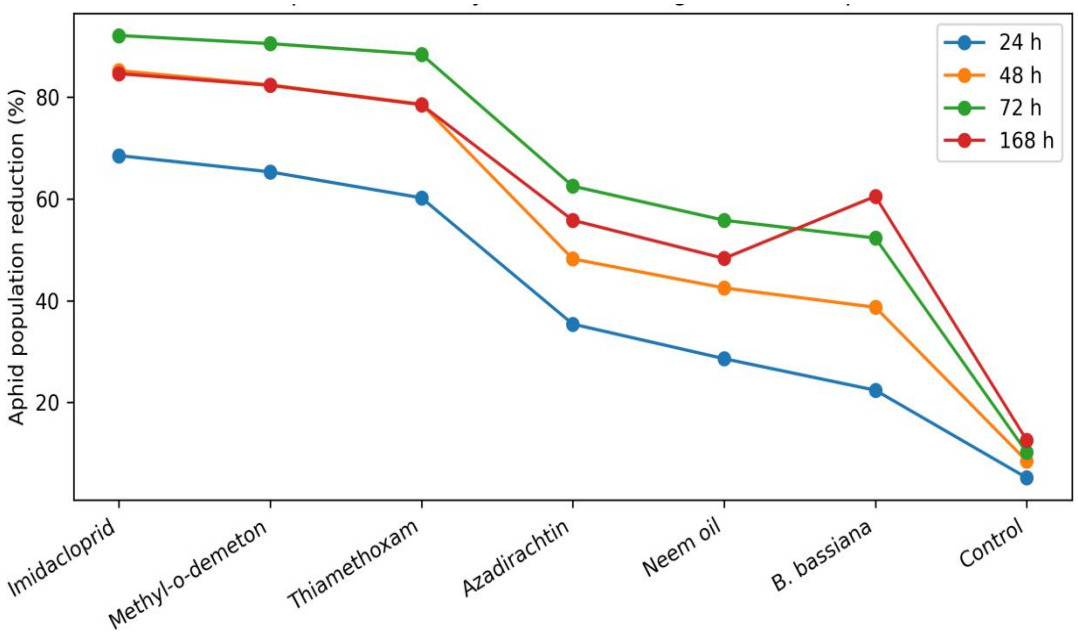

Figure 1. Comparative reduction of *WHEAT APHID (Diuraphis noxia)* population under synthetic and biological treatments.

3.2 Treatment persistence

Imidacloprid provided the longest effective control period of 16 days. Methyl-o-demeton remained effective for 13 days and thiamethoxam for 12 days. Among biopesticides, B. bassiana persisted for 10 days, followed by azadirachtin for 8 days and neem oil for 7 days. The longer persistence of imidacloprid explains its strong overall suppression, but persistence must be balanced with resistance and non-target

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risk in IPM planning.

Table 2. Persistence of treatments against *WHEAT APHID (Diuraphis noxia)*

Treatment	Days of effective control	Mean +/- SE
Imidacloprid 0.006%	16	16.0 +/- 0.5a
Methyl-o-demeton 0.025%	13	13.0 +/- 0.4b
Thiamethoxam 0.0075%	12	12.0 +/- 0.4b
Azadirachtin 0.001%	8	8.0 +/- 0.3c
Neem oil 2%	7	7.0 +/- 0.3c
Beauveria bassiana	10	10.0 +/- 0.3d

Note. Persistence was measured as days with effective suppression relative to untreated control.

3.3 Effect on natural enemies

Natural enemy abundance was higher in biopesticide treatments than in synthetic insecticide treatments. Untreated control had the highest counts because no insecticide pressure was imposed. Among treated plots, azadirachtin maintained 3.8 coccinellids and 2.5 chrysopids per 10 plants, whereas imidacloprid maintained only 1.2 coccinellids and 0.8 chrysopids per 10 plants. Thiamethoxam recorded the lowest natural enemy abundance among synthetic treatments.

Table 3. Impact of treatments on natural enemy populations

Treatment	Coccinellids/10 plants	Chrysopids/10 plants	Syrphid larvae/10 plants
Imidacloprid 0.006%	1.2	0.8	0.5
Methyl-o-demeton 0.025%	1.5	1.0	0.8
Thiamethoxam 0.0075%	1.0	0.6	0.4
Azadirachtin 0.001%	3.8	2.5	1.8
Neem oil 2%	3.2	2.0	1.5
Beauveria bassiana	2.8	1.8	1.2
Untreated control	4.5	3.0	2.2

Note. Values are mean counts recorded from treated plots.

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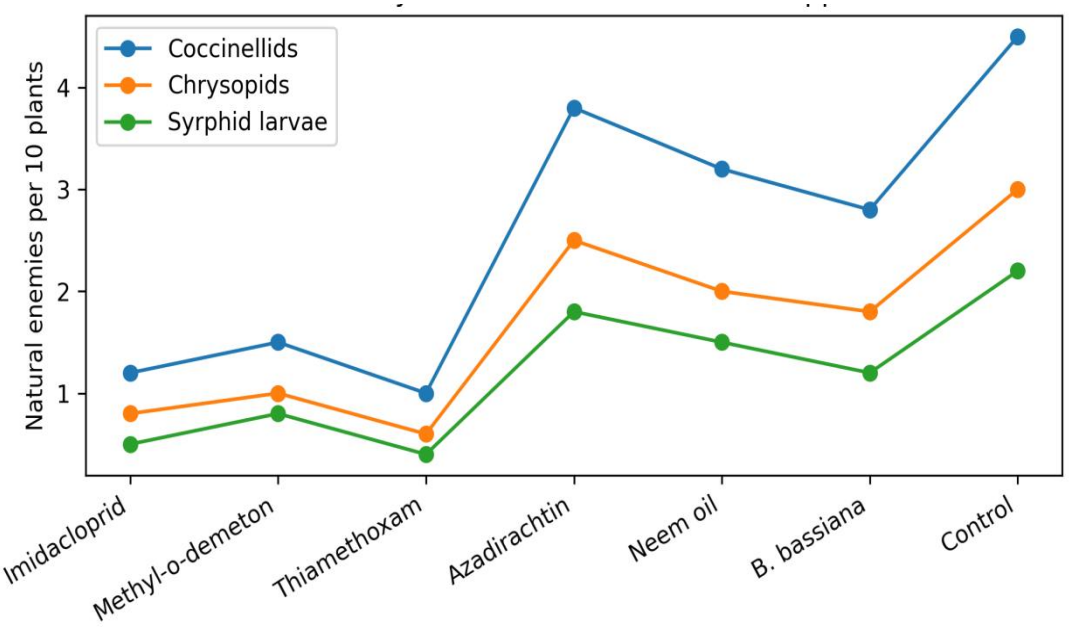

Figure 2. Natural enemy abundance after application of synthetic and biological treatments.

3.4 Yield and economic performance

Imidacloprid produced the highest yield of 3580 kg ha-1 and the highest net return over control of Rs 9350 ha-1. Methyl-o-demeton gave slightly lower yield but the highest cost-benefit ratio of 1:12.96 because of lower treatment cost. Thiamethoxam produced a lower economic ratio because its treatment cost was higher. Among biopesticides, azadirachtin gave the highest net return, followed by B. bassiana and neem oil.

Table 4. Economics of different *WHEAT APHID (Diuraphis noxia)* management treatments

Treatment	Cost (Rs/ha)	Yield (kg/ha)	Net return (Rs/ha)	Cost:benefit ratio
Imidacloprid 0.006%	850	3580	9350	1:11.20
Methyl-o-demeton 0.025%	700	3520	9074	1:12.96
Thiamethoxam 0.0075%	1900	3320	5090	1:2.67
Azadirachtin 0.001%	950	3120	3500	1:3.68
Neem oil 2%	800	2980	2650	1:3.31
Beauveria bassiana	1200	3050	2950	1:2.46
Untreated control	0	2680	-	-

Note. Net return was calculated relative to the untreated control using field-

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recorded treatment costs.

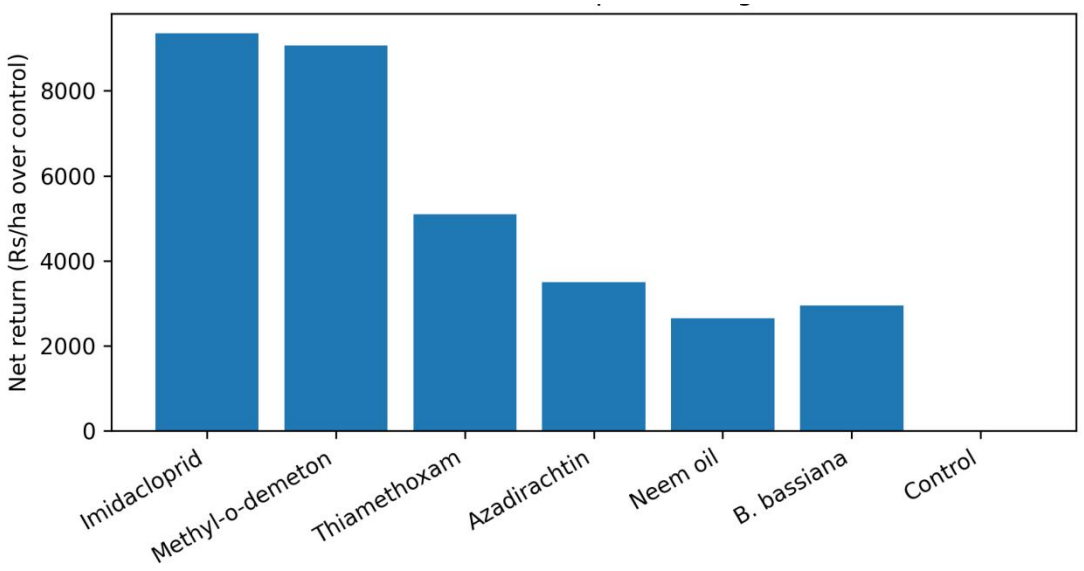

Figure 3. Net economic return from different *WHEAT APHID (Diuraphis noxia)* management treatments.

3.5 Weather correlation and natural enemy association

Minimum temperature and morning relative humidity were positively correlated with aphid abundance. Rainfall showed a negative correlation, suggesting that rain events may reduce aphid establishment or physically remove aphids from plants. Aphid abundance also showed positive association with coccinellids, chrysopids and syrphid larvae, indicating predator aggregation in response to prey density.

Table 5. Correlation coefficients between *WHEAT APHID (Diuraphis noxia)* population and weather parameters

Weather parameter	r value	Significance
Maximum temperature	-0.58*	p <= 0.05
Minimum temperature	0.72*	p <= 0.05
Morning RH	0.64*	p <= 0.05
Evening RH	0.42	NS
Sunshine hours	0.38	NS
Total rainfall	-0.52*	p <= 0.05

*Note. * = significant at p <= 0.05; NS = non-significant.*

Table 6. Correlation coefficients between aphids and natural enemies

Natural enemy	r value	Significance
Coccinellids	0.81**	p <= 0.01
Chrysopids	0.76**	p <= 0.01
Syrphid larvae	0.68*	p <= 0.05

*Note. ** = significant at p <= 0.01; * = significant at p <= 0.05.*

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4. Discussion

The results demonstrate a clear trade-off between immediate aphid knockdown and natural enemy conservation. Imidacloprid, methyl-o-demeton and thiamethoxam were superior in suppressing aphids within 72 hours, which is expected from systemic and broad-spectrum insecticides. Neonicotinoid chemistry is known for strong activity against sucking pests because it targets insect nicotinic acetylcholine receptors (Jeschke et al., 2011). However, the same chemical efficiency can create ecological and resistance concerns if products are used repeatedly without thresholds or rotation (Bass et al., 2015; Pisa et al., 2015).

Imidacloprid had the strongest efficacy and longest persistence, but methyl-o-demeton had the highest cost-benefit ratio because lower cost compensated for slightly lower yield and efficacy. From a farmer decision perspective, the best product is not always the one with maximum biological control; it must also be economically rational and compatible with future pest pressure. In aphid systems, rapid population growth can cause sudden increases in field density (Dixon, 1998), so severe infestations may justify a fast-acting product. However, routine preventive use is not defensible under IPM principles.

The botanical treatments showed moderate aphid suppression but were more compatible with natural enemies. Azadirachtin maintained higher coccinellid and chrysopid populations than synthetic treatments. This is consistent with the broader literature on botanical insecticides, which often act through feeding deterrence, growth regulation and reproductive disruption rather than instant mortality (Isman, 2006; Isman, 2020). Neem oil also reduced aphids but its performance was lower than azadirachtin. This may be due to variation in active ingredient concentration, spray coverage, environmental degradation and aphid colony position within the crop canopy.

Beauveria bassiana showed slower action, with improved relative reduction at 168 hours. This pattern is biologically expected because entomopathogenic fungi require spore attachment, germination, penetration and host colonization before mortality becomes visible. The performance of fungal biopesticides depends strongly on humidity, temperature and formulation quality (Faria & Wraight, 2007; Meyling & Eilenberg, 2007; Lacey et al., 2015). In dry or hot field conditions, microbial products may underperform unless application timing and microclimate are favorable.

Natural enemy results are important for IPM. Untreated plots had the highest predator abundance, but they also retained higher aphid populations and lower yield. This indicates that natural enemies alone may not always prevent economic aphid injury. The practical aim should therefore be integration: conserve predators during low to moderate aphid pressure, use botanical or microbial products when compatible suppression is sufficient, and reserve selective synthetic products for threshold-level outbreaks. The sublethal effects of pesticides on beneficial arthropods should be considered because predators may survive direct exposure but suffer reduced mobility, fecundity or prey consumption (Desneux et al., 2007).

Weather correlations suggest that aphid surveillance should be intensified during periods of warmer nights and higher morning humidity. Rainfall had a negative association with aphids, similar to many soft-bodied insects that are vulnerable to wash-off. These correlations should not be interpreted as causal proof from a single

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season, but they can support field advisories. A locally calibrated model with multi-year data would improve prediction accuracy.

Overall, the findings support a threshold-based *WHEAT APHID (Diuraphis noxia)* strategy at Haripur. Synthetic insecticides should not be rejected because they provide essential rescue control during heavy infestations. At the same time, exclusive dependence on them is risky because it can reduce beneficial arthropods, increase resistance pressure and undermine biological control. Biopesticides and natural enemies should therefore be treated as core components of sustainable *WHEAT APHID (Diuraphis noxia)* management rather than secondary options.

5. Conclusion

Imidacloprid 0.006% and methyl-o-demeton 0.025% gave the strongest aphid suppression, with imidacloprid producing the highest reduction and methyl-o-demeton giving the best cost-benefit ratio. Thiamethoxam was also effective but comparatively less economical. Azadirachtin and neem oil were less effective as knockdown treatments but better conserved natural enemies. Beauveria bassiana showed delayed efficacy and can be useful where humidity favors fungal infection. Minimum temperature and morning relative humidity favored aphid abundance, while rainfall reduced it. The recommended approach is an IPM program based on regular scouting, economic thresholds, conservation of predators, use of biopesticides under moderate pressure and judicious synthetic insecticide application during severe outbreaks.

Declarations

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Conflict of interest: The author declares no conflict of interest.

Ethics statement: This study involved field observations and agronomic trials only; therefore, human or animal ethics approval was not applicable.

Data availability: The numerical data used for tables and figures are presented within the manuscript. Additional raw field sheets should be retained by the author for journal review, if requested.

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