Università degli Studi della Campania Luigi Vanvitelli

Ecophysiological and mechanistic post-fire strategies of *Pinus pinaster* Aiton growing in an area prone to multi-stress conditions.

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RESEARCH CONTEXT AND EXPERIMENTAL AREA

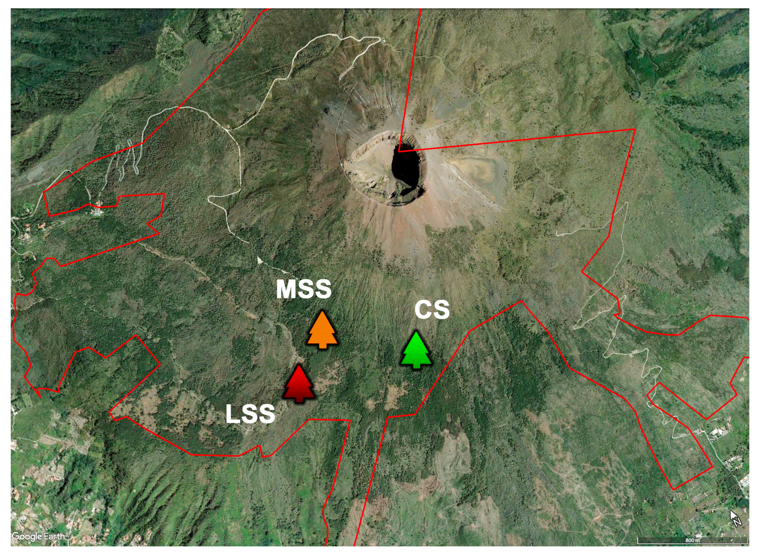

Fig. 1 – Study site inside of Vesuvius Park Reserve

Climate changes favor the ignition of large wildfires causing decline in tree growth and mortality. Although trees are often able to survive, partial injuries, such as crown defoliation, could compromise their physiology and resilience amplifying pre-existing climatic/site-specific stresses. Our research aim to characterize the resilience of *Pinus pinaster* Aiton plantations located in the Vesuvius National Park, an area of southern Italy, affected by a large wildfire in 2017 (Niccoli et al., 2019), which determined a severe defoliation of burned trees (50% in 2020). We selected different study sites (Fig.1) along a wildfire severity gradient, control (CS) low (LSS) and medium (MSS), in which we analyzed for the post-fire years (2017-2020) tree growth and their water use efficiency, foliar traits and nutrients content of needles, as well as the forest soil properties.

TREE-RINGS STUDY

To perform dendro-anatomical and isotopic analyses in the tree-rings, wood-cores were collected from 15 dominant trees of the 3 study sites. Standardized dendrochronological data show that trees at the burned versus control sites in the post fire years had steadily lower growth rates, in particular for MSS (Fig.2). The analyses of the wood anatomy revealed evidence of a lower carbon allocation to growth in burned stands: their cumulative cell wall area was significantly lower than that found in control trees suggesting a lower photosynthesis capacity due to the strong defoliation (Fig.3). Finally, based on wood isotopic data, the intrinsic water use efficiency (WUEi) in the burnt versus control sites decreased (Fig.4), highlighting higher transpiration costs for the assimilated carbon (Farquhar et al., 1982).

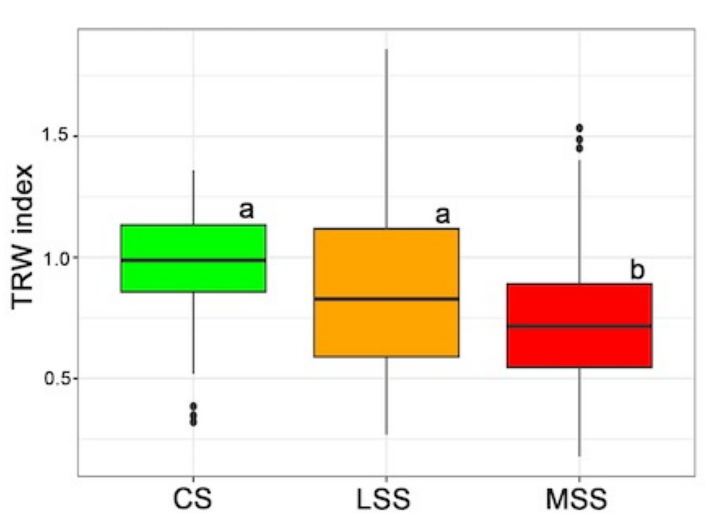

Fig. 2 Tree-growth

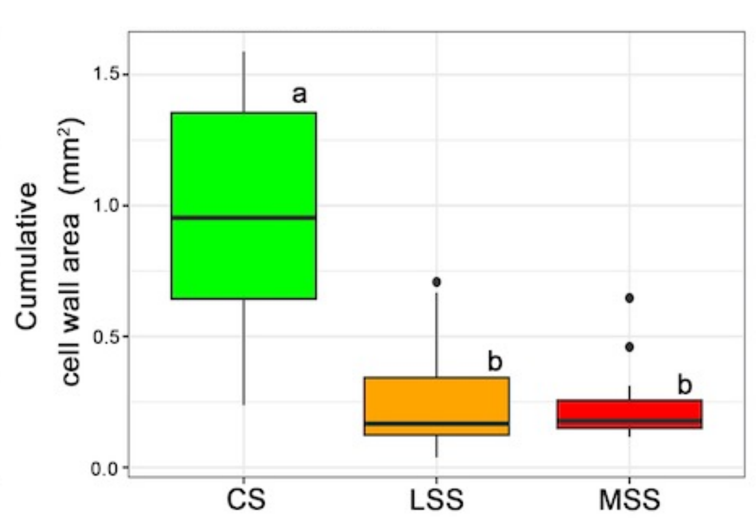

Fig. 3 Cumulative cell wall area

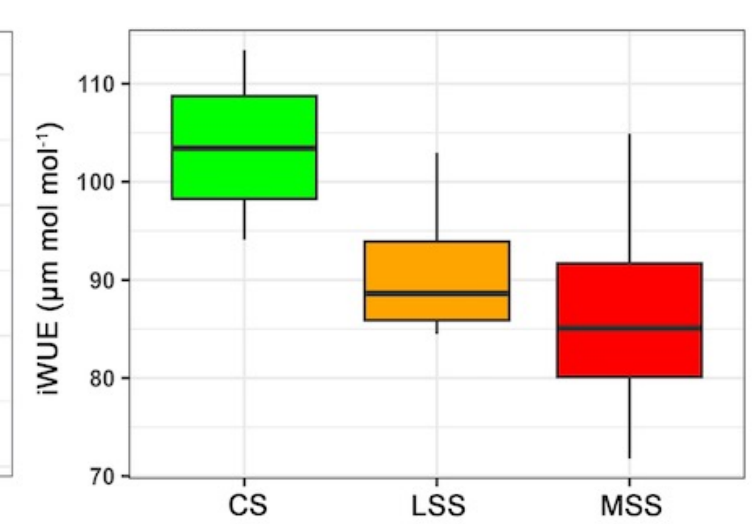

Fig. 4 Trees' Intrinsic water use efficiency

FOLIAR TRAITS AND NUTRIENT ANALYSIS

The morpho-anatomical traits in the last four shoot and needle increments (2017-2020), together with needle macro- and micro-nutrients, were assessed in branches sampled in the top crown of 10 dominant trees at each study site. At burned sites, the trees responded to wildfire forming longer (Fig.5) and weighty (Fig. 6) needles than CS.

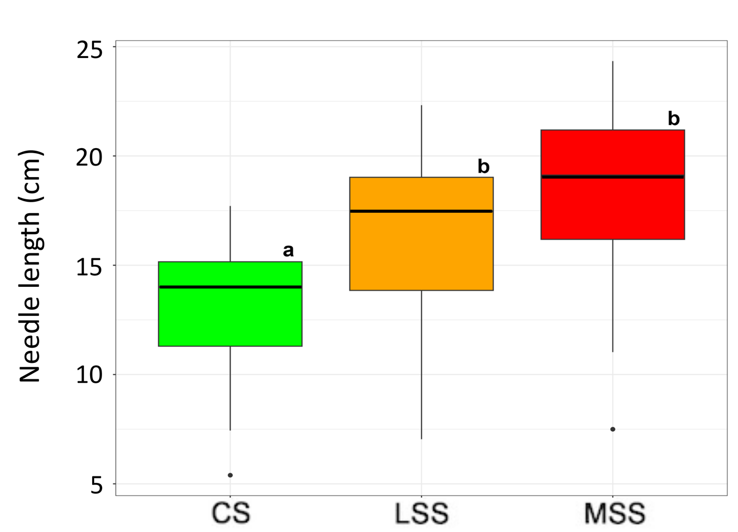

Fig. 5 Needle length

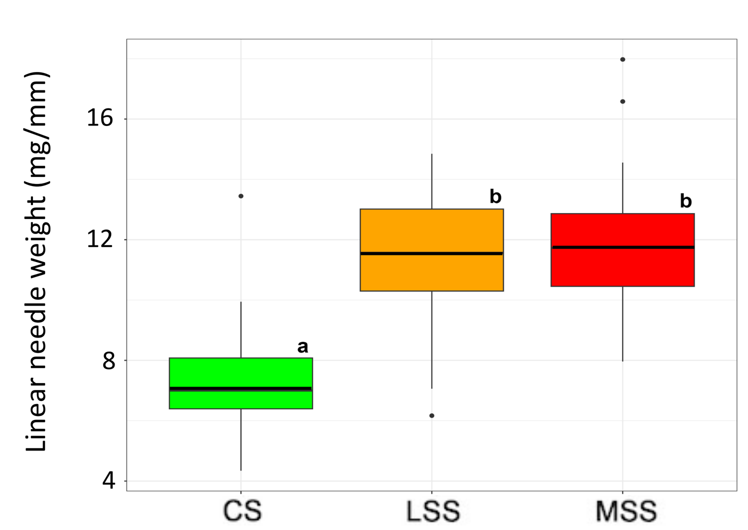

Fig. 6 Linear needle weight

This new foliage was also more defensive, as indicated by increased amounts of resin ducts (results not shown). These findings suggest a resilience strategy after major disturbance, to counteract assimilation decreases in consequence of severe defoliation, following the 2017 wildfire.

The needle nutrient content indicated severe deficiencies of several main macro- and micro-nutrients in the Vesuvius pine stands (especially N, P, K; Tab.1). The poor nutritional status of pine foliage was further worsened by toxic Al concentrations (Rout et al, 2001). Overall, these results indicated for all sites pre-existing nutritional deficiencies, also underlining how the forest-fire did not favor the release of the missing nutrients.

		Measured average	Average sufficiency	Toxicity
Macronutrients	N	0.94 %	1.5 %	NA
	P	824.7	2,000	10,000
	K	4,190	10,000	NA
	Ca	2,527.5	5,000	NA
	Mg	1,368.1	2,000	15,000
	S	1,094.2	1,000	NA
Micronutrients	Na	464.64	NA	NA
	Mn	28.82	50	200-5,300
	B	32.01	20	400
	Fe	66.39	100	500
	Al	63.86	NA	30
	Zn	16.8	20	> 300

Tab 1 – Needles nutrients. In yellow the values below the sufficiency threshold, in red the values above the limit of toxicity

SOIL CHARACTERIZATION

Treatment	Depth (cm)	LOI (%)	CEC (meq/100 g)	TOC (%)
CS	0-2	NA	NA	4.15±3.88ab
	2-8	3.58±1.87a	3.32±2.46b	0.94±0.64bcd
	13-20	1.19±0.40a	1.81±0.60c	0.45±0.14d
LSS	0-2	NA	NA	3.78±1.82abc
	2-8	3.32±0.82a	3.15±1.28b	0.78±0.42cd
	13-20	0.95±0.13a	1.78±0.62c	0.32±0.08d
MSS	0-2	NA	NA	5.32±2.70a
	2-8	5.18±1.77a	4.35±1.12a	0.91±0.31bcd
	13-20	1.41±0.58a	2.80±1.38b	0.52±0.29d

Table 2 Summary of soil analysis

Fig. 7 Top soil profile for each sites

For each site, five soil samples were collected at different depths to determine Loss on ignition (LOI), Exchange capacity (CEC) and Total organic carbon (TOC) (Tab.2). LOI was similar for all depths and sites, while CEC showed low values at all depths with no effect on sites. Only TOC showed a large difference between depths: the surface horizons had the most carbon content. Therefore, our results indicated that the nutrient pool was restricted to the upper soil horizons. However, the top soil profile (Fig.7) shows that in LSS and MSS under the litter there was a layer made up of charcoal, highlighting that nutrient pool was destroyed compromising the resilience of burned trees in the years after fire.

RESULTS SYNTHESIS AND CONCLUSIONS

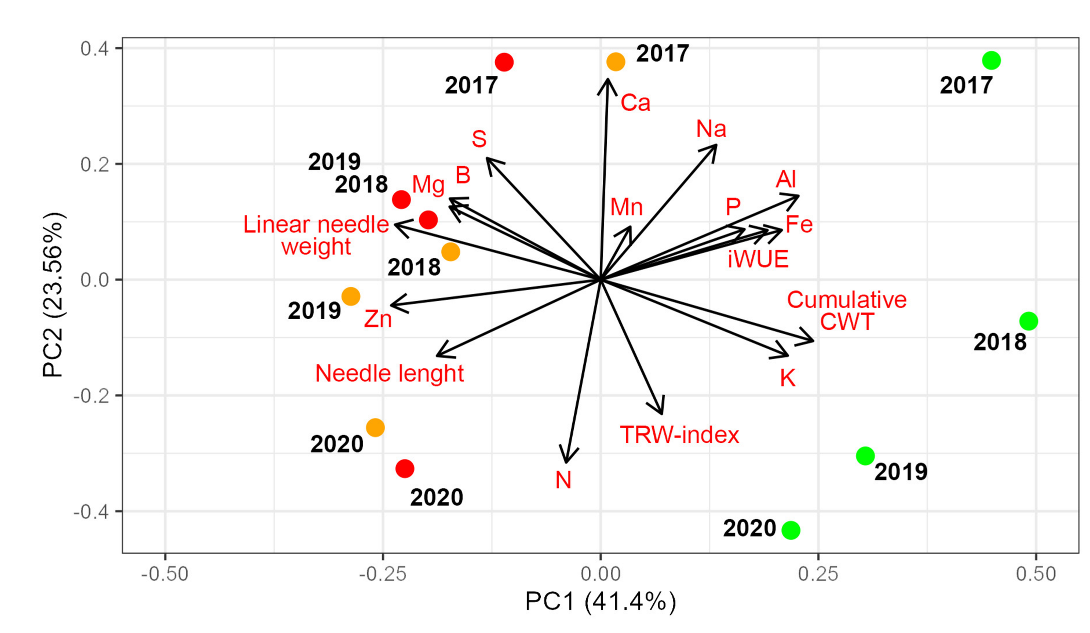

Fig. 8 PCA using tree-rings and needles data

Multivariate analysis (PCA) performed using tree-rings and needle data (Fig.8) showed that the wildfire effects (PC1, 41.4%) and time (PC2 23.6%) formed the main sources of variation, with a cumulated share of total variation reaching 65%. Negative correlations between the cumulative cell wall thickness and the needle linear weight were suggestive of carbon starving in stem tissues because of carbon allocation in foliage. Other negative correlations, such as that between the needle length and water use efficiency measured in stem, were suggestive of higher transpiration rates, despite the enhanced needle xeromorphy.

Our results suggest that although burned trees adopted mechanistic and physiological strategies to survive in the post-fire years, they are unlikely to recover their previous growth performances, due to the synergistic effects of various stressors: poor pre-existing nutritional conditions, consumption of nutrient pool in the soil, and scarce carbon allocation to growth.

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ABSTRACT ID

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