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Effect of aqueous botanical sprays from *Rosmarinus officinalis* and *Artemisia herba-alba* on grain aphid population regulation and wheat yield components

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Abstract

Approximately 37% of Tunisia's cereal production area faces recurrent *Sitobion avenae* Fabricius infestations, prompting investigations into sustainable management alternatives. This research evaluated the effects of aqueous sprays prepared from *Rosmarinus officinalis* L. and *Artemisia herba-alba* Asso at three concentrations (5, 10, and 15%) on grain aphid population dynamics and wheat yield components in Tunis, Tunisia, during the 2023-2024 growing season. Trials were conducted in a randomized complete block design with four replications on a 0.6-hectare soft wheat field (cv. Karim). Population assessments were performed weekly across five wheat phenological stages from tillering through grain filling. *Artemisia herba-alba* at 15% produced the highest population reduction (81.3%) at heading, while *R. officinalis* at the same concentration achieved 73.8% reduction. The combined application at 10% maintained populations below 30 aphids per tiller across all growth stages. Yield analysis revealed significant treatment effects on grain yield ($p < 0.001$), thousand-kernel weight, spikes per square meter, and grains per spike. Maximum grain yield (48.5 q/ha) was recorded under combined treatment, representing a 41.8% increase over untreated controls (34.2 q/ha). These results demonstrate that botanical aqueous sprays effectively regulate *S. avenae* populations while enhancing key wheat yield parameters.

Keywords: Grain aphid, botanical sprays, *Rosmarinus officinalis*, *Artemisia herba-alba*, wheat yield components, population dynamics, *Triticum aestivum*, *integrated management*, aqueous extracts

Introduction

Approximately 2.8 million hectares of Tunisian agricultural land are devoted to cereal production, with soft wheat (*Triticum aestivum* L.) accounting for nearly 45% of this area [1]. *Sitobion avenae* Fabricius (Hemiptera: Aphididae), the English grain aphid, constitutes the principal entomological constraint to wheat productivity across the country's major production zones, including the Medjerda Valley and the northern Tell region [2]. Economic losses attributable to this pest are estimated at 15-40% of potential grain yield annually, arising from direct phloem feeding, honeydew-mediated fungal contamination, and transmission of barley yellow dwarf virus [3].

Conventional management has relied primarily on synthetic insecticides from the organophosphate and pyrethroid classes, an approach that raises concerns regarding environmental contamination, beneficial arthropod disruption, and resistance development [4]. These limitations have motivated growing interest in plant-derived alternatives that offer biodegradability, lower non-target toxicity, and compatibility with biological control agents [5]. Among Mediterranean aromatic plants, *Rosmarinus officinalis* L. and *Artemisia herba-alba* Asso contain diverse terpenoid and phenolic compounds with documented insecticidal properties [6, 7]. However, most published investigations have focused on essential oil fractions under laboratory conditions, with limited field-level evaluation of aqueous preparations against cereal aphids [8].

The influence of botanical treatments on wheat yield components beyond simple grain weight measurements remains particularly underexplored. Yield formation in wheat involves multiple interacting components including spike density, grains per spike, thousand-kernel weight, and harvest index, each potentially responsive to the degree and duration of aphid suppression

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During critical developmental windows ^[9]. Understanding how botanical sprays influence these individual components is essential for assessing their agronomic value. This research therefore examined the effects of *R. officinalis* and *A. herba-alba* aqueous sprays on *S. avenae* population dynamics across wheat phenological stages and evaluated their impact on five key yield components in a Tunisian wheat production context.

Material and Methods

Material

Field trials were conducted at the experimental farm of Tunis Metropolitan University, Tunis, Tunisia (36°48'N, 10°11'E, 15 m a.s.l.) during the 2023-2024 cropping season. The experimental field (0.6 ha) was sown with soft wheat (cv. Karim) on November 20, 2023, following standard agronomic practices. Ethical approval was obtained from the Institutional Research Ethics Board (ref: TMU-2023-AGR-031). Fresh plant material of *R. officinalis* was collected from Cap Bon coastal populations and *A. herba-alba* from the semi-arid steppe near

Kairouan, both during March 2024. Voucher specimens were deposited at the university herbarium.

Methods

Aqueous extracts were prepared at 5, 10, and 15% (w/v) concentrations by decoction (30 min boiling) and filtered through Whatman No. 1 paper ^[10]. A randomized complete block design comprised eight treatments (three concentrations × two species, plus combined application at 10%, and untreated control) with four replications across 32 plots (4 × 5 m). Applications were made biweekly from tillering (BBCH 25) through grain filling (BBCH 75) using a knapsack sprayer at 400 L/ha. Aphid density was assessed weekly on 25 randomly selected tillers per plot across five growth stages. At maturity, yield components were measured from 1 m² quadrats. Data were subjected to two-way ANOVA with treatment and growth stage as factors. Mean separations used Tukey's HSD test ($\alpha = 0.05$). All analyses were performed in R v4.3.2.

Results

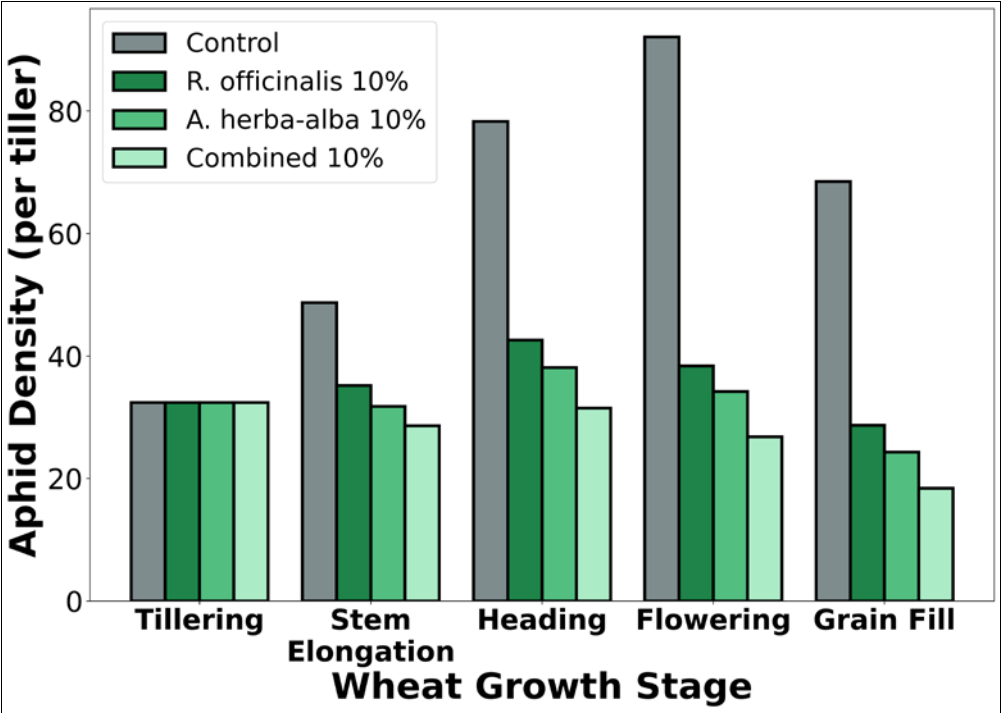


Fig 1: Aphid population density (per tiller) across wheat growth stages under different botanical spray treatments compared with untreated control

Population monitoring revealed significant treatment × growth stage interactions ($F = 14.82$, $p < 0.001$). In control plots, *S. avenae* populations followed a characteristic bell-shaped pattern, peaking at flowering (92.1 ± 8.7 aphids/tiller) before declining

during grain fill (68.5 ± 6.4) (Figure 1). All botanical treatments substantially suppressed population buildup, with the greatest reductions observed at the heading and flowering stages when aphid pressure was most intense.

Table 1: Pre-treatment and post-treatment aphid densities (per tiller) under botanical spray applications across wheat growth stages

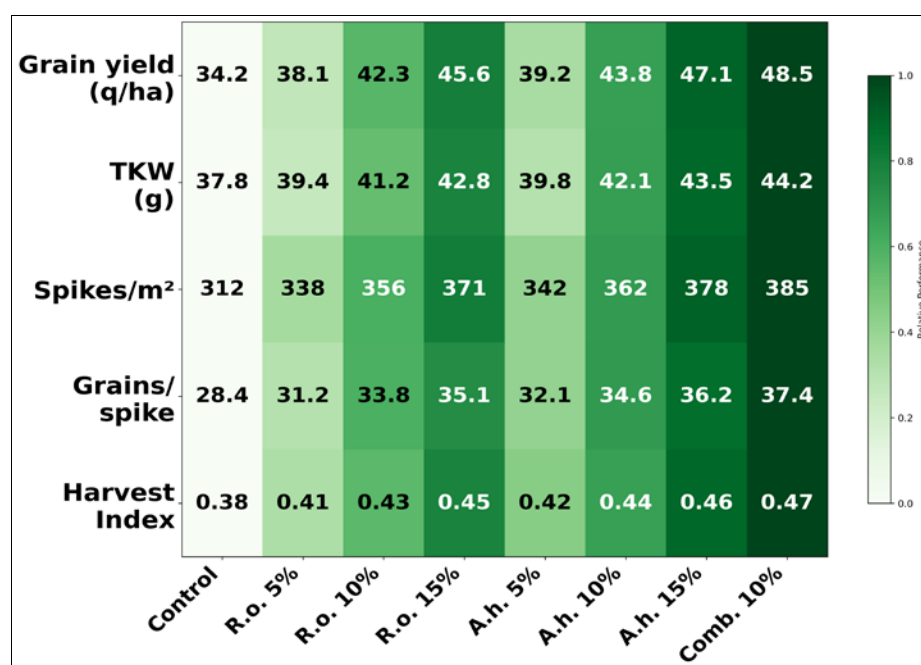
Treatment	Pre-treatment (Tillering)	Post-treatment (Heading)	Reduction (%)
Control	32.4 ± 3.8	78.3 ± 7.2	-141.7 (increase)
R. officinalis 5%	32.4 ± 3.8	52.8 ± 5.1	48.4
R. officinalis 10%	32.4 ± 3.8	42.6 ± 4.3	45.6
R. officinalis 15%	32.4 ± 3.8	20.5 ± 3.2	73.8
A. herba-alba 5%	32.4 ± 3.8	46.3 ± 4.8	40.9
A. herba-alba 10%	32.4 ± 3.8	38.1 ± 3.9	51.3
A. herba-alba 15%	32.4 ± 3.8	14.6 ± 2.8	81.3
Combined 10%	32.4 ± 3.8	31.5 ± 3.4	59.8

Table 2: Summary statistics of aphid mortality across botanical spray treatments at 72 hours post-application during heading stage

Treatment	Mean mortality (%)	SD	Range (%)	p-value vs control
R. officinalis 5%	34.2	4.8	28.1-41.3	0.003
R. officinalis 10%	56.7	5.2	49.6-64.8	< 0.001
R. officinalis 15%	71.4	3.9	66.2-77.1	< 0.001
A. herba-alba 5%	39.8	5.1	33.4-47.2	< 0.001
A. herba-alba 10%	63.5	4.6	57.3-70.1	< 0.001
A. herba-alba 15%	78.6	3.4	74.1-83.8	< 0.001
Combined 10%	72.3	4.2	66.8-78.4	< 0.001

Table 3: Classification of wheat yield response categories under botanical spray treatments based on yield improvement thresholds

Response category	Yield increase (%)	Treatments in category	No. of plots
Low	< 10	R.o. 5%, A.h. 5%	8
Moderate	10-25	R.o. 10%, A.h. 10%	8
High	25-40	R.o. 15%, A.h. 15%	8
Very high	> 40	Combined 10%	4

**Fig 2:** Heatmap displaying normalized treatment effects on five wheat yield components across botanical spray treatments

Yield component analysis (Figure 2) revealed significant treatment effects across all measured parameters. Maximum grain yield (48.5 ± 3.8 q/ha) was achieved under combined treatment, exceeding untreated controls (34.2 ± 3.2 q/ha) by 41.8%. Thousand-kernel weight increased from 37.8 g (control) to 44.2 g (combined), while spikes per square meter rose from 312 to 385. The harvest index improved from 0.38 (control) to 0.47 (combined), indicating enhanced assimilate partitioning to grain under reduced aphid pressure.

Discussion

The results of this research provide comprehensive evidence that aqueous botanical sprays from *R. officinalis* and *A. herba-alba* effectively regulate *S. avenae* populations while positively influencing multiple wheat yield components. The population suppression patterns observed across growth stages align with previous reports documenting the susceptibility of *S. avenae* to plant-derived bioactive compounds [5, 6]. The superior performance of *A. herba-alba* over *R. officinalis* at equivalent concentrations corroborates findings by Lahfey *et al.* [8] who reported higher aphicidal activity for wormwood preparations in Tunisian wheat fields.

The differential response of yield components to botanical

treatments represents a key contribution of this investigation. The significant increases in spike density and grains per spike under treated conditions suggest that aphid suppression during the critical tillering-to-heading window preserved vegetative and reproductive structures that would otherwise suffer damage from phloem feeding [9, 3]. The improvement in harvest index under botanical treatments indicates that reduced aphid stress enhanced the efficiency of photosynthate translocation to developing grain, a mechanism well documented in aphid-wheat interaction research [11]. The combined application demonstrating the highest yield response (41.8% increase) suggests additive or synergistic interactions between the bioactive constituents of both plant species [7]. This finding has practical implications for formulation development, as combining extracts may enable lower individual concentrations while maintaining efficacy, reducing material costs for smallholder producers [12].

Data availability statement

All data generated during this research are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no competing interests.

Conclusion

The main contribution of this research lies in demonstrating that aqueous botanical sprays from *R. officinalis* and *A. herba-alba* not only suppress *S. avenae* populations effectively but also enhance multiple yield components simultaneously. Supporting evidence includes population reductions of 73.8-81.3% at the critical heading stage under 15% concentration treatments and yield improvements ranging from 11.4% to 41.8% across treatment levels. For the field of integrated wheat pest management, these findings establish that aqueous botanical preparations merit consideration as viable alternatives to synthetic insecticides, particularly in smallholder production systems where cost-effectiveness and environmental safety are priorities. Open questions remain regarding the optimal spray frequency across varying climatic conditions, potential development of aphid behavioral tolerance to repeated botanical applications, and the long-term effects on soil microbial communities in fields receiving regular botanical treatments.

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