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Combined use of mowing and chemical control for the efficient control of the noxious invasive species *Typha* spp.

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Abstract

Changes in weed communities due to changes of climate and agricultural practices have already been indicated. Cattail (*Typha* spp.) is considered as a noxious invasive species with an increasing dispersal in Greece and other countries, where it starts to become a serious problem particularly in wet areas and especially for perennial crops. Pot and field experiments were conducted in order to evaluate the efficacy of several herbicides and mowing against cattail. The results of the present study revealed the low efficacy of several herbicides (like imazamox, 2,4-D and MCPA) against *Typha* spp. plants. On the other hand, pot experiments showed that especially glufosinate and glyphosate (in high rate) killed the majority of cattail plants grown by rhizomes. Moreover, they key result of our field experiment is the strong indication of a synergistic action of mowing and chemical control, especially in the case of glufosinate and glyphosate. The case of *Typha* spp. confirms that the integration of several control methods and agronomic practices may ensure an efficient, long-term management of noxious and invasive weeds.

Keywords: *Typha* spp., Invasive, Management, Mowing, Herbicides

Introduction

Plant invasions have received global attention due to the environmental problems and economic costs that may cause (Richardson et al., 2000). These plants have often the potential to become competititve and noxious weeds and pose long-term problems for agriculture and natural environments (Westbrooks, 1991). Most invasive species are characterized by high growth rates, rapid and massive reproduction, high dispersal ability, phenotypic plasticity, high competitiveness and adaptability and tolerance of a wide range of environmental conditions (Bazzaz et al., 1986; Brunel, 2005). Early detection and rapid response to invasive species is viewed as the most economically efficient and ecologically effective approach (Hobbs and Humphries, 1995).

Typha is a genus with more than 30 species and hybrids, belonging to the family Typhaceae. Cattail species are aquatic or semi-aquatic herbaceous, rhizomatous, perennial plants which can be found as dominant competitors in wetland ecosystems in various environments both in Northern and Southern hemisphere (Ciotir et al., 2017). They are obligate wetland indicator plant species, which tolerate perennial flooding and moderate salinity. These characteristics, plus the rhizomatous expansion, are also responsible for species high capacity for colonization and formation of dense patches, resulting to monospecific dominance events (Bansal et al., 2019). Among the most common cattail species are *Typha latifolia* (broadleaf cattail) and *T. angustifolia* (narrow-leaf cattail); while lately *Typha x glauca* is also widely spread in North America (Ciotir et al., 2017; Pieper et al., 2018).

In general, *Typha* spp. is not a major weed problem in large scale agricultural systems (Bansal et al., 2019). However, maintenance and interspersion of *Typha* plants can lead to economic losses and reduced yield in several crops, both annual and perennial. The biological characteristics of *Typha* is the cause of this result, because this species forms dense patches in the invaded areas and acts as roost site for some

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animals and birds. Linz and Homan (2011) reviewed the effects to sunflower production by the presence of blackbirds in North & South Dakota, U.S, in hybrid cattail (*T. x glauca*) dominated wetlands. Another study from Leitch et al. (1997) showed that farmers may observe >15% losses in the presence of birds and roost zones of *Typha* just 3 km away from their fields.

During the last years, there have been complaints from several regions of Greece for reduced efficacy of herbicides or increased competitiveness of many recently problematic species (Travlos and Chachalis, 2010; Travlos 2013). *Typha* spp. is one of these species, which has an ongoing spread in Greece and especially during the last decade it tends to be an agronomic problem for several perennial crops (olives, citrus etc), usually forming dense monocultures. The management of *Typha* species is considered to be very difficult (Bonanno and Cirelli, 2017). The individual characteristics of cattail spreading by rhizomes makes the management with mechanical methods of this species expensive and usually insufficient, while herbicides often fail to control this weed (Kanatas, unpublished data). The present study was conducted because of the increasing dispersal and the many reports in Greece of *Typha* spp. becoming increasingly difficult to control with mechanical or chemical methods. The main objectives of the present study were to evaluate the efficacy of several herbicides and to study the effect of mowing against cattail.

Materials and Methods

Pot experiments

Pot experiment was conducted at the Agricultural University of Athens (Greece) (Latitude: 37° 59' 1.70" N, Longitude: 23° 42' 7.04" E, Altitude: 30 m) during May-August 2019. Rootstocks and creeping rhizomes of *Typha sp.* from species dense stands were collected in mid-May 2018 from an olive orchard in western Greece (Fig 1). The propagating material was transferred to the laboratory of Agronomy in the Agricultural University of Athens, where a pot experiment was conducted. Plastic pots of 25 cm width and 25 cm depth were used. The pots were filled with clay loam soil from the specific olive orchard (Table 1). In each pot, two rhizomes were planted. The plant material was uniformly well-watered for a short period of 3 weeks, in order to have a vigorous and uniform growth of *Typha* spp.

At the height of 50-60 cm, the plants were sprayed with the herbicides described in Table 2 using a custom-built, compressed-air, low-pressure, flat-fan nozzle experimental sprayer, calibrated to deliver 300 L ha^{-1} at 250 kPa. The treatments were 6 (glyphosate at the recommended and double the recommended rate, imazamox, glufosinate, 2,4-D and MCPA) plus untreated control. Five replicates (pots) were used for each treatment. Survival of *Typha sp.* plants was recorded and dry biomass of the above-ground plant part was also measured (plants were oven-dried for 48 h at 70 ^{o}C) at 7, 21 and 35 days after treatment (DAT).

Field trial

In the olive orchard mentioned above a preliminary mowing experiment during summer of 2018 revealed the high regrowth capacity of *Typha* spp. after mowing (data not shown). Therefore, a field trial was conducted during summer of 2019 in order to evaluate the efficacy of the same herbicides tested in the pot experiments with or without a previous mowing treatment. Field experiment was arranged in a randomized block design with two factors, mowing (2 levels) and chemical control (7 levels, including the untreated control) and 3 replicates. The dimensions of each plot were 4 m x 1.5 m. Herbicides were applied with the same equipment as above and survival was recorded at 21 DAT.

Statistical analysis

For all the data, ANOVA was performed with Statistica 9.0 software package (StatSoft, Inc. 2300 East 14th Street, Tulsa, OK74104, USA). Mean comparison was performed using Student's least signification difference (LSD) test at $P < 0.05$, while all data were tested for normality and variance before further analyses.

Results and Discussion

In the pot experiment, survival and dry weight of cattail were measured at 7, 21 and 35 days after treatment (DAT). The results in Table 3 show that only glufosinate had a high efficacy even at 7 DAT, while glyphosate resulted in a survival reduction by 60 to 95% for the recommended and double the recommended rate, respectively. On the contrary, imazamox, 2,4-D and MCPA resulted in low efficacy against *Typha* spp. (survival ranged from 70 to 100% compared with the untreated control), while in some cases regrowth was obvious at 35 DAT (Table 3). In a previous study, Rodgers and Black (2012) showed that applications of imazamox at intermediate rates provided moderate control of cattail. Effects of the several herbicides on the biomass of cattail was also in full agreement with the previously mentioned effects on survival. Glufosinate and glyphosate in the high rate significantly reduced dry weight of sprayed *Typha* spp. plants (Table 4). This finding is in full accordance with previous studies, showing that chemical treatment with glyphosate is considered to be efficient, mostly in late summer when a carbohydrates storage in rhizomes occurs (Linz and Homan, 2011; Wilcox et al., 2018). Significant differences in the efficacy between several herbicides have been also reported by Enloe and Netherland (2017), who evaluated the efficacy of the herbicides clethodim, sethoxydim and fluazifop-P-butyl against aquatic native grasses, including broad-leaf cattail (*T. latifolia*). The biomass reduction of common cattail at 8 weeks after treatment with glyphosate (at a rate of 4.2 kg a.e. ha^{-1}) and imazapyr (at a rate of 1.4 kg a.i. ha^{-1}) was higher than 90% in both cases, in comparison with the three selective herbicides which did not provide sufficient control.

Field trial revealed the crucial role of the combined use of mowing accompanied by chemical weed control with specific herbicides, while other herbicides remained rather ineffective in both cases. In particular, none herbicide succeeded to adequately control *Typha* spp. without previous mowing. On the other hand, glufosinate and glyphosate applied during summer at 2-3 weeks after mowing resulted in efficacy up to 90% (Table 5). This finding reveals the important role of the age of leaves on the efficacy of herbicides against cattail (Lishawa et al., 2017) and it can plausibly attributed to the significantly lower absorption of the herbicides in the surface of the older and harded *Typha* spp. leaves. Lishawa et al. (2017) where among the first who attempted to address the control of *Typha x glauca*, when plants are in young age, in contrast to most techniques which aim to mature plants when the species is already dominant.

The findings of the present study are also in agreement with the study conducted by Wilcox et al. (2018), suggesting that cattail will resprout even after cutting, so combined treatments with cutting and secondary applications could suppress regrowth. In particular, they found that wicking in late summer of cattail ramets with glyphosate was the most effective treatment to reduce *Typha* cover. Therefore, the authors suggest mid-summer cutting of *Typha ramets* and after that late-summer herbicide wicking of resprouted stems. This is applicable in small scale, but other options which are not labor-intensive and cost-ineffective should also integrated. Among them, as our findings revealed, mowing followed by chemical control is a very good option for larger areas. Another beneficial effect of mowing and cutting is that they ensure the removal of aboveground biomass of cattail and the reduction of degradation process of *Typha* spp. plant tissues. It is noticeable that previous studies have shown that removal of *Typha* spp. aboveground biomass is recommended in highly productive areas or in constructed wetlands, in order to avoid the accumulation of organic matter after decomposition (Álvarez and Bécares, 2006; Vroom et al., 2018). Elgersma et al. (2017) results showed that in high-nutrient wetlands the most effective combination to manage cattail hybrid invasion was herbicide with burning, proposing that nutrient inputs in wetland ecosystems can improve management efforts. Johnson et al. (2019) reported that one year after mechanical harvesting of dominant clonal cattail, the light transmission increased due to the aboveground biomass removal, while a submerged harvest lead to soil nutrients increasing availability. Another study showed that aboveground harvesting of *T. x glauca* stems and litter lead to reduced litter 4 years after the removal (Keyport et al., 2019). Lawrence et al. (2016) reported that herbicide application of cattail with glyphosate significantly affected wetland dynamics, by reducing *Typha* biomass and abundance, enriched nutrient pool (NH^{4+}, N, P, K) and increased light penetration one year after treatment. Nevertheless, the chemical treatment lead to significant degradation of native plant richness.

It has to be noted that the excessive use of herbicides results in selection pressure over time which eliminates susceptible weeds and biotypes and thus causes evolutionary changes in weed communities. Such a typical example is the one of *Conyza* spp. which found “empty space” due to the high efficacy of glyphosate on the majority of weeds, progressively developed resistance to glyphosate, invaded orchards and vineyards and now is one of the most serious weed problems of perennial crops throughout the Mediterranean area (Travlos and Chachalis, 2010). Consequently, sometimes they key in the management of *Typha* spp. could be the utilization of this plant. For instance, Lawrence et al. (2016) suggested that combined treatment of biomass harvest and disking can add to cattail control and could be a positive economical perspective for farmers due to cattail biomass utilization as biofuel, while at the same time the native plant community will be boosted. Lishawa et al. (2019) suggested that restoration techniques of cattail dominant areas should focus on periodic treatments including biomass removal, in order to preserve the native biodiversity. Vroom et al. (2018) proposed that *T. latifolia* can be utilized for the restoration of peatlands after their rewetting, because of the species capacity to control nitrogen and phosphorus concentrations from surface and pore water, as well as regulate CH_4 and N_2O emissions. Nevertheless, the selection of cattail species for potential phytoremediation must be based upon the species invasiveness risk (Bonanno and Cirelli, 2017; Gikas et al., 2018). Comprehensive studies regarding utilization of *Typha* biofuel production after following harvesting of plants biomass have been extensively reviewed by Bansal et al. (2019).

Fig 1. Olive orchard with a heavy Typha spp. infestation in western Greece.

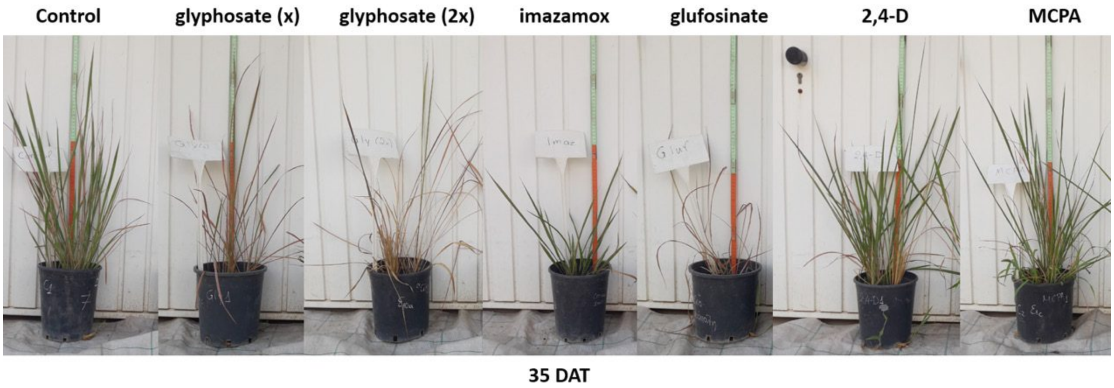

Fig 2. Efficacy of several herbicides against Typha spp. at 35 DAT.

Table 1. Soil texture and chemical components of used soil (in both pot and field experiments)

Parameter	Value
Clay (%)	31.1
Loam (%)	35.3
Sand (%)	33.6
pH (1:1 H_2O)	7.09
NO_3 (mg kg^{-1})	11.4
P (mg kg^{-1})	14.4
K (mg kg^{-1})	187
$CaCO_3$ (%)	14.61
Organic matter (%)	1.77

Table 2. Herbicide treatments and application rates

Active ingredient	Rate (kg a.i. or a.e. ha^{-1})
glyphosate (x)	3.24
glyphosate (2x)	6.48
imazamox	0.05
glufosinate	0.75
2,4-D	0.9
MCPA	1.6

Table 3. Survival of Typha sp. plants at 7, 21 and 35 days after treatment (DAT) in comparison to the untreated control

Treatment	Survival (% of the untreated control)		
	7 DAT	21 DAT	35 DAT
glyphosate (x)	40^{ab}	20^{b}	30^{b}
glyphosate (2x)	20^{b}	10^{b}	5^{b}
imazamox	80^{a}	80^{a}	100^{a}
glufosinate	0^{b}	0^{b}	10^{b}
2,4-D	100^{a}	80^{a}	100^{a}
MCPA	90^{a}	70^{a}	100^{a}

Values followed by different letter in the same column indicate significant differences (P<0.05) based on Student's test

Table 4. Dry weight (DW) of Typha sp. plants at 7, 21 and 35 days after treatment (DAT) in comparison to the untreated control

Treatment	DW (% of the untreated control)		
	7 DAT	21 DAT	35 DAT
glyphosate (x)	70^{ab}	40^{b}	50^{b}
glyphosate (2x)	40^{bc}	30^{b}	20^{c}
imazamox	70^{ab}	70^{a}	100^{a}
glufosinate	30^{c}	30^{b}	20^{c}
2,4-D	100^{a}	90^{a}	100^{a}
MCPA	80^{a}	80^{a}	100^{a}

Values followed by different letter in the same column indicate significant differences (P<0.05) based on Student's test

Table 5. Survival of Typha sp. plants at 21 days after treatment (DAT) in comparison to the untreated control with and without previous mowing

Treatment	Survival (% of the untreated control)	
	Without previous mowing	With previous mowing
glyphosate (x)	70[b]	30[b]
glyphosate (2x)	50[c]	10[b]
imazamox	90[a]	70[a]
glufosinate	50[c]	10[b]
2,4-D	100[a]	80[a]
MCPA	100[a]	70[a]

Values followed by different letter in the same column indicate significant differences ($P<0.05$) based on Student's test

Conclusions

The results of the present study revealed the low efficacy of several herbicides (like imazamox, 2,4-D and MCPA) against *Typha* spp. plants. On the other hand, our pot experiments showed that especially glufosinate and glyphosate (in high rate) killed the majority of cattail plants grown by rhizomes. Moreover, they key result of our field experiment is the strong indication of a synergistic action of mowing and chemical control, especially in the case of glufosinate and glyphosate. The case of *Typha* spp. confirms that the adaptation of an integrated approach that employs chemical methods along with other agronomic practices may ensure a long-term invasive weed management. Consequently, integrated management strategies are essential in order to prevent the introduction and further dispersal of noxious invasive weeds.

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