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Ethanol, a simple and inexpensive biological product, triggers multiple responses in grapevines

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Ethanol, a co-product of the wine industry, could have interesting applications in viticulture. Recent studies show that it could help vines adapt to drought and heat waves. It can also modulate bud break, stimulate anthocyanin accumulation, increase berry size, and delay the development of *Botrytis* on berries, among other potential applications. The aim of this article is to encourage further research and development into the potential of this treatment. It also lists some administrative constraints that need to be removed so that professionals can use it to treat vines.

Introduction

Ethanol is a molecule produced by most plants[1], particularly under stressful conditions, such as root hypoxia, which has been well studied in rice. Small amounts of ethanol are also found inside grape berries, which are a hypoxic environment[2]. This alcohol is, of course, best known for being produced by yeast or bacteria, and is a by-product of winemaking activities. Several recent studies show that ethanol is a signal perceived by organisms[3] and that it stimulates reactions in plants that could be of interest to winegrowers.

Numerous trials, under different soil and climate conditions and on many varieties, will need to be carried out before this method can be applied on a large scale in vineyards. The aim of this article is precisely to encourage the emergence of such trials, particularly by professional organizations, technical institutes, interprofessional associations, and winegrowers' associations with significant R&D capabilities. This would make it possible to establish the effectiveness of ethanol under real conditions, optimize the quantities used, define the most suitable application methods, and refine its positioning.

In this article, we will list the reactions that ethanol causes in plants, and conclude with a paragraph on the constraints that winegrowers will have to overcome if they wish to use it.

Stimulation of drought or heat tolerance

Among these reactions, researchers observed a better adaptation to drought[4]; they tested it on wheat, rice, and Arabidopsis (model plant). This adaptation, induced by brief exposure to ethanol prior to water deficit, has also been observed in grapevines[5], by applying approximately 1% ethanol in irrigation water before water deficit (Figure 1A). This adaptation to water stress appears to be due to an anticipated decrease in transpiration. It will be necessary to verify that spraying ethanol on vines creates the same reaction in multiple vineyard trials, but this can be expected to be the case, as previous studies on established vines have shown that grape berries are 10 % larger than controls after spraying 2 to 10 % ethanol at veraison[6], trials in vineyards in France and Australia. This may have been due to water conservation within the plant, but this aspect was not studied in these trials.

Preliminary studies were conducted by the IFV on vines *in situ* this summer, showing that spraying with 10 % ethanol resulted in a smaller decrease in leaf water potential during periods of water stress compared to the control group (Figure 1B), but summer rainfall prevented verification of the stability of this effect over an extended period or under more pronounced water stress conditions. Experiments will therefore be repeated in the future, involving platforms in Montpellier and Bordeaux that allow water stress to be controlled.

Another recent study shows that Gamay cells are more resistant to heat stress[7], which could compared a heatwave episode. In this study, the negative effects of heat stress were observed by measuring the cellular leakage of pigments contained in these cells (Figure 2). For ethanol, a concentration of one millimolar (mM) corresponds to 0.006 % (v/v). This adaptation appears to be due to the expression of "small heat shock proteins" following temporary exposure to ethanol. These proteins are known to stabilize and protect many cellular compounds. Field trials are needed to confirm this protective role.

Stimulation of natural defenses and preservation of table grapes

Jardine & McDowell[8] describe defense mechanisms against pathogenic microorganisms, stimulated in plants by the oxidized form of ethanol, acetic acid. Figure 3 is extracted from studies conducted with technical institutes, in commercial vineyards, showing that ethanol limits the development of *Botrytis*[9] and can replace end-of-cycle and preservation treatments, which producers and marketers wish to limit. The role of ethanol as a stimulator of

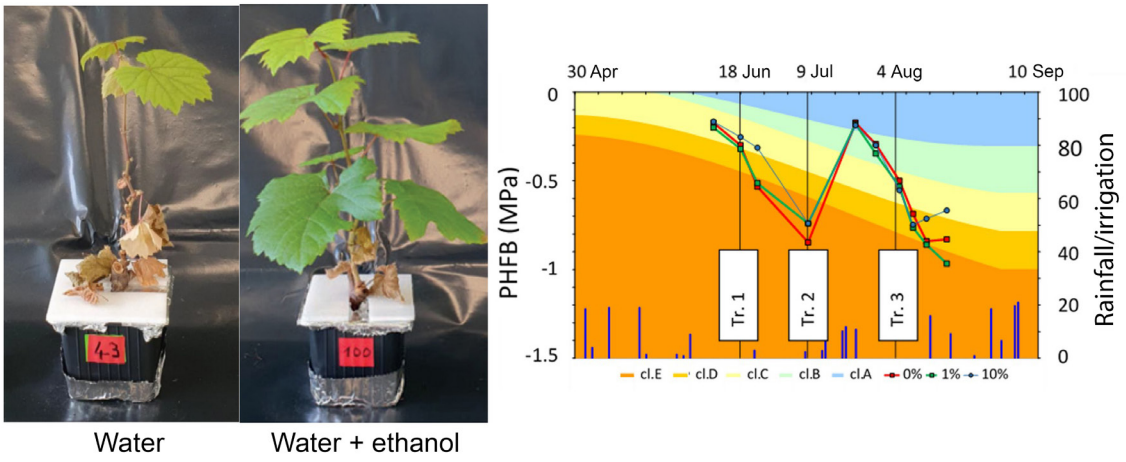


FIGURE 1. A) One-month-old vine cuttings, cv. Gamay, irrigated with water or an aqueous ethanol solution (1 % v/v), then left without water for 28 days, and irrigated again[5]. B) Evolution of basic leaf water potential, PHFB, Merlot variety, IFV Rodilhan 2025, block B. The red curve represents the control treated with water (0 % ethanol), the green curve represents the treatment with 1 % ethanol, and the blue curve represents the treatment with 10 % ethanol. Three spraying treatments: Tr. 1, Tr. 2, and Tr. 3, were carried out for each ethanol concentration using a crop sprayer. The water stress classes are shown for reference: cl. A = absent, cl. B = low, cl. C = optimal, cl. D = high, cl. E = severe. The blue histograms represent precipitation.

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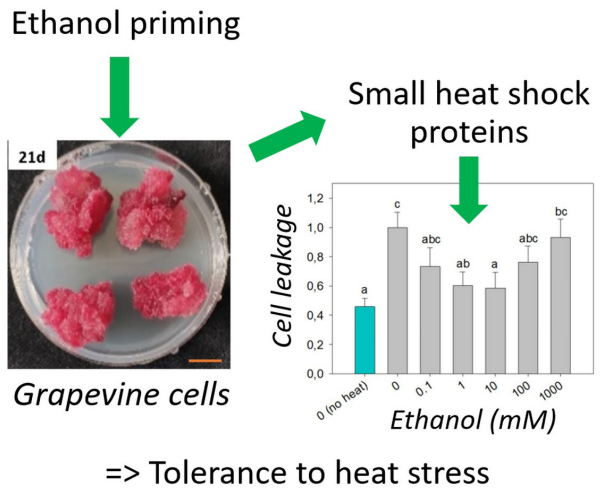


FIGURE 2. Grapevine cells (cv. Gamay) pretreated with ethanol (at different concentrations), then heat treated (40°C) and monitored for red pigment leakage[7].

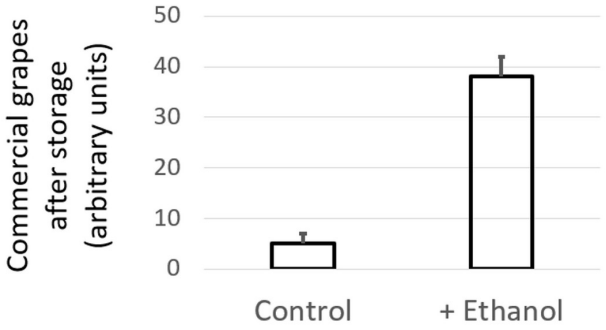


FIGURE 3. Quantity of marketable table grapes (cv. Chasselas) after pre-treatment in the vineyard with water with or without added ethanol (16 % v/v) during the two months prior to harvest, then stored for 6 weeks at 1°C and one week at 20°C[9].

natural defenses on all grapevine varieties remains to be tested in relation to downy mildew, powdery mildew, and black rot, among others.

Other interesting roles in viticulture

Chervin & Fenell[10] showed that spraying small amounts of ethanol (around 5 %) could regulate bud break, which becomes desynchronized in hot climates when buds have not accumulated enough cold days. These results would allow winegrowers to limit their use of cyanamide-based solutions. Ethanol can also stimulate anthocyanin accumulation[11] when applied around veraison, according to trials carried out in vineyards.

Constraints to be lifted for professionals to use ethanol in vineyard treatment

We detail here the specific case of France (and Europe on certain points), but similar regulations may be in place in other countries. In order to use ethanol in aqueous solution on vines, it would need to be approved as a "basic substance" (Article 23 of Regulation (EC) 1107/2009); information is available online (iuclid website). National agencies can take charge of these applications at the initiative of interprofessional organizations. In France, beer is authorized as a "basic substance" in viticulture (https://itab.bio/sites/default/files/medias/fichier/2025/03/Fiche%20filiere%20Viticulture.pdf), so why not grape pomace spiritor even wine itself? That said, ethanol may already be used as a solvent, in small doses, in certain formulations of plant protection products.

To purchase grape pomace spirit, many professionals, including winegrowers, already have an excise license number or a UTI number (https://www.douane.gouv.fr/demarche/deposer-une-declaration-prealable-de-profession-afin-dobtenir-un-numero-utilisateur). Organic-quality ethanol is also available from certain distillers. In Europe, ethanol is already produced and distributed for domestic use, but it is denatured, and some bittering agents may be persistent, which is something that needs to be tested.

Finally, to store alcohol on the farm, you must be an authorized warehouse keeper (https://www.douane.gouv.fr/fiche/devenir-entrepositaire-agree). Many winegrowers already are.

One solution for winegrowers would be to rely on technical institutes and chambers of agriculture, which have experts capable of studying the feasibility and taking the necessary steps, if the effectiveness of such treatments is proven in the various territories.

Conclusion

Numerous studies have demonstrated the potential of ethanol, a natural compound produced by all plants, to induce reactions that would enable vines to better respond to various biotic (fungi, etc.) and abiotic (heat, drought) stresses. However, extensive applied research is now needed to validate the benefits of this treatment. Research will need to focus on, among other things: the optimal doses of ethanol, the best timing for applications, the most appropriate system for applying this treatment, whether by spraying or irrigation, when the winegrower is equipped (and this treatment could help limit water usage). Irrigation is expected to require lower effective concentrations of ethanol (less than 1 %) than spraying (2 to 10 %). This compound is very inexpensive, provided it is subject to little or no tax for these uses. Applications for approval will also be required. ■

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