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Impact of the Dry Cone Syndrome on commercial kernel yield of stone pine cones

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Abstract. The economic relevance of Mediterranean stone pine is based on the harvest of its cones for extracting the edible Mediterranean pine nuts kernels. Recently, a severe loss of kernel-per-cone yield has been reported from cone processing industries: up to half of the extracted seeds are empty or contain only withered remains of the kernel. Additionally, a high percentage of small unripe conelets abort before maturity. The coincident emergence of both phenomena in several countries has coined the common name *Dry Cone Syndrome* (*DCS*). *DCS* has spread out all over the Mediterranean range of stone pine in the last four years, after first reports from Italy ten years ago. If persisting, *DCS* is regarded as a serious threat for commercial pine nut harvesting, an activity essential for the economic sustainability of Mediterranean pine forests and plantations, as well as for the cone processing industry in Europe, with a market of several hundred million euros annually. Cone processors surveys and reports in the framework of the stone pine group within the FAO-CIHEAM Network on Nuts have allowed plotting the spread of the syndrome throughout the Mediterranean, and its comparison with the invasion of Europe by the exotic seed bug *Leptoglossus occidentalis*, a seed-feeding pests known to produce analogous damages in more than 40 conifer species in the Northern America and Europe.

Keywords. *Pinus pinea* – Processor industry survey – Kernel yield loss – *Leptoglossus occidentalis.*

I – Introduction

Mediterranean stone pine, *Pinus pinea* L., is a characteristic tree of most Mediterranean countries. The economic relevance of its forests and plantations is based on the harvest of its cones for extracting the edible Mediterranean pine nuts kernels (Mutke *et al*., 2012, 2013). But in the last years, a severe loss of kernel-per-cone yield has been reported by processing industries for stone pine cones collected in all main producing countries, namely Portugal, Spain, Italy, Morocco, Turkey and Lebanon: when cracking apparently sane cones, up to half of the seeds are empty or contain only withered remains of the kernel. Additionally, cone pickers have also been observing in the pine crowns a high percentage of small unripe conelets aborted before maturity, decreasing the final number of harvested cones.

The recent coincidence of both phenomena has coined the common name *Dry Cone Syndrome* (*DCS*), suggesting a possible common agent. Awareness has grown about the emergence of *DCS* all over the Mediterranean range of stone pine only in the last four years, after first alarms from Italy ten years ago. Since 2011, the subnetwork for stone pine within the FAO-CIHEAM Network on Nuts has been gathering this information from its members, though local incidence might actually have started several years before awareness rose (Fig. 1). *DCS*, if persisting, is regarded as a serious threat for commercial pine nut harvesting, an activity essential for economic sustainability of Mediterranean pine forests and for cone processing industries, with a market exceeding 200 million euros annually (INC, 2016; Santos, 2015; Sattout, 2016).

Generalised awareness up to alarm in the sector has contrasted with the lack of official data to back up the severity of the problem. Though statistics of non-wood forest products are published by ministries of agriculture in several countries, data are often mere estimates for actual amount of annual crops, based on processing industries' declarations or extrapolated from public forests, lacking detailed information from private forests which prevail widely e.g. in Spain or Portugal. Small private forest owners, as well as cone pickers and first processors which are as mostly self-employed workers or small family enterprises, are for fiscal reasons quite reluctant to declare their actual turnovers and revenues to third parties, and traceability systems have been built only few years ago and are not yet fully implemented and fulfilled, persisting hence a significant informal sector. Also in Turkey, small-sized private plantations exceed widely public forests, 132,000 ha versus less than 60,000 ha state forests that give the published annual yield series (Can, 2016).

National import-export data are not sound either, because statistics codes under TARIC or Combined Nomenclature subsume within the same code NC 0802 90 50 any kind of '*pine nuts, fresh or dried, whether or not shelled*'. From average prices it can be deduced that data for shelled kernel (25-45 €/kg), pine nuts in shell (2-5 €/kg) and even cones (less than 1 €/kg) are completely mingled. E.g., part of export from Portugal to Spain has been in form of unprocessed cones, not pine nuts, and hence adds to apparently "Spanish" pine nut kernel production (re)-exported. Moreover, code NC 0802 90 50 doesn't even allow for distinction between Mediterranean pine nuts (*Pinus pinea*) and imports of lower-priced seeds of other, Asiatic pine species, such as *P. koraiensis*, *P. sibirica* or *P. gerardiana*, whose global trade volumes exceed the genuine Mediterranean pine nuts widely (Pastor, 2014; Agri-Ciência, 2014).

In this context, the primary source for raw data would be the cone pickers and processors that trace usually the geographic origin of different incoming cone lots, as well as the final pine nut and kernel yields obtained from each lot. Especially cooperatives as next-level corporations are disposed for more transparency and less secretiveness than individual self-employed or family-based enterprises.

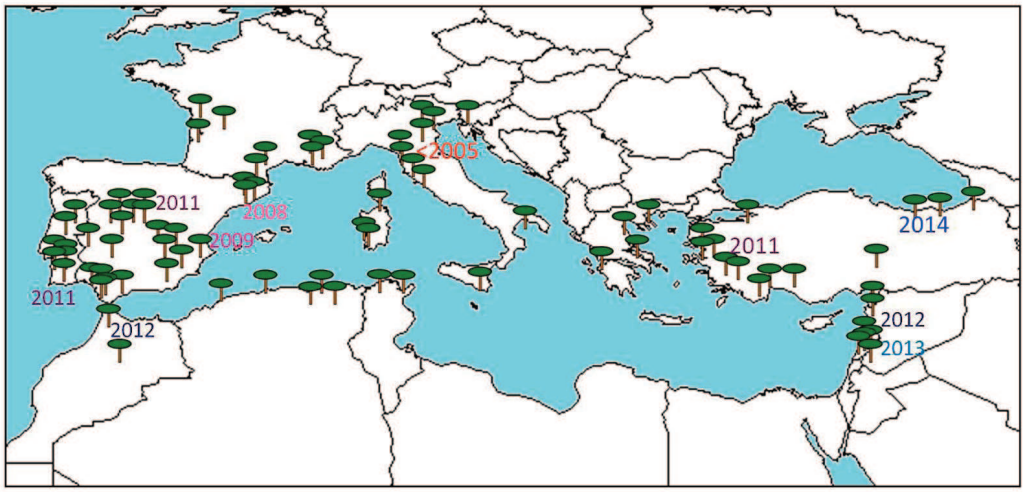

Fig. 1. Distribution of stone pine, and year of first regional report of *Dry Cone Syndrome*.

II – Materials and methods

In 2014, a first survey of cone processing industries about the seed and kernel-per-cone yield had produced a short dataset (Mutke *et al.*, 2014), which has now been updated and enlarged, in order to assess the impact of DCS on the pine nut sector in Mediterranean countries. Nevertheless, the quoted lack of transparency and traceability of the regional, national and international pine nut supply chains has resulted in a short number of responses from cone processors, with regional seed-per cone and kernel-per cone yields data from only four Spanish and two Portuguese processors or processor cooperatives, though their cone supply spans a wide geographic range and includes all relevant stone pine growing areas on the Iberian peninsula, namely Castilla y León, Madrid, Castilla-La Mancha, Catalonia, Andalusia, and Portugal. The Lebanese Pine Farmers Association *Nakabet al Farratin* has contributed with yield series of 23 forest management units (FMU), 15 FMU in Baabda district, and 8 FMU in Jezzine district, reported by 15 forest owners who harvest and process their own cones and have registered the proportion of empty seeds in the last 7 years.

III – Results

Available time series of seed per cone yield data from Iberian cone processors showed that average pine nut per cone weight yield has dropped from a stable yield of 17 (16.9-17.5)% before 2010 to 5-12% since 2012, except the single preliminary value from the currently processed yield, 14.7% (Fig. 2). Average kernel per cone weight yield has decreased from stable 3.8 (3.6-4.1)% before 2008 to 2.2-2.8% since 2011 (Fig. 3). Unusual increases in percentage of empty or internally damaged among normal-sized seeds were specified as main reason: historic values were less than 10%, but currently proportions of 30-50% are observed. The same increase of empty seed proportion has been observed in the Lebanese data series, interestingly with a one-year delay between the two pine forest clusters of the country, Baabda and Jezzine, 40 km south, were incidence of DCS has rocketed only last year (Fig. 4).

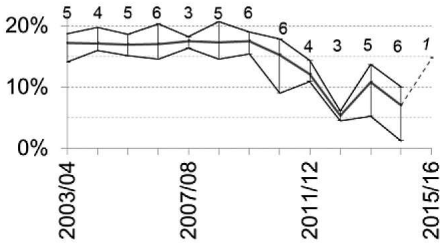

Fig. 2. Annual range and average of pine nut yields in *Pinus pinea* cones from Spain and Portugal [kg seed in shell per kg cones, n 3-6 per year, but only 1 preliminary value in 2015/2016].

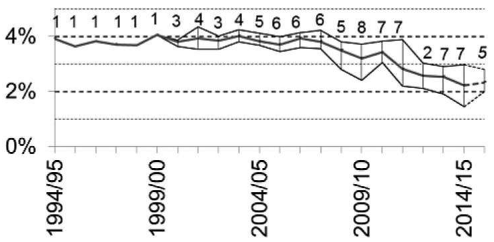

Fig. 3. Annual range and average of pine nut kernel yields in *Pinus pinea* cones from Spain and Portugal [kg kernel per kg cones, n 3-8 per year; 2015/2016 preliminary data].

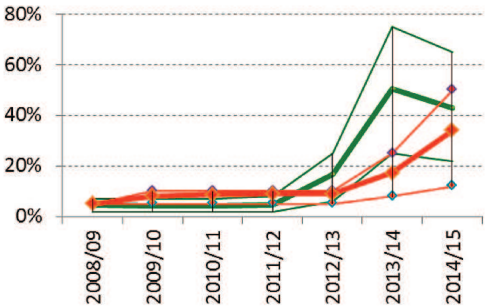

Fig. 4. Annual range and average percentage of empty seeds in *Pinus pinea* cones from Central (green) and South Lebanon (red, diamonds) [% of total seeds; n 16-23 per year].

IV – Discussion

The data reported by cone processors are showing diminishing kernel yields in the last 5 years in cones from Spain and Portugal, the last 2-3 years in Lebanon. These results confirm oral information and published data by colleagues of FAO/CIHEAM Research Network on Nuts and other researchers from all relevant pine nut producing countries (Tiberi, 2007; Bracalini *et al.*, 2013; Calama *et al*., 2016; Can, 2016; Parlak, 2016; Ponce *et al*., 2016) that reflect the spread and prevalence of *DCS* reaching opposite edges of the Mediterranean. Especially interesting is the fine-scale differentiation between the two stone pine areas in Lebanon with a delay in arrival of the syndrome; this suggests the spread of a biotic causal agent, the same as the great picture between countries from Italy outwards (Fig. 1). Putative alternatives like climate factors (for instance, increasing droughts) would not have produced this *"contagious"* pattern.

Not surprisingly, there is an invasive exotic cone pest, the Western Conifer Seed Bug *Leptoglossus occidentalis* of North American origin, pinpointed as putative causal agent of *DCS* as it has been spreading parallelly over Mediterranean and the rest of Europe after its first introduction in Italy in 1999 (Taylor *et al.*, 2001). In 2003, the pest has been first recorded in Spain, probably followed by other introduction events, in 2009 in Turkey and in 2010 in Portugal, although usually it takes a certain time for detecting an alien species because the invasion period takes place before the population densities increase to a critical level causing apparent harm (Fent and Kment, 2011). Types of damages observed in stone pine cones and seeds reported from processing industries do coincide with the whole range of damages caused by *Leptoglossus occ.* feeding on cones of conifers in Europe and Northern America, namely conelet abortion, normal-sized cones with high proportion of fused or aborted seeds, or normal-sized but empty or only partially filled seeds (cf. Strong *et al*., 2001; Bates *et al*. 2002; Strong 2006; Lesieur *et al*., 2014; Boivin and Davi, 2016).

The economic relevance of this problem in Mediterranean stone pine is overwhelming: Formerly, 1 kg of kernel was obtained from 25 kg cones (4%), now about 40 kg cones are necessary for yielding the same amount of kernels (2.5%). Moreover, due to the shortage, cone prices paid to forest owners have increased (Calado, 2012) and profitability of cone processing is jeopardised, pine nut value chain facing a very difficult situation if the syndrome persists.

V – Conclusions

Stone pine cone processors surveys from Portugal, Spain and Lebanon have confirmed a severe decrease of kernel-per-cone weight yield the last years, due to a high proportion of empty seeds or damaged kernels within the cones. These kind of damages observed in factory, together with the general shortage of harvested cones due to massive conelet abortions before ripening, are known as *Dry Cone Syndrome*, reported also from Italy and Turkey.

Observed damages are plainly compatible with the kinds of damage caused by the *L. occidentalis*, confirmed by feeding experiments on caged bugs (Calama *et al*., 2016; Ponce *et al.*, 2016). The prevalent causality of *Leptoglossus* as main biotic agent, however, or possible implications of increasing draughts and phenological shifts due to climatic change (Mutke *et al.*, 2005; Calama *et al.*, 2011) or pathogen fungi like *Diplodia* sp. (Luchi *et al.*, 2011), must be elucidated by ongoing research.

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