

RESEARCH ARTICLE **OPEN ACCESS**

Controlling *Cynodon dactylon* in Vineyards Under Arid Conditions: Superior Efficacy of Consecutive-Year Polyethylene Mulching Compared to Herbicide Application

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Received: 26 July 2025 | **Revised:** 3 May 2026 | **Accepted:** 7 May 2026

Academic Editor: Michela Centinari

Keywords: arid environment | bermudagrass | plastic mulch | *Vitis vinifera* L | Yaghuti grapevine

ABSTRACT

Effective management of *Cynodon dactylon* (bermudagrass) is critical for grapevine production in arid environments. A three-year field study (2018–2020) was conducted in a commercial Yaghuti table grape (*Vitis vinifera* L.) vineyard in southeastern Iran to compare polyethylene mulch (PEM) and four selective herbicides for bermudagrass control and their effects on grape yield and fruit quality. The experiment followed a randomized complete block design in which herbicide treatments and 1 year PEM were rerandomized annually, whereas 2- and 3-year PEM treatments were maintained on fixed plots to evaluate cumulative effects. Among herbicides, clethodim provided the greatest suppression of both above- and below-ground bermudagrass biomass during the first year, followed by haloxyfop R-methyl ester. Multiyear PEM applications resulted in near-complete suppression of bermudagrass biomass by the second consecutive year, with similar levels of control observed in the third year. Grape yield varied among treatments across years. In general, treatments that effectively reduced bermudagrass competition, including clethodim and multiyear PEM, were associated with higher yields relative to the untreated control. In 2020, grapevines under clethodim and multiyear PEM treatments exhibited higher total soluble solids (TSS) at harvest, while titratable acidity (TA) also differed among treatments. These differences likely reflect indirect effects of weed suppression on vine water status and fruit microclimate rather than direct physiological effects of the herbicides. Overall, repeated PEM application provided sustained bermudagrass suppression under arid conditions, whereas clethodim offered effective short-term control. Long-term environmental and economic implications of multiyear PEM use warrant further investigation.

1 | Introduction

Cynodon dactylon (L.) Pers., commonly known as bermudagrass, is a perennial C4 grass widely recognized as one of the most aggressive and competitive weed species in perennial cropping systems worldwide [1]. In vineyards, bermudagrass is particularly damaging because of its extensive rhizome and stolon network, which enables rapid vegetative spread and persistent

regrowth following mechanical disturbance. Its deep and highly branched root system competes intensely with grapevines for water and nutrients, especially under water-limited conditions, thereby reducing vine vigor, yield potential, and long-term vineyard sustainability [2, 3]. The competitive impact of *C. dactylon* is exacerbated in arid and semiarid environments, where limited soil moisture increases resource competition. Bermudagrass exhibits strong drought tolerance and desiccation

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avoidance strategies [4], allowing it to persist and proliferate under high temperatures, low precipitation, and elevated evapotranspiration rates. Projected climate change scenarios, including rising temperatures, altered precipitation patterns, and increased evaporative demand, may further favor C4 species such as *C. dactylon*, potentially intensifying weed pressure in vineyards [3, 5]. Chemical control using selective postemergence herbicides remains a common management strategy in vineyards. Acetyl-CoA carboxylase (ACCase) inhibitors, such as clethodim, fluazifop, and haloxyfop, are widely used for grass control [6–8]. However, several challenges limit their long-term effectiveness. Bermudagrass exhibits physiological tolerance and detoxification capacity, partly mediated by cytochrome P450 enzymes [9]. In addition, repeated herbicide use may select for resistant biotypes and can influence soil microbial communities and root symbioses. For example, Zaller et al. [10] reported that herbicide use in vineyards reduced mycorrhizal colonization of grapevine roots and altered nutrient composition in roots, leaves, xylem sap, and grape juice, including shifts in mineral nutrient concentrations and microbial populations in xylem sap. Although selective herbicides are generally considered safe for grapevines when properly applied, indirect yield reductions may occur through off-target injury, altered soil microbial activity, or disruption of beneficial root–microbe interactions [10, 11]. Moreover, in arid soils characterized by low organic matter, herbicide persistence may be prolonged, increasing the risk of environmental contamination and unintended ecological impacts [12, 13]. Nonchemical alternatives, including mulching, mechanical cultivation, and cover cropping, are increasingly explored as components of integrated weed management. Polyethylene mulch (PEM) acts as a physical barrier that limits light penetration to the soil surface, suppressing weed emergence and reducing rhizome growth [14–16]. In addition to weed control, plastic mulches reduce soil evaporation, moderate soil temperature, and improve soil water availability [17, 18]. By conserving soil moisture, mulches may enhance vine water status, indirectly supporting photosynthetic activity and carbon assimilation under arid conditions. Reflective (silver-on-black or white-on-black) mulches can also modify canopy light distribution and reduce heat stress in high-temperature environments [19]. However, the use of PEM in perennial fruit systems involves important tradeoffs. Installation and removal require substantial labor and material costs [20–22]. Disposal of contaminated plastic residues poses agronomic and environmental challenges, and long-term accumulation of plastic fragments or microplastics in soil has raised concerns regarding soil structure, microbial dynamics, and potential contaminant release [23, 24]. Furthermore, although PEM is often described as a nonchemical alternative to herbicides, uncertainties remain regarding additives and polymer processing, and their long-term environmental implications warrant continued investigation.

Yaghuti grape is an early-ripening table grape cultivar of regional economic importance in southeastern Iran, valued for its early market availability and adaptability to saline and arid conditions [25]. Despite its resilience to abiotic stress, yield losses due to weed competition remain significant in water-limited vineyards, where vine–weed competition for soil moisture can strongly influence vegetative growth, berry development, and fruit composition. In commercial vineyards of southeastern Iran, weed management in table grape systems such as Yaghuti

typically relies on postemergence herbicide applications in the undervine strip, often combined with periodic mechanical cultivation in the inter-row [26–28]. Selective ACCase-inhibiting herbicides are commonly used to control perennial grasses such as *C. dactylon*. However, under arid conditions, repeated herbicide use may provide only partial or short-term suppression due to rapid regrowth from rhizomes, and concerns related to cost, resistance development, and environmental impact have encouraged the exploration of alternative or complementary strategies. Previous studies in vineyards have evaluated alternative ground cover and mulching strategies for bermudagrass suppression [29, 30], highlighting the importance of integrated management approaches. However, direct comparisons between consecutive-year PEM applications and commonly used selective herbicides under arid vineyard conditions remain limited.

Therefore, the objectives of this 3-year field study were to (i) evaluate the effectiveness of PEM applied for one, two, and three consecutive years in suppressing *C. dactylon* biomass, (ii) compare its performance with selective ACCase-inhibiting herbicides, and (iii) assess associated effects on grape yield and fruit quality under arid vineyard conditions. We hypothesized that consecutive-year PEM application would result in cumulative suppression of bermudagrass biomass and would achieve levels of control comparable to, or greater than, those obtained with selective herbicide treatments, thereby improving grapevine performance under arid conditions.

2 | Materials and Methods

2.1 | Study Location and Crop Management

This experiment was conducted from 2018 to 2020 in a 2-ha commercial vineyard of Yaghuti table grape (*Vitis vinifera* L.) located in southeastern Iran (30.8914° N, 61.6792° E), characterized by an arid climate with a mean annual temperature of 23°C and annual precipitation of 57.7 mm (Figure 1). Yaghuti is an early-ripening table grape cultivar of regional economic importance, harvested in late spring to early summer.

The grapevines were 8 years old at the beginning of the experiment (2018) and spaced 3.5 m between rows and 2 m within rows. Vines were spur-pruned and trained using a low vertical shoot positioning system adapted to local wind conditions. Due to strong seasonal winds (“120-day wind of Sistan”), shoots were maintained close to the ground and supported by low training structures rather than elevated trellises.

Irrigation was supplied via furrow irrigation at approximately 0.7 crop evapotranspiration (ET_c). ET_c was calculated as

$$ET_c = K_c \times ET_o, \quad (1)$$

where ET_o represents reference evapotranspiration and K_c is the crop coefficient. A seasonal K_c of 0.7–0.8 was adopted based on regional viticulture guidelines for mature table grape vineyards under arid conditions [31]. Irrigation was initiated on February 22, 21, and 25 in 2018, 2019, and 2020, respectively, for a total of 12 irrigation events per season, with cumulative seasonal water application of approximately 830 mm.

Soil properties (0–30 cm depth) are reported as mean ± standard deviation based on composite samples collected from multiple

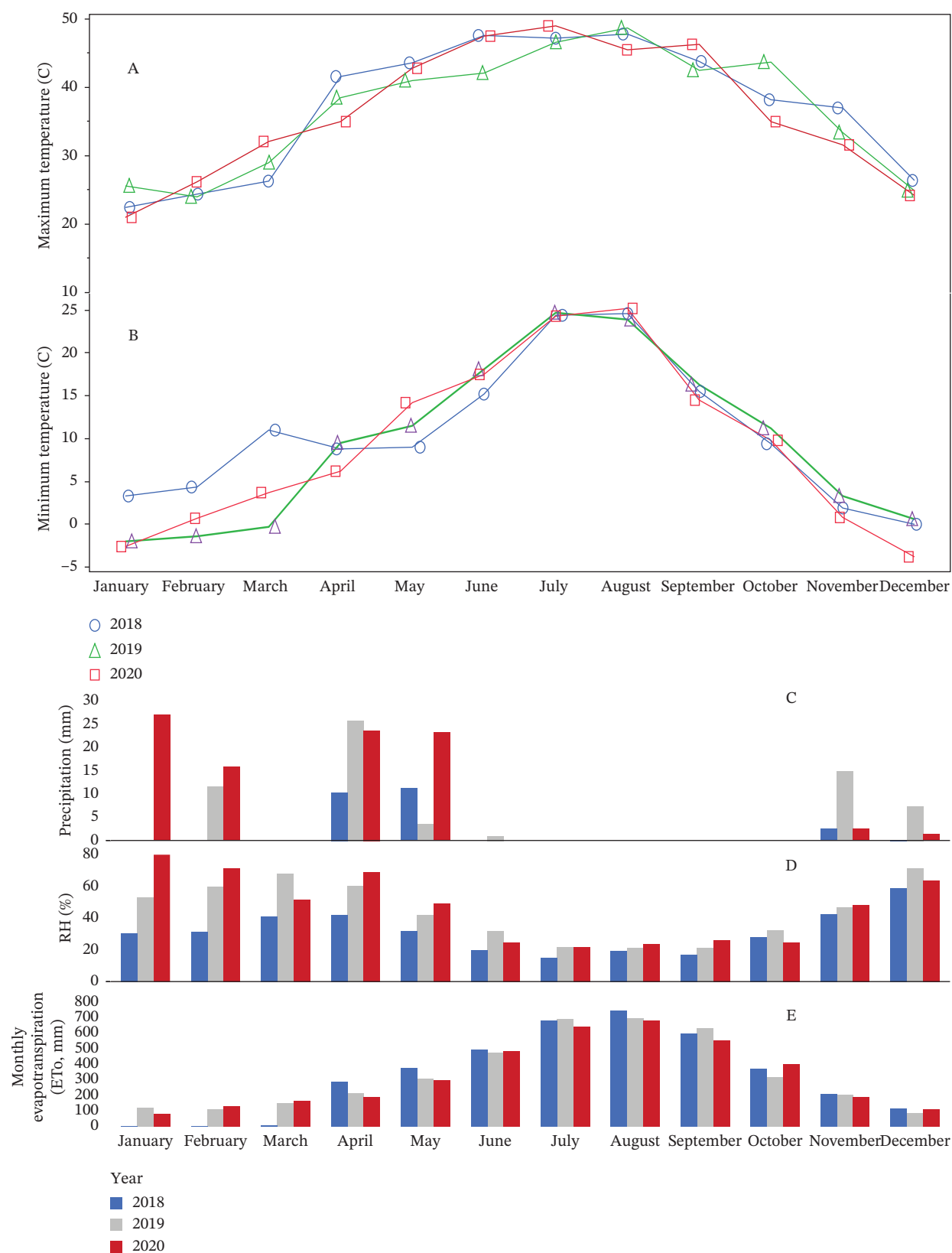


FIGURE 1 | Maximum (A) and minimum (B) temperatures, precipitation (C), relative humidity (RH) (D), and monthly evapotranspiration (E) at the experimental site for the years 2018, 2019, and 2020.

locations within the experimental area prior to treatment establishment. Soil electrical conductivity was $5.2 \pm 0.6 \text{ dS m}^{-1}$, pH 8.5 ± 0.19 , organic carbon $0.48 \pm 0.05\%$, total nitrogen $0.045 \pm 0.003\%$, and texture consisted of $15 \pm 1.3\%$ clay, $22 \pm 2.1\%$ silt, and $63 \pm 3.1\%$ sand.

2.2 | Experimental Design and Treatments

Prior to treatment establishment, bermudagrass (*C. dactylon*) density averaged 230 ± 28 shoots m^{-2} across the vineyard. The study was conducted using a randomized complete block design with four replications per year. Each experimental unit consisted of five adjacent grapevines within a single row (9 m length $\times$ 5 m width), with 3-m buffer zones between plots. Weed management treatments were applied exclusively to the undervine (in-row) strip, while the inter-row area was managed uniformly across the vineyard according to standard grower practices (periodic mechanical cultivation). Herbicide treatments and 1-year PEM were rerandomized annually within each block. In contrast, plots assigned to 2-year and 3-year PEM treatments were maintained on the same fixed experimental units across consecutive growing seasons to evaluate cumulative mulch effects. In 2018, treatments included four herbicides, 1-year PEM, and a weed-infested control. In 2019, treatments included four herbicides, one-year PEM, 2-year PEM (continuation of 2018 PEM plots), and a weed-infested control. In 2020, treatments included four herbicides, one-year PEM, 2-year PEM, three-year PEM (continuation of the original PEM plots), and a weed-infested control. Four ACCase-inhibiting herbicides were evaluated: clethodim (12% EC, 180 g ha^{-1} ai), sethoxydim (12.5% OEC, 375 g ha^{-1} ai), fluazifop-p-butyl (15% EC, 225 g ha^{-1} ai), and haloxyfop R-methyl ester (10.8% EC, 180 g ha^{-1} ai), applied at a spray volume of 350 L ha^{-1} (Table 1). Herbicides were applied postemergence using a rechargeable sprayer equipped with a flat fan nozzle (TeeJet TP8002EVS). Applications were directed to the undervine strip to avoid contact with grapevine foliage. PEM consisted of a silver-on-black film (100 μm thickness). The mulch was applied along the vine row, covering the undervine strip over a width of approximately 1.0 m centered on the vine line. The black surface was placed in contact with the soil, while the reflective silver surface faced upward. The same mulch type and installation method were used consistently across all 3 years. In multiyear PEM treatments, the mulch remained in place continuously across seasons without removal. Weed biomass was assessed at multiple time points during the growing season. The first sampling was conducted at bermudagrass emergence and served as a baseline measurement prior to treatment effects. The second sampling (30 days after emergence) was performed 1–2 days before herbicide application and was used as a pretreatment reference for herbicide-treated plots. Subsequent samplings were conducted after treatment application to evaluate temporal changes in above- and below-ground biomass. Because multiyear PEM treatments were maintained on fixed experimental units, whereas herbicide treatments were rerandomized annually, comparisons involving cumulative PEM treatments and annually applied herbicides should be interpreted cautiously due to potential positional effects within the vineyard.

2.3 | Grape Yield and Fruit Quality

The grape bunches were harvested manually on June 23, 2018, June 19, 2019, and June 27, 2020. Subsequently, the yields per

plant (in kilograms) were converted to yields per hectare (in kilograms per hectare). In the third year of the experiment (2020), the total soluble solids (TSS) were determined using a manual refractometer (model N52436, Nijkerk, Netherlands) based on °Brix. The titratable acidity (TA) (g L^{-1}) was assessed using the NaOH titration method. For this, 5–6 droplets of phenolphthalein were added to a 10-mL sample of fruit juice, and the mixture was titrated with 0.3 N NaOH until a color change to purple occurred [32]. The pH of the fruit juice was measured using a digital pH meter (Jenway 3510, Cambridgeshire, United Kingdom).

2.4 | Statistical Analysis

Because herbicide treatments and 1-year PEM were rerandomized annually, whereas two- and 3-year PEM treatments were maintained on fixed experimental units across seasons, statistical analyses were conducted separately for each year. Within each year, analysis of variance (ANOVA) was performed to evaluate treatment effects using a randomized complete block framework. Data normality and homogeneity of variance were assessed using Shapiro–Wilk and Bartlett tests, respectively. When assumptions were met, treatment means were compared using protected least significant difference (LSD) at $p < 0.05$. Due to the fixed-plot structure of the multiyear PEM treatments, comparisons between cumulative PEM treatments (two- and 3-year PEM) and annually randomized herbicide treatments may be partially confounded by positional effects. Therefore, such comparisons are interpreted cautiously and discussed primarily in terms of cumulative suppression trends rather than strict inferential equivalence. Regression analyses were conducted to describe temporal changes in above- and below-ground biomass across sampling dates. Polynomial quadratic models were fitted, and coefficients of determination (R^2) and associated significance levels are reported. All statistical analyses were performed using the agricolae package [33] in R (Version 4.3.2).

3 | Results and Discussion

3.1 | Efficacy of *C. dactylon* Control

ANOVA conducted separately for each year revealed significant treatment effects on both shoot and underground dry matter of *C. dactylon* (Figure 2). Within each experimental year, all weed management treatments reduced bermudagrass biomass compared with the untreated control. In 2018, clethodim provided the greatest suppression of both shoot and underground biomass among the randomized treatments, reducing shoot dry matter to below 17 g m^{-2} and underground biomass to approximately 58 g m^{-2} . Haloxyfop R-methyl ester and one-year PEM also significantly reduced shoot biomass compared with the control, whereas fluazifop-p-butyl and sethoxydim were comparatively less effective, although still achieving substantial reductions relative to the untreated plots. The superior performance of clethodim during the first season is consistent with previous reports of its effectiveness against bermudagrass when applied at early growth stages [34, 35]. In 2019, continuation of PEM for a second consecutive year resulted in minimal above- and below-ground biomass in the fixed PEM plots. Within the 2019 randomized treatments, clethodim and one-year PEM also significantly reduced shoot biomass relative to the control.

TABLE 1 | Commercial name, formulation, application rate, and manufacturer of the herbicide used in the experiment.

Common name	Commercial name	Formulation	Weight of active ingredient*	Manufacturer (location)
Clethodim	Select Super	12% EC	180 g ha ⁻¹	Syngenta (Basel, Switzerland)
Sethoxydim	Segment	12.5% OEC	375 g ha ⁻¹	BASF (Rheinland-Pfalz, Germany)
Fluazifop-p-butyl	Fusilade II	15% EC	225 g ha ⁻¹	Syngenta (Basel, Switzerland)
Haloxypop R-methyl ester	Gallant Super	10.8% EC	180 g ha ⁻¹	Dow AgroScience (Horgen, Switzerland)

*Volume of spray per hectare: 350 L ha⁻¹.

Nevertheless, the marked decline in underground biomass observed in consecutive-year PEM plots suggests a cumulative suppression effect on rhizome reserves. By 2020, both two-year and three-year PEM plots exhibited near-complete suppression of bermudagrass biomass, with negligible shoot and underground dry matter detected. Among the annually randomized herbicide treatments, clethodim continued to provide the most consistent suppression. The progressive reduction of underground biomass in consecutive-year PEM treatments likely reflects depletion of carbohydrate reserves in rhizomes due to prolonged light exclusion and disruption of photosynthetic recovery.

Figure 3 presents temporal biomass dynamics during the 2020 growing season over the 90-day assessment period, illustrating treatment responses over time. Notably, 1-year PEM resulted in levels of underground biomass suppression comparable to those observed with fluazifop-p-butyl and haloxypop R-methyl ester during the posttreatment period. This similarity suggests that even short-term light exclusion can substantially limit rhizome

activity, at least within a single growing season. However, unlike herbicide treatments, which rely on repeated annual applications, PEM provides continuous physical suppression, which may contribute to the cumulative effects observed in multiyear treatments. In untreated control plots, shoot and underground biomass increased rapidly throughout the season. Herbicide-treated plots exhibited initial growth prior to application, followed by a decline in biomass, with clethodim showing earlier and more pronounced suppression of underground dry matter compared with the other herbicides. In contrast, PEM treatments limited biomass accumulation from early in the season by restricting light penetration and inhibiting regrowth of stolons and rhizomes. The cumulative suppression observed under multiyear PEM treatments highlights the potential of physical light exclusion as a long-term strategy for managing perennial grasses in arid vineyards. Future experiments employing fully balanced repeated-measures designs would allow stronger inferential comparison between cumulative mulch strategies and annually applied herbicides. Overall, the results indicate that clethodim provides effective short-term suppression of

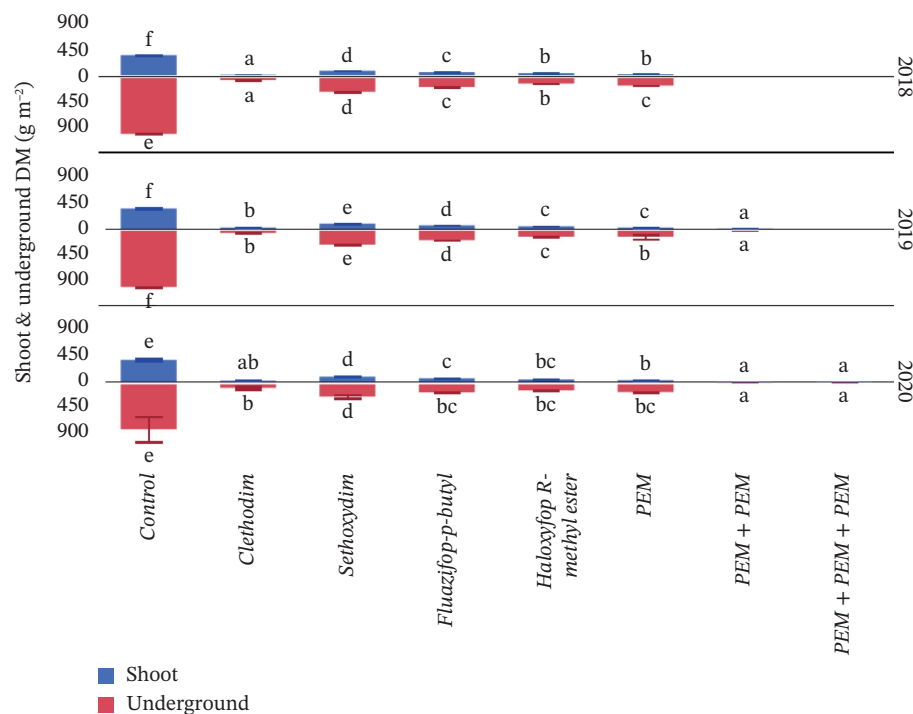
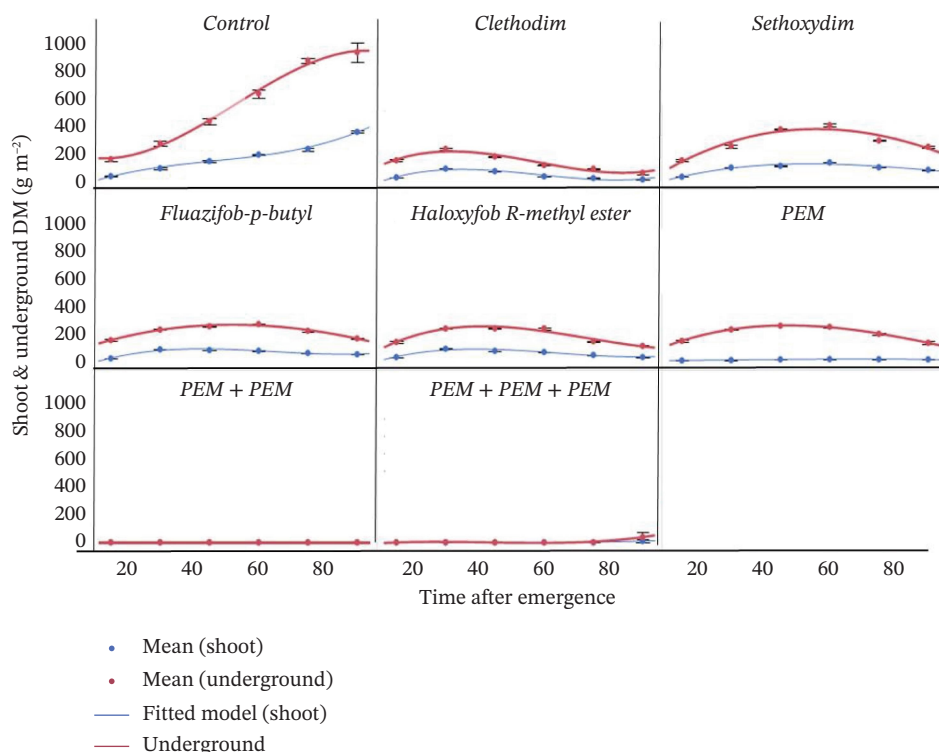


FIGURE 2 | Shoot dry matter (represented by blue bars) and underground dry matter (DM) (represented by red bars) of *Cynodon dactylon* were measured in the experimental plots 90 days after emergence for three consecutive years (2018, 2019, and 2020). The abbreviations PEM, PEM + PEM, and PEM + PEM + PEM indicate polyethylene mulch applied for 1, 2, and 3 years, respectively. The error bars indicate the standard errors. Columns with the same letters indicate no significant differences as determined by the protected LSD test.



<i>Control</i> RMSE (shoot): 26.38 R^2 (shoot): 0.94 RMSE (underground): 119.4 R^2 (underground): 0.86	<i>Clethodim</i> RMSE (shoot): 7.22 R^2 (shoot): 0.94 RMSE (underground): 24.98 R^2 (underground): 0.84	<i>Sethoxydim</i> RMSE (shoot): 7.89 R^2 (shoot): 0.94 RMSE (underground): 38.88 R^2 (underground): 0.82
<i>Fluzifop-p-butyl</i> RMSE (shoot): 5.34 R^2 (shoot): 0.95 RMSE (underground): 17.67 R^2 (underground): 0.86	<i>Haloxyfop R-methyl ester</i> RMSE (shoot): 6.48 R^2 (shoot): 0.92 RMSE (underground): 21.14 R^2 (underground): 0.87	<i>PEM</i> RMSE (shoot): 3.55 R^2 (shoot): 0.48 RMSE (underground): 23.02 R^2 (underground): 0.82
<i>PEM + PEM</i> RMSE (shoot): 0.00 RMSE (underground): 0.00	<i>PEM + PEM + PEM</i> RMSE (shoot): 7.60 R^2 (shoot): 0.21 RMSE (underground): 30.21 R^2 (underground): 0.21	

FIGURE 3 | The growth trend of shoot and underground biomass (U-G) of *Cynodon dactylon* was analyzed after the application of herbicide and polyethylene film mulch (PEM). The abbreviations PEM, PEM + PEM, and PEM + PEM + PEM indicate polyethylene mulch applied for 1, 2, and 3 years, respectively. A polynomial quadratic model was used for the regression analysis. The graphs include the R-squared (R^2) value and the p value, indicating the significance of the trend.

C. dactylon, whereas consecutive-year PEM applications may progressively reduce underground propagule viability, contributing to sustained control under arid conditions.

3.2 | Grapevine Yield and Fruit Quality

Grape yield differed among treatments within each experimental year (Figure 4). Across seasons, treatments that effectively reduced bermudagrass biomass were generally associated with higher yields compared with the untreated control, likely reflecting not only reduced vine-weed competition for soil moisture and nutrients but also improved soil water retention associated with mulch application. By reducing soil evaporation, PEM may have enhanced vine water status, thereby contributing

to improved vegetative growth and yield under arid conditions. In 2018, yields ranged from approximately 10,434 kg ha⁻¹ in the untreated control to 11,302 kg ha⁻¹ under one-year PEM. Clethodim and fluzifop-p-butyl also resulted in higher yields relative to the control. In 2019, yields increased across all treatments, with two-year PEM plots showing the highest mean yield (13,739 kg ha⁻¹). In 2020, two- and three-year PEM plots again exhibited numerically higher yields (approximately 13,000 kg ha⁻¹), whereas clethodim and one-year PEM produced intermediate values. This trend is consistent with the progressive reduction in underground biomass observed in consecutive-year PEM treatments, suggesting that sustained suppression of rhizome reserves may play a key role in limiting bermudagrass regrowth and associated competition over time. Although

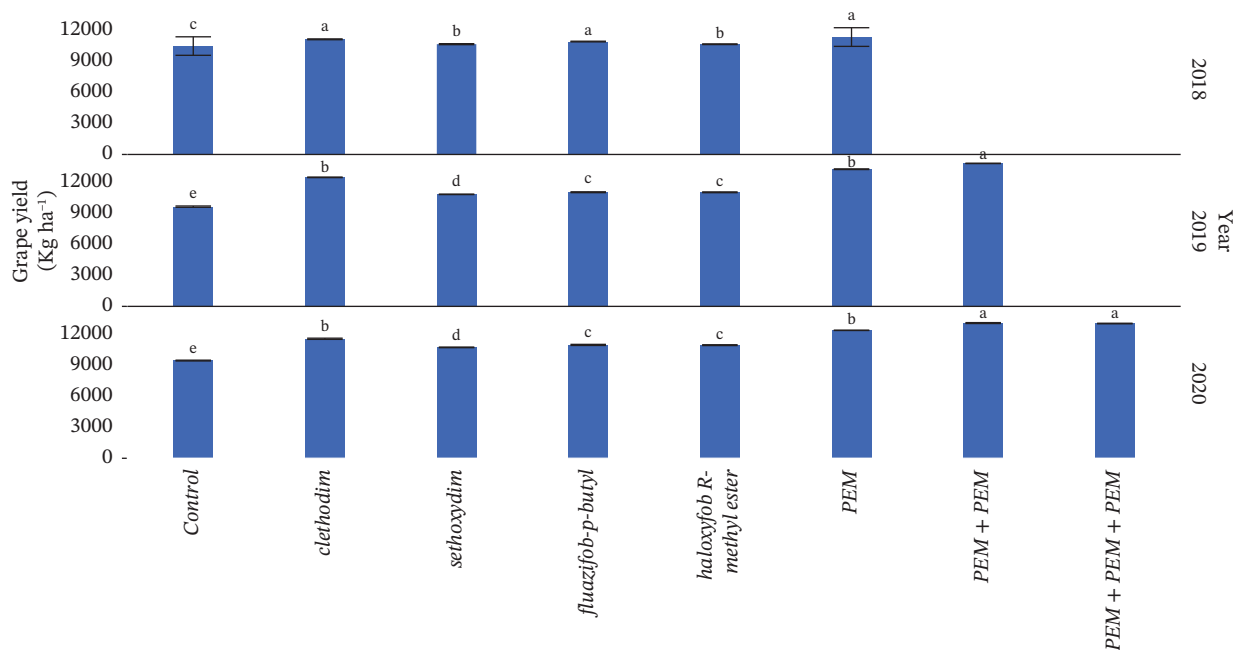


FIGURE 4 | Effects of herbicide and polyethylene mulch (PEM) treatments on grapevine yield in 2018, 2019, and 2020. The abbreviations PEM, PEM + PEM, and PEM + PEM + PEM indicate polyethylene mulch applied for 1, 2, and 3 years, respectively. Error bars indicate standard errors. Bars within a year that share the same letters are not significantly different based on the protected LSD test.

cumulative PEM treatments were associated with the highest yields in the latter years, these plots were maintained on fixed experimental units, and therefore positional effects cannot be fully excluded. Nonetheless, the consistent yield advantage observed in treatments with effective bermudagrass suppression supports the role of weed competition in limiting grape production under arid conditions. The yield levels recorded in this study ($10\text{--}14\text{ t ha}^{-1}$) are within the expected commercial range for early-ripening table grapes cultivated under arid and saline conditions in southeastern Iran. Under such environments, yield variability is often strongly influenced by water availability and vine vigor, both of which may be affected by weed pressure.

Weed suppression may influence grapevine performance through several mechanisms [36, 37]. Reduced competition for soil moisture can improve vine water status, promote shoot growth, and enhance canopy development. Conversely, excessive weed competition may limit vegetative growth, reduce leaf area, and alter canopy microclimate, potentially affecting berry temperature and ripening dynamics. Vine vegetative growth and canopy size were not directly measured in this study; therefore, the contribution of canopy differences to yield variation cannot be quantified. Future studies integrating shoot growth, pruning weight, or leaf area index measurements would help clarify the relative roles of resource competition and canopy-mediated microclimatic effects.

Fruit quality parameters measured in 2020 (Figure 5) revealed treatment-related differences in TSS and TA, whereas juice pH was not significantly affected. Grapevines under clethodim and multiyear PEM treatments exhibited higher TSS values compared with the untreated control. These differences may reflect improved vine water status and more favorable ripening conditions resulting from reduced weed competition [38–40]. Interestingly, TA values were also higher in some of the

treatments associated with strong weed suppression. Although TSS and TA often exhibit an inverse relationship during berry ripening, their dynamics are influenced by environmental conditions, vine water status, and berry temperature. In arid climates with high daytime temperatures and variable nocturnal cooling, alterations in canopy structure and fruit exposure may influence malic acid degradation patterns. It is therefore possible that treatments reducing weed competition modified vine vigor and canopy architecture, affecting berry microclimate in ways that influenced both sugar accumulation and organic acid metabolism. Because canopy structure and berry temperature were not measured, these interpretations remain speculative.

From a management perspective, repeated PEM application provided sustained weed suppression and was associated with stable or increased yields across seasons. However, economic feasibility must be considered [41–43]. Installation, maintenance, and removal of PEM involve material and labor costs that may limit adoption in commercial vineyards. In addition, long-term environmental implications, including plastic residue management and potential soil microplastic accumulation, require careful evaluation [23, 24]. In contrast, selective herbicides such as clethodim offer effective short-term control with lower immediate labor requirements but may necessitate repeated annual applications. Overall, the results suggest that effective bermudagrass suppression—whether achieved through selective herbicides or consecutive-year PEM—can mitigate vine-weed competition and support grape production in arid vineyards, although long-term agronomic, economic, and environmental trade-offs should be carefully assessed.

3.3 | Experimental Limitations

A limitation of this study relates to the experimental structure of the multiyear PEM treatments. Because the two- and 3-year PEM

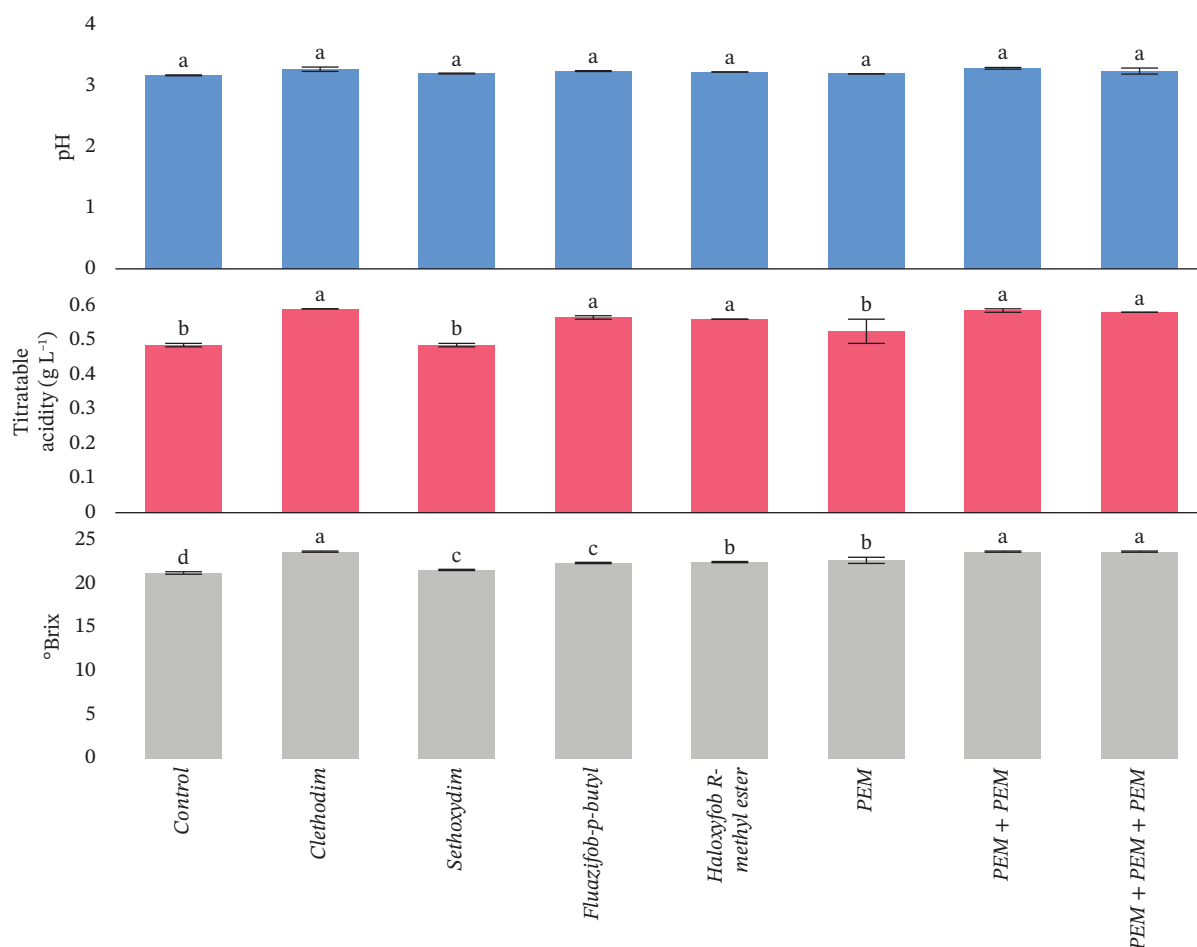


FIGURE 5 | Effects of managing *Cynodon dactylon* with herbicide and polyethylene mulch treatments on the grape juice parameters: total soluble solids (Brix), titratable acidity, and pH. The abbreviations PEM, PEM + PEM, and PEM + PEM + PEM indicate polyethylene mulch applied for 1, 2, and 3 years, respectively. Significant differences, tested by protected LSD, are indicated by different letters, and the error bars represent standard errors of means.

plots were maintained on fixed experimental units across seasons, whereas herbicide treatments were rerandomized annually, complete statistical independence among all treatments cannot be assumed. As a result, positional effects within the vineyard may partially contribute to differences observed between cumulative PEM treatments and annually applied herbicides. Future studies employing fully balanced repeated-measures designs would allow stronger inferential comparisons.

4 | Conclusion

This 3-year field study evaluated PEM and selective ACCase-inhibiting herbicides for the management of *C. dactylon* in an arid table grape vineyard. Within individual seasons, clethodim consistently provided effective short-term suppression of bermudagrass biomass among the annually randomized treatments. Consecutive-year PEM application was associated with progressive reductions in both above- and below-ground biomass, suggesting cumulative suppression of rhizomatous reserves under prolonged light exclusion. Nevertheless, sustained bermudagrass suppression—regardless of method—was generally associated with improved grape yield relative to untreated conditions, highlighting the importance of minimizing

vine-weed competition in water-limited environments. Multi-year PEM may offer a viable nonchemical component of integrated weed management strategies in arid vineyards, particularly where long-term suppression of perennial grasses is desired. However, economic feasibility, labor requirements, and environmental considerations, including plastic waste management and potential soil microplastic accumulation, must be carefully evaluated. Future research should employ fully balanced experimental designs and integrate measurements of vine vegetative growth, canopy architecture, and fruit microclimate to better elucidate the mechanisms linking weed management practices with grapevine productivity and fruit composition under arid conditions.

Author Contributions

Mansoor Sarani performed the experimental work. Mostafa Oveisi experimental design methodology, and analysis. Ramin Piri edited and improved the manuscript. Andrea Mastinu reviewed and edited the final manuscript.

Funding

This research was funded by AREEO under grant number 2-66-16-175-961383 and University of Brescia under grant number EX60%. Open

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding authors on reasonable request.

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