EXTENDED ABSTRACT

Grapevine abiotic stress induce tolerance to bunch rot

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ABSTRACT

Context and purpose of the study – The effect of grapevine vegetative growth on bunch rot expression results from direct effects (cluster architecture, nitrogen status among others) and indirect ones (via microclimate). Previous studies of our group showed strong differences in bunch rot incidence between floor management treatments: under vine cover crop (CC) vs herbicide treatment (H).

Bunch rot incidence and severity were remarkably lower in CC compared to H treatment even when vegetative expression were comparable among treatments. We observe under some circumstances that water restriction during short periods pre-version period (below -0.9 MDSWP < 20 days) also reduce significatively bunch root incidence, even when vegetative expression, cluster compactness and fruit composition were comparable with plots, were associated with higher soil water holding capacity those threshold were never reached. The aim of the present study was to better understand the factors involved in this differential response observed.

Materials and methods – The experiment was conducted over 2020/21 growing season in southern Uruguay (34°44′ S, 56°13′ W). Plants of Vitis vinifera (Tannat), grafted on to SO4 rootstocks, grown in 100 L pots were used. The vines were trained on vertical shoot positioning system (VSP) located inside an experimental vineyard. We tested the effect and interactions of soil management treatments and grapevine water status (irrigation schedules) on grapevine tolerance to disease development. Treatments were arranged in a split-plot randomized block design with 6 replications, whit cover crop schemes as main plots and water availability during pre-veraison period as subplots. Cover crop treatment (CC), consisting of full cover of the plot soil with tall fescue versus bare soil (H). Supplementary irrigation was applied daily to maintain equal water status during the entire growing season regardless of soil management treatment. The same thresholds were used for water stress (WS) treatment except for the period of 20 days previous veraison where plants were not irrigated until reached 1.1 MPa MDSWP. To minimize effects of treatments related to vine vigor, treatments were arranged interspersed in the row and the "arms" of contiguous plants were overlapped.

Results – Bunch rot incidence and severity were remarkably lower in CC compared to H treatments while water restriction during perversion period also reduce significatively bunch root incidence. Interactions between soil management and irrigation treatments were detected. The results were consistently significant even when vegetative expressions cluster compactness and grape composition were comparable among treatments. Our experiment allows us to affirm that other factors besides vegetative expression/bunch compactness, and fruit zone environment, are playing an important role on disease development.

INTRODUCTION

Bunch rot occurrence is the most important limitation for the wine industry in humid environments. The effect of grapevine vegetative growth on bunch rot expression results from direct effects (cluster architecture, nitrogen status among others) and indirect ones (via microclimate) (Abad *et al.* 2021. Previous studies of our group showed strong differences in bunch rot incidence between floor management treatments: cover crop (CC) vs weed-free bare soil (Coniberti *et al.* 2018 and 2023). In both studies we observed that in some circumstances this reduction in bunch rot incidence occurred without major vine growth differences among treatments. We also observe under some circumstances that water restriction during short periods pre-version period (below -0.9 MDSWP < 20 days) also reduce significatively bunch root incidence, even when vegetative expression, PAR% at the fruit zone, cluster size and compactness and fruit composition were comparable among other treatments plots or blocks, were mostly associated with higher soil water holding capacity, those threshold were not reached (Coniberti *et al.* 2018). The aim of the present study was to test the general hypothesis that other factors (abiotic stress) unrelated to grapevine vegetative expression could be more relevant to grapevine susceptibility to bunch rot.

MATERIAL AND METHODS

Plant material, treatments and growing conditions

Materials and methods – The experiment was conducted over 2020/21 growing season in southern Uruguay (34°44′ S, 56°13′ W). A hundred ninety-two plants of Vitis vinifera (Tannat), grafted on to SO4 rootstocks, grown in 100 L pots with a mixture of compost and soil (30:70) were used. The four years old vines were trained on vertical shoot positioning system (VSP) in north-south oriented rows (0.6 × 2.8 m, vine (pot) × row spacing) located inside an experimental vineyard. The height of the cordon was 0.7 m, and the top of the canopy was approximately 2.1 m above the ground. At approximately 30 cm shoot length, all shoots not located on spurs and all unfertile shoots were removed. During the growing season, shoots were vertically positioned by hand ensuring homogeneous distribution of vine canopies. Catch wires were used to keep shoots in position. We tested the effect and interactions of soil management treatments and grapevine water status (irrigation schedules) on grapevine tolerance to disease development. Treatments were arranged in a split-plot randomized block design with 6 replications, whit cover crop schemes as main plots and water availability during pre-veraison period as subplots. We tested two treatments: Cover crop (CC), consisting of full cover of plot soil with Tall fescue (*Festuca arundinacea*) versus weed-free pots treated with herbicide (H). CC was established in March 2019 (seeding rate: 6 g/m2). Main plots, comprising 16 adjacent vines. Nitrogen was applied twice at a rate of 6 and 10 g per plot on H and CC treatments respectively when shoots reached approximately 30 cm and after fruit set. To avoid excessive vine-cover crop competition, the grass was maintained short (less than 5 cm) between both fertilization times. Supplementary irrigation was applied daily with drip emitters (4 L/hr emitters) located on each vine, to maintain equal water status during the entire growing season regardless of soil management treatment. A second line was used to add extra water on NWS treatment when needed. To ensure correct water distribution, spiders with 4 elbow mini stakes were used on each drip emitter. Irrigation thresholds in NWS treatment were −0.5 MPa until fruit set (stage 29; Eichhorn and Lorenz, 1977), −0.6 MPa from fruit set to veraison (stage 35; Eichhorn and Lorenz, 1977) and −0.8 MPa from veraison to harvest. Midday stem water potential (Ψstem) was measured from approximately 40 days after bud-break until harvest (~bi-weekly) between 14:00 and 16:00 h using a leaf pressure chamber (Soil Moisture Equipment Corp., Santa Barbara, CA) on one leave per plant (Allen *et al*. 1998). The same thresholds were used for water stress (WS) treatment except for a period of 20 days previous veraison starting on stage 32 - Eichhorn and Lorenz, 1977, where plants were not irrigated until reached 1.1 MPa MDSWP. To minimize effects of irrigation treatments related to vine vigor and cluster zone aeration (usually observed in soil management experiments), irrigation treatments were arranged interspersed in the row and the "arms" of contiguous plants were overlapped. To minimize differences of canopy exposure among vines, in half of the vines the pruning canes were tied to the face exposed to the east and the others to the west face. To avoid possible effects of excessive canopy shade reducing bud fertility, plants were maintained in the same vineyard but 1.2 m apart until the end of the previous season of evaluation. In Figure 1 vine arrangements in main experimental plots is presented.

Harvest and vegetative growth measurements

All treatments were harvested on the same date. The percentage of bunches infected by Botrytis bunch rot (incidence) as well as the percentage of each bunch that was infected (severity) was determined by visual inspection using a seven-point scale (0, 5, 15, 25, 50, 75 and 100%). Botrytis severity (S) was calculated as follows: $S = \Sigma\ Si/n$; where Si = % severity for the i-th bunch and n= the total number of affected bunches. During harvest, every cluster from de experiment was characterized by its compactness, bunch rot incidence and severity. Bunch compactness was rated by visual inspection according to OIV descriptor No 204 (O.I.V., 2007) by two experienced judges to reduce subjectivity. This descriptor categorizes a bunch under 9 categories, based on the number of visible pedicels and the mobility of the berries. The strong correlation between the average value assigned for each judge and the Bunch compactness index (Bunch weight (g)/[Rachis length (cm) + First ramification length (cm)] (Fermaud 1998)), was presented in previous studies of our group (Coniberti *et al*. 2023). Total fruit yield and clusters per vine were determined for each plant. Mean cluster weight and compactness index was calculated. Berry weight, total soluble solids (TSS), titratable acidity (TA), pH and free amino nitrogen (YAN) were analyzed (OIV, 2009). Leaf blade and petiole samples were taken for Nitrogen analysis at bloom and veraison, in every sub-plot. Pruning weight and number of shoots, were determined at pruning time on every vine. Before harvest, photosynthetically active radiation (PAR) available in the fruit zone, was estimated on individual vines with an average of two readings taken on each side of the canopy fruit zone, with the ceptometer (AccuPAR L80; Decagon Devices, Pullman, WA). Pruning weight/m of trellis as an index of canopy density was calculated for each vine (as a canopy density index), adding to the pruning weight of the "n" vine, the pruning weight of the portion of contiguous vines sharing the trellis (Pw/m = Pw (n vine) + (n-1 vine) + (n+1 vine). All measurements were averaged by treatment.

Statistics

A split-plot ANOVA was used to analyze the significance of treatments' main effects and their interactions using INFOSTAT free software (Di Rienzo *et al*. 2011). The fixed effects of the model were under-trellis ground cover (Herbicide vs. Cover crop), irrigation (NWS and WS) and their interactions; the random effects were block interactions with main effects. Bunch rot incidence and severity variables were transformed (square-root) to fit a normal distribution. A Tukey's HSD test (5% significance level) was used to compare treatment means.

RESULTS AND DISCUSSION

Bunch rot incidence and severity were remarkably lower in CC compared to H treatments even when vegetative expression (Vine PW, PW/m), PAR% at the fruit zone, cluster size and compactness and fruit composition (TSS, titratable acidity, pH) were comparable among treatments (H vs CC) (Table 1). Abad *et al*. (2021), in a systematic review of the implications of cover crops on vineyard agronomic performance in viticulture report that in most studies, Botrytis incidence on cover-cropped vineyards, resulted in no change or in a significant reduction of the disease. These results were generally linked to a reduction in grapevine vegetative growth. Other authors (Jacometti *et al*. 2007) attribute the reduction of Botrytis cinerea severity observed in cover crops treatments to a higher rate of biological activity, increased vine debris degradation and the reduction of primary inoculum compared to bare soil. However, in previous conducted by our group using similar experimental design but were plants form different soil management treatments (CC and H) were arranged interspersed in the row and the "arms" of contiguous plants were overlapped strong differences on cluster diseases were detected when no differences in primarily inoculum should be expected (Coniberti et. al. 2023). Guilpart *et al*. (2017) concluded that to water stress at flowering had a direct effect on reducing grapevine susceptibility to Botrytis, effect linked to plant growth. In this study, berry weight was also affected, what may reduce cluster compactness and could affect disease development. In our study "water stress (-1.1 MPa MDSWP) was applied later in season for a relatively short period of time (20 days period starting on stage 32 - Eichhorn and Lorenz, 1977) with no significant effect on berry size and cluster size or compactness. Nevertheless, in our study significant effects on bunch disease development were detected between water management treatments when no effect on cluster architecture or vine vigor was detected. On the other hand, our experimental design allows us to compare the effect of two irrigation treatments (water status), when clusters from both treatments shared the exact same environment, minimizing also the effect of other factors such as primarily inoculum or microclimate. That suggests that even though all these factors may have a significant effect on bunch rot, our study suggests abiotic stress (cover crop competition and/or water stress and its interactions) could play an important role in the induced tolerance to diseases in grapevines. On the other hand, although no significant differences were detected in leaf nitrogen content or vine growth development, the potential effect of the lower YAN content observed in CC treatment can't be discarded. However, previous studies suggest that these slight YAN differences observed in grapes, may not explain by themselves the major variation of bunch rot development observed in this study (Mundy and Beresford 2007, Coniberti *et al*. 2018).

CONCLUSIONS

Our results do not allow us to identify the specific mechanism by which soil management (CC) and water stress, and its interaction, induced grapevines tolerance to bunch rot. However, it is possible to affirm that other factors besides vegetative expression/bunch compactness, primarily inoculum and fruit zone environment, are playing an important role on disease development.

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TABLE AND FIGURE

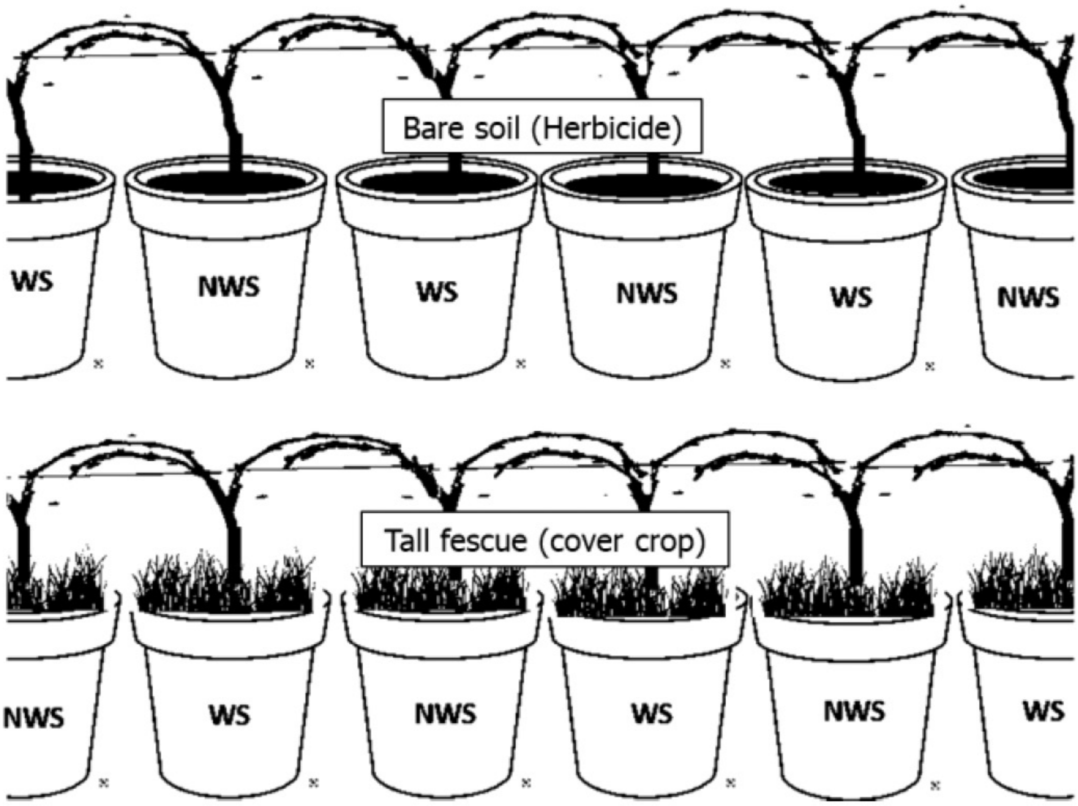

Figure 1. Experimental design (treatments distribution).

Table 1. Canopy characteristics and fruit composition of *Vitis vinifera* (Tannat) grapevines as affected by soil management and irrigation treatments.

Soil management and irrigation treatments							
Soil treatments	**Herbicide**		**Cover crop**		**Statistical significance**		
Irrigation treatments	**NWS**	**WS**	**NWS**	**WS**	**Soil (S)**	**Water (W)**	**S*W**
Canopy characteristics and fruit yields							
Berry w. (g)	1.53	1.50	1.51	1.51	ns	ns	ns
Cluster w, (g)	227	229	244	239	ns	ns	ns
Cluster CI	4.63	4.51	4.64	4.47	ns	ns	ns
Yield (kg)	2.84	2.84	2.81	2.56	ns	ns	ns
Pw (kg)	0.36	0.34	0.33	0.32	ns	0.09	ns
Pw/m (kg)	0.58	0.58	0.54	0.54	ns	ns	ns
PAR (%)	4.6	4.6	4.9	4.9	ns	ns	ns
Fruit composition							
Brix	23.5	23.6	23.6	23.6	ns	ns	Ns
pH	3.54	3.62	3.58	3.60	ns	ns	ns
T acidity (g/L)	6.57	6.48	6.68	6.50	ns	ns	ns
YAN (mg/L)	124 a	115 ab	119 ab	110 b	<0.05	<0.07	<0.05
Bunch rot							
Incidence (%)	71.9 a	64.9 b	47.6 c	34.1 d	<0.001	<0.05	<0.01
Severity (%)	26.7 a	19.7 b	11.6 c	7.7 d	<0.001	<0.01	ns

Cover crop: complete floor cover with tall Fescue; NWS: No water stress treatment; WS: Water stress treatment; Cluster w.: Cluster weight; Pw: Pruning weight; Pw/m: Pruning weight per meter of trellis; PAR: photosynthetic active radiation received in the fruit zone; T. acidity: Titratable acidity; YAN: must free amino nitrogen, Cluster CI: Cluster compactness index OIV descriptor No 204 (O.I.V., 2007). Botrytis bunch rot severity was determined by visual inspection using a seven-point scale (0, 5, 15, 25, 50, 75 and 100%). Botrytis severity was calculated as follows: $S = \Sigma Si/n$; where Si = % severity for the i-th bunch and n = the total number of affected bunches. Values with different letters in single rows are significantly different at $p < 0.05$.