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The weed vegetation of the bean "Fagiolo Cannellino di Atina" and the red pepper "Peperone di Pontecorvo" PDO crops (Latium, central Italy)

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Abstract

The weed vegetation of the bean "Fagiolo Cannellino di Atina" (*Phaseolus vulgaris* L.) and the red pepper "Peperone di Pontecorvo" (*Capsicum annuum* L.) PDO (Protected Designation of Origin) crops was surveyed by means of 16 relevés, sampled in four farms of southern Latium during July 2019. The relevés were subjected to multivariate analysis, which revealed that the two crops are weeded by vegetation types referable to two different subassociations of *Panico-Polygonetum persicariae* (*Spergulo-Erodion*, *Eragrostietalia*, *Digitario-Eragrostietea)*. Namely, communities colonizing bean fields, which are more mesophilous and richer in Eurasian taxa, are ascribable to the subassociation *sorghetosum halepensis*. Communities colonizing red pepper fields, which are more thermophilous and richer in Mediterranean taxa, are ascribable to the subassociation *cyperetosum rotundi*. Floristic, structural, and chorological features of the communities are discussed in relation to environmental factors and agricultural management.

Keywords

Agroecosystems, Arable weeds, Bean, Biodiversity, *Digitario-Eragrostietea*, Phytosociology, Protected Designation of Origin, Red Pepper

Introduction

Plant species that grow in arable land are among the most characteristic elements of agroecosystems. They consist of pioneer, wide-ranging, mostly annual species (Holzner 1978, 1982). Due to the competition that they exert towards crops, the fight against plants spontaneously colonizing cultivated fields is as old as agriculture itself. Nevertheless, arable weeds have been acknowledged, in recent years, for the benefits they provide in agricultural ecosystems. In fact, their presence considerably increases the biodiversity of arable land, also by supporting pollinators and birds (Marshall et al. 2003; Storkey 2006; Petit et al. 2011; Bretagnolle and Gaba 2015).

Shifts from traditional, extensive to modern, intensive agriculture had a relevant negative impact on arable weed biodiversity in Europe, which suffered a decline in quantity and quality (Storkey et al. 2012; Richner et al. 2015). Arable weed communities suffered a decrease in species richness and a banalization of their floristic composition, through the increase in generalist taxa (Meyer et al. 2013; Arslan 2018; Fanfarillo et al. 2019a). This implied not only a decrease of environmental sustainability, but even troubles from an agronomic perspective. In fact, species-rich arable weed communities are less competitive and less harmful for the crop. The massive usage of herbicides and chemical fertilizers caused through the years the selection of few but very competitive species, which cause major damages to crops (Storkey and Neve 2018). Thus, the interest in the knowledge of arable weed vegetation considerably increased in the last years, both for agronomic and environmental reasons.

In climates with a cold season, the weed communities of summer crops are very different from those of winter crops. They include a much higher proportion of neophytes and cosmopolitan taxa (Lososová et al. 2004; Brullo and Guarino 2007; Abbate et al. 2013). In Italy, summer-annual crops like maize and sunflower are usually grown under intensive agriculture and host very impoverished weed communities, due to herbicide spraying (Fanfarillo et al. 2019a).

The Protected Designation of Origin (PDO) mark identifies a European product that only originates in a specific place and whose quality and features are due to a particular geographical environment, with its natural and human factors. The production, processing, and preparation of PDO products take place in a defined geographical area and are in line with the established production protocols (European Commission 2019). This makes PDO products emblematic of European traditional agriculture.

Latium region, in central Italy, hosts a high number of PDO products. The "Fagiolo Cannellino di Atina" (*Phaseolus vulgaris* L., bean) and "Peperone di Pontecorvo" (*Capsicum annuum* L., red pepper) obtained the PDO mark in 2010. Both of them are grown within a few hundreds of square kilometres in the Province of Frosinone, in the southern part of the region. Given the absence of information on the weed vegetation of PDO crops in Italy and the opportunity to study summer arable weed communities under traditional agricultural management provided by these two crops, we aimed at carrying out a phytosociological survey on their weed vegetation in four selected farms.

Materials and methods

Study areas

The two study areas are located in the Province of Frosinone (southern Latium, central Italy), in the surroundings of Atina (beans) and Pontecorvo (red peppers) (Fig. 1).

The production area of Atina bean is located in the middle Comino Valley, at elevations around 400 m a.s.l. The area is crossed by the Melfa and Mollarino rivers. The phytoclimate is Temperate Submediterranean (Pesaresi et al. 2017). Soils are alluvial loamy, with a neutral reaction (Hengl et al. 2017). Along the courses of Melfa and Mollarino rivers, the potential natural vegetation is constituted by hygrophilous woods with *Salix alba*, *S. purpurea*, *Populus* spp. and *Quercus robur* (*Fraxino-Quercion roboris*, *Salicion albae*). These are replaced, on the gentle slopes further from the waterbodies, by mesophilous *Quercus cerris* woods (*Daphno laureolae-Quercetum cerridis*) (Blasi 2010).

The production area of Pontecorvo red pepper lies in the lower Liri Valley, at elevations around 50 m a.s.l. The main waterbody is the Liri River. The phytoclimate is Temperate Submediterranean, close to the contact with the Mediterranean region (Pesaresi et al. 2017). As in Atina, soils are alluvial loamy and have a neutro-alkaline reaction (Hengl et al. 2017). Hygrophilous woods, along waterbodies (*Fraxino-Quercion roboris*, *Salicion albae*), and mesophilous *Quercus cerris-Q. frainetto* woods, in less humid sites (*Malo florentinae-Quercetum frainetto*), represent the potential natural vegetation (Blasi 2010).

Agricultural management

Both beans and red peppers are summer-annual crops and are grown with traditional methods of low-input agriculture. Each farmer was asked to compile a questionnaire about the agricultural management, his relationship with arable plants, and some personal piece of information.
According to the production protocols, both crops need irrigation. Chemical weeding and fertilization are not allowed for beans. On the contrary, these practices can be carried out in red pepper crops, if needed. Crop rotation is facultative for bean crops, whereas it is mandatory for red pepper ones, which cannot follow themselves or other Solanaceae before three years.

Vegetation survey

In late spring 2019, we contacted the owners of 14 certified PDO bean and red pepper farms. Two bean and two red pepper producers were available to collaborate. The survey was carried out in July 2019. The vegetation sampling was carried out by means of fixed area plots of 1×16 m², oriented along crop rows (Chytrý and Otýpková 2003; Güler et al. 2016). One plot was placed in the centre of each cultivated field. In red pepper farms, we also surveyed three fields that were in their rest year. All the occurring plant species were recorded and cover values were attributed according to the Braun-Blanquet scale (Braun-Blanquet 1964). We surveyed seven red pepper and nine bean fields, carrying out 16 relevés.

The collected specimens were identified according to Pignatti et al. (2017–2019). The taxonomic nomenclature was then updated according to Bartolucci et al. (2018) and Galasso et al. (2018), and their respective following updates. The syntaxonomic nomenclature follows the original authors for associations and subassociations and Mucina et al. (2016) for higher-rank syntaxa. We proposed corrections of names according to the rules of the International Code of Phytosociological Nomenclature (Weber et al. 2000). Species were attributed to syntaxa according to the original authors for associations and subassociations, and to Biondi et al. (2014) and Mucina et al. (2016) for higher-rank syntaxa.

Statistical analyses

We performed a modified TWINSPAN classification analysis of the relevés in the program JUICE (version 7.0.227 – Tichý 2002), using default settings (five pseudospecies cut levels: 0, 2, 5, 10, 20; minimum group size

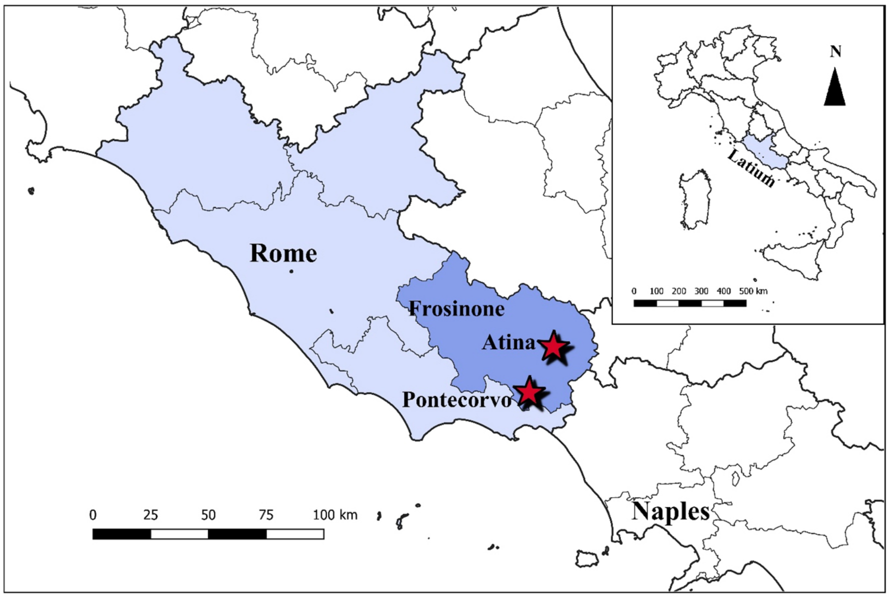

Figure 1. Location of the study areas in Latium and location of Latium in Italy.

= 5) and total inertia as a dissimilarity measure. For the ordination of the relevés, we carried out a NMDS analysis using the function isoMDS in the mass package of R project (dissimilarity measure: Bray-Curtis) (Venables and Ripley 2002).

We calculated life form and chorological spectra for each cluster resulting from the classification. Life forms and chorotypes follow Pignatti et al. (2017–2019). Archaeophytes, neophytes, and cryptogenic species are according to Bartolucci et al. (2018) and Galasso et al. (2018), and their respective following updates.

Results

Agricultural management and farm histories

All the farmers carried out agricultural practices in line with the production protocols of each crop. All the interviewees declared to perceive arable weeds as a problem for production, with special regards to *Cirsium arvense, Sorghum halepense*, and *Xanthium italicum* in bean crops and to *Cyperus rotundus* in red pepper crops. The two red pepper growers did not have other jobs. On the contrary, farming was a side job for bean growers.

Beans were cultivated since 2011 in both of the surveyed farms. Soil tillage and sowing were carried out in early June 2019. Sprinkle or drip irrigation was performed each 5-6 days. In one farm, beans were rotated with winter wheat. In the other one, only fallowing was carried out. The control of weed vegetation was achieved by either manual eradication or hoeing.

Red peppers were cultivated since 2015 in a surveyed farm and since 2018 in the other. Soil tillage was carried out in early May in a farm and in early June in the other, and transplantation in the open field was performed in late May and early June, respectively. Red peppers were rotated with winter broad bean, maize, and *Brassica* sp. Drip irrigation was provided each 2-15 days. Organic fertilizers were applied a couple of times per growing season. Mulching sheets were used to control weed vegetation.

Vegetation analysis

The numerical analysis of the relevés produced two interpretable clusters, exactly separating the arable weed communities of Atina from those of Pontecorvo. The results of the NMDS ordination reflect this split, with the two groups being well separated in space (Fig. 2).

The detected vegetation types were attributable to two different subassociations of the *Panico-Polygonetum persicariae*, in the alliance *Spergulo arvensis-Erodion cicutariae* (*Eragrostietalia*, *Digitario sanguinalis-Eragrostietea minoris*). The alliance includes the sub-thermophilous summer-annual weed communities that develop on sandy and sandy-loamy soils in the Atlantic to subcontinental regions of the nemoral zone of Europe (Mucina et al. 2016) (Table 1). The floristic composition of the association actually overlaps that of the alliance, hosting summer-annual taxa as *Amaranthus* spp., *Datura stramonium*, *Echinochloa crus-galli*, *Persicaria maculosa*, *Setaria* spp., and *Xanthium italicum*. Frequent class characteristics are *Digitaria sanguinalis* and *Portulaca oleracea*. Some ruderal generalist from the *Sisymbrietea* constantly occur, including *Chenopodium album*, *Convolvulus arvensis*, and

Table 1. Analytic table of the relevés. Crops: B = bean; P = red pepper; R = red pepper field in its first rest year.

Relevé number	16	10	13	14	11	12	15	8	3	9	7	4	2	1	5	6
Crop	P	P	P	R	R	R	P	B	B	B	B	B	B	B	B	B
Relevé area (m^2)	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Elevation (m a.s.l.)	55	50	55	55	50	50	55	380	410	390	415	410	380	380	415	415
Cover of weed vegetation (%)	3	10	90	30	90	70	90	80	20	10	25	10	100	60	20	25
Number of species	6	12	11	8	8	19	11	9	7	5	11	9	6	9	14	6
Panico-Polygonetum persicariae **and *Spergulo-Erodion***																
Amaranthus retroflexus	.	1	r	r	.	.	r	r	2	2	.	.	4	1	r	2
Xanthium italicum	.	.	.	.	.	+	.	1	.	.	1	.	2	2	2	r
Setaria pumila	.	.	.	.	.	.	+	2	.	.	.	.	.	.	.	.
Persicaria maculosa	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.
Datura stramonium	.	.	.	.	.	.	.	.	.	.	.	.	.	1	r	.
Echinochloa crus-galli subsp. *crus-galli*	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	r
Setaria italica subsp. *viridis*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Char. ***cyperetosum rotundi***																
Cyperus rotundus	1	1	4	2	1	+	3	.	.	.	.	.	.	+	.	.
Char. ***sorghetosum halepensis***																
Sorghum halepense	.	.	.	.	.	.	.	1	1	r	2	2	1	+	1	r
Abutilon theophrasti	.	.	.	.	.	.	.	.	.	.	+	r	3	.	.	+
Facies of fallow pepper fields																
Kickxia elatine subsp. *elatine*	.	.	+	r	1	3	.	.	.	.	.	.	.	.	.	.
Artemisia verlotiorum	.	+	+	.	5	.	.	.	2	.	.	.	.	.	.	.
Erigeron sumatrensis	.	.	.	.	+	2	.	.	.	.	.	.	.	.	.	.
Erigeron canadensis	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Eragrostietalia **and *Digitario-Eragrostietea***																
Portulaca oleracea	+	1	2	1	.	.	3	r	.	r	.	.	.	+	2	.
Digitaria sanguinalis	.	+	+	+	.	+	1	3	+	.	.	.	.	.	.	.
Cynodon dactylon	.	.	.	.	.	.	.	1	+	.	.	.	.	.	r	.
Heliotropium europaeum	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polygonum aviculare subsp. *aviculare*	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.
Euphorbia prostrata	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Euphorbia maculata	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Euphorbia chamaesyce	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Sisymbrietea																
Convolvulus arvensis	.	1	1	1	.	.	2	.	r	r	+	1	+	.	+	.
Sonchus oleraceus	r	+	r	+	r	.	.	.	r	.	r	+	.	.	.	.
Chenopodium album subsp. *album*	.	.	.	.	.	r	.	+	1	.	.	r	1	2	1	.
Cirsium arvense	+	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.
Sinapis arvensis subsp. *arvensis*	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
Papaveretea rhoeadis																
Mercurialis annua	.	.	.	.	.	.	.	.	.	.	1	1	.	1	+	.
Veronica persica	+	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.
Visnaga daucoides	.	.	r	.	.	1	.	.	.	.	.	.	.	.	.	.
Lysimachia arvensis subsp. *arvensis*	.	.	.	.	r	+	.	.	.	.	.	.	.	.	.	.
Euphorbia helioscopia subsp. *helioscopia*	.	.	.	.	.	.	.	.	r	.	.	.	.	.	r	.
Companions																
Artemisia vulgaris	.	.	.	.	.	.	.	.	.	.	+	.	.	.	r	+
Rumex crispus	.	.	.	.	+	.	+	.	.	.	.	.	.	.	r	.
Centaurium pulchellum subsp. *pulchellum*	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.
Sporadic species	0	1	0	0	0	7	2	3	0	0	1	2	0	0	0	0

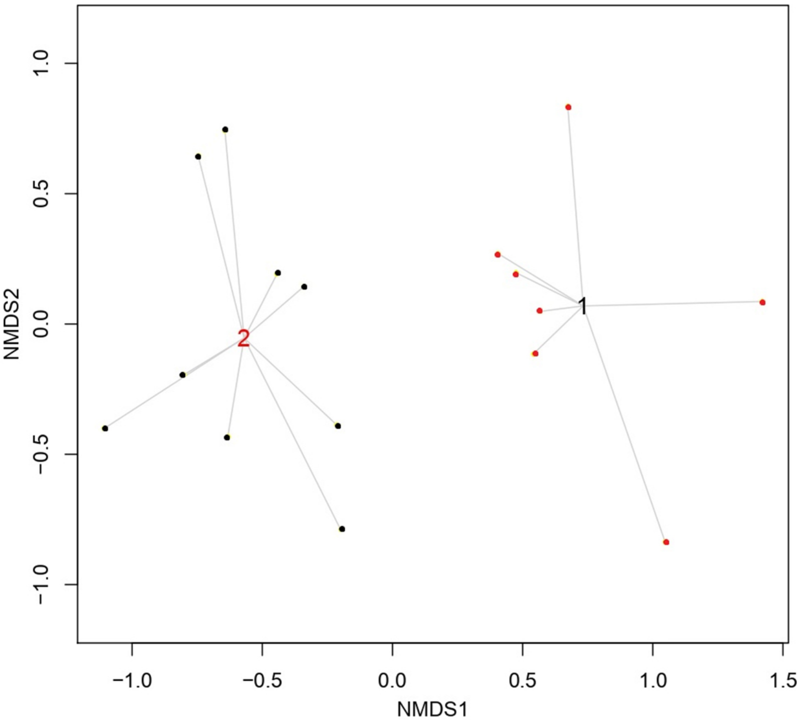

Figure 2. Ordination diagram based on the results of the NMDS: 1 = *Panico-Polygonetum cyperetosum* (red pepper fields); 2 = *Panico-Polygonetum sorghetosum* (bean fields); dots = relevés.

Sonchus oleraceus. The community was described in hoed summer crops of the eastern Po Plain (Pignatti 1953). Later, many authors detected it in other parts of Italy, especially in maize crops (Lorenzoni 1963-1968; Covarelli 1968; De Dominicis et al. 1988; Zanin et al. 1991).

For the weed vegetation of bean fields, we recognized the subassociation *Panico-Polygonetum persicariae* Pignatti 1953 *sorghetosum halepensis* Baldoni 1995 (Fig. 3), which was described in Marche (central Italy). In our relevés, it is distinguished by the occurrence of *Sorghum halepense* and *Abutilon theophrasti*, which sometimes reach high cover values. It develops in summer-annual crops growing in areas with a shallow water table and with nutrient-enriched soils (Baldoni 1995). The mean number of species per relevé was 8.

The weed vegetation of red pepper crops was referred to the subassociation *Panico-Polygonetum persicariae* Pignatti 1953 *cyperetosum rotundi* Lorenzoni 1967 *nom. corr. hoc loco* (Art. 14 and 41b; Fig. 4). It was originally named "*Panico-Polygonetum persicariae* Pignatti 1953 subassociazione a *Cyperus rotundus*" in Lorenzoni (1967 – Quaderno VII di Maydica, page 4). It was described as a weed community of maize crops in Latium and Campania, and later detected in Calabria. The community is physiognomically characterized by the geophyte *Cyperus rotundus* and it develops in lowlands, on moist and sandy soils (Lorenzoni 1967, 1968). The mean number of species per relevé was 11. In fallow red pepper fields, due to the lack of irrigation, we detected a xerophilous facies characterized by *Artemisia verlotiorum*, *Erigeron canadensis*, *E. sumatrensis*, and *Kickxia elatine*, without a specific sociological value.

Structurally, the two communities are distinctively annual, but a fair amount of geophytes is also present. A higher incidence of therophytes featured the *cyperetosum* subassociation, while a slightly higher amount of perennials was present in the *sorghetosum* subassociation. As regards perennials, the occurrence of rhizomatous geophytes as *Artemisia verlotiorum*, *Convolvulus arvensis*, *Cynodon dactylon*, *Cyperus rotundus*, and *Sorghum halepense* stood out. The chorological analysis highlighted a poor consistency of the communities with the phytogeographic context of the study areas. This is underlined by the predominance of neophyte and cosmopolitan taxa and by the reduced occurrence of Eurasian (more abundant in the *sorghetosum*) and Mediterranean (more represented in the *cyperetosum*) species (Fig. 5). Neophytes are all invasive in Latium (Galasso et al. 2018) and all of them are of American origin (e.g., *Amaranthus retroflexus*, *Datura stramonium*, *Erigeron* spp.), with exception of the eastern Asian *Artemisia verlotiorum*. Several cryptogenic taxa are present too, in both the subassociations (*Cyperus rotundus*, *Digitaria sanguinalis*, *Portulaca oleracea*, and *Setaria italica* subsp. *viridis*). Archaeophytes are *Abutilon theophrasti* and *Sorghum halepense*, exclusive to and characteristic of the *sorghetosum* subassociation.

Figure 3. *Panico-Polygonetum persicariae sorghetosum halepensis* community colonizing a bean field in Atina.

Figure 4. P*anico-Polygonetum persicariae cyperetosum rotundi* community colonizing a red pepper field in Pontecorvo.

Discussion and conclusions

The results highlighted the presence of weed communities previously detected in different summer-annual crops in central Italy, like maize and sugarcane (Covarelli 1968; De Dominicis et al. 1988; Baldoni 1995). These stands are floristically very different from those colonizing winter-annual crops in the same area (Covarelli 1979; Baldoni and Frattaroli 1998; Fanfarillo et al. 2019b). This confirms how crop seasonality is one of the most important factors shaping arable weed communities at middle-high latitudes, as shown in many parts of Eurasia (Lososová et al. 2004; Fried et al. 2008; Abbate et al. 2013; Nowak et al. 2015).

Syntaxonomy

Syntaxonomically, the weed vegetation of Italian summer-annual crops pertains to the class *Digitario sanguinalis-Eragrostietea minoris* (Mucina et al. 2016). Within this class, it is mainly ascribable to the alliance *Spergulo-Erodion* (syn. *Panico-Setarion*), and subordinately to the *Diplotaxion erucoidis* and to the *Chenopodion botryos*. Within the *Spergulo-Erodion*, the *Panico-Polygonetum persicariae* is the most common association. Some authors consider it as a synonym of the central European *Echinochloo-Setarietum pumilae* (Poldini et al. 1998; Tasinazzo 2011).

At the best of our knowledge, the weed vegetation of bean and red pepper crops is practically unknown from a phytosociological perspective in Italy. In southern Calabria, some winter-spring communities colonizing bean fields were framed in the *Fumario agrariae-Brassicetum fruticulosae* (*Fumarion wirtgenii-agrariae*, *Papaveretea rhoeadis*). Summer stands of bean fields in the same area were referred to the *Setario-Echinochloëtum colonum* (*Spergulo-Erodion*, *Digitario-Eragrostietea*) (Brullo et al. 2001). No references were found for the weed communities of red pepper crops.

According to past evidences, the *Panico-Polygonetum persicariae* is particularly common in Italian summer-annual crops, in sites where either naturally or because of irrigation an adequate amount of moisture is present (Lorenzoni 1963-1968). This plant community was described by Pignatti (1953) in the eastern Po Plain. Its affinity with the *Echinochloo-Setarietum pumilae*, previously described in central Europe by Felfoldy (1942), was soon remarked by Lorenzoni (1963). Nevertheless, the latter and later authors preferred to use the *Panico-Polygonetum* as a reference for the weed vegetation of Italian summer-annual crops (Covarelli 1968; De Dominicis et al. 1988; Zanin et al. 1991; Baldoni 1995). Poldini et al. (1998) then statistically proved that there was no floristic difference between the *Echinochloo-Setarietum* and the *Panico-Polygonetum*. Thus, the authors put the latter syntaxon in synonymy with the former. Since syntaxonomic issues go beyond the aims of this work, we followed the original framing of the detected subassociations in the *Panico-Polygonetum*.

Other arable weed communities dominated by *Cyperus rotundus* and/or *Sorghum halepense* are present in Europe. The summer-annual weed communities of the woody crops of Sicily were ascribed by Maugeri (1979) to the *Amarantho-Cyperetum rotundi*, with several subassociations. In southern Calabria, Brullo et al. (2001) described the *Setario ambiguae-Cyperetum rotundi* in irrigated citrus groves. Since it was invalidly published, the *Amarantho-Cyperetum* was later synonymized with the *Setario-Cyperetum*, and its subassociation *echinochloëtosum coloni* was put in synonymy with the *Setario glaucae-Echinochloëtum colonum* (Brullo et al. 2007). The *Setario-Cyperetum* is very different from our communities, in which the diagnostic *Cyperus esculentus* and *Setaria verticillata* are missing, as well as constant species as *Galinsoga quadriradiata*, *Chenopodium vulvaria*, and *Urtica membranacea*. In Catalonia (Spain), Ninot et al. (2010–2011) described the *Convolvulo arvensis-Cyperetum rotundi* in fruit orchards and kitchen gardens under low-intensity agricultural practices, including low irrigation. This community was later detected also in irrigated summer crops of Tajikistan (Nowak and Nowak 2013). It is featured by generalist and widely distributed species and this makes possible, in the future, that it could be detected elsewhere, including Italy. Summer arable weed communities dominated by *S. halepense* are the *Setario ambiguae-Sorghetum halepensi*, present in Eastern Europe and Middle Asia (Nowak and Nowak 2013), and the *Hibisco trioni-Sorghetum halepensi*, described for Dalmatia (Mitić et al. 2009). Because of differences in floristic composition and the different geographic location, these syntaxa are not a good reference for our relevés.

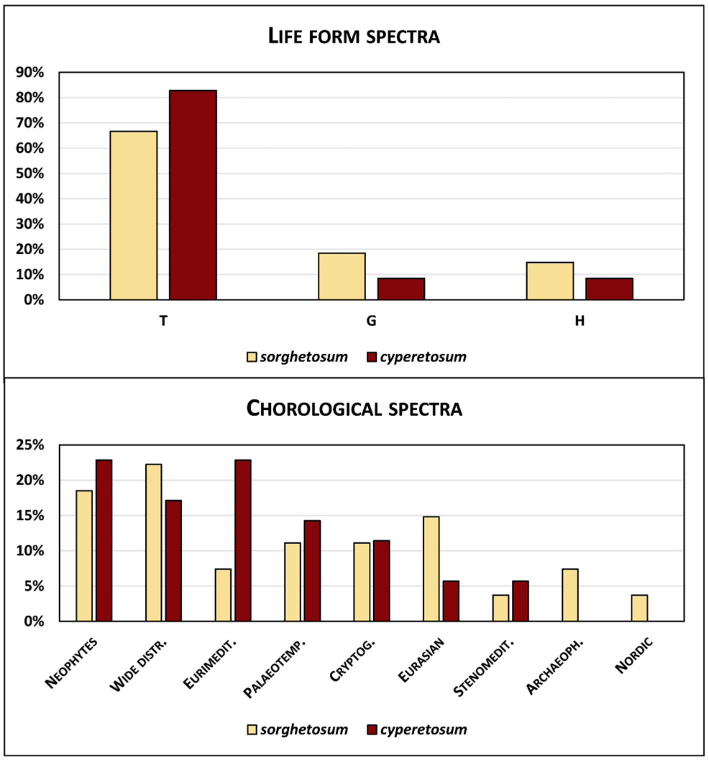

Figure 5. Life form and chorological spectra for the subassociations *sorghetosum halepensis* and *cyperetosum rotundi* of the *Panico-Polygonetum persicariae*.

Synecology

Given the affinity in agricultural management between beans and red peppers (late spring tillage, irrigation, no use of herbicides), the detected differences in the weed vegetation are restrained and mainly due to geographic and environmental factors. The lower elevation and the higher proximity to the sea give to the area of Pontecorvo a phytoclimate closer to a Mediterranean type, with a clear period of summer drought. The area of Atina lies more inland and in the hilly belt, so that its phytoclimate is more clearly Temperate. Furthermore, bean fields are located very close to the courses of Melfa and Mollarino rivers. At the same level of irrigation, site conditions are featured by a higher moisture availability in Atina. That is why weed vegetation hosts meso-hygrophilous differential species of the *sorghetosum* subassociation. On the contrary, the warmer and dryer conditions of Pontecorvo promote the development of the *cyperetosum*, anyway in a context of alluvial soils with a fair moisture amount. These differences are also highlighted by the higher amount of therophytes and Mediterranean species in the *cyperetosum* communities, whereas perennials, Eurasian, and palaeotemperate taxa have a higher incidence in the *sorghetosum* ones.

Considerations on environmental and agricultural sustainability

Despite the low-input agricultural practices, the surveyed arable weed vegetation resulted rich in elements of no conservation value, such as neophyte, widely distributed, and generalist taxa. This evidence is consistent with the general patterns known in Europe and does not necessarily point towards a low environmental sustainability of the studied crops. Both bean and red pepper, as most of the summer-annual crops of Italy, were "recently" introduced from tropical America. Their spread provided a new ecological and phenological niche across Europe, whose climatic features make annual plants that complete their life cycle under hot and wet conditions poorly represented in the native flora. Neotropical and generalist taxa soon occupied this niche, which was not suitable for many native species (Brullo and Guarino 2007).

The interviewed farmers mentioned *Cyperus rotundus* and *Sorghum halepense* as the most troublesome weeds in their fields. This was not surprising, since these taxa are between the worst agricultural weeds worldwide (Holm et al. 1977). They had a big spread in summer crops of Latium in the last decades, as well as other rhizomatous grasses as *Cynodon dactylon* and *Paspalum distichum* (Fanfarillo et al. 2019a). Their success as arable weeds is due to rhizome dispersion by tillage, to herbicide resistance, to a very efficient C4 metabolism, and even to the release of allelochemicals (Bryson and Richard 2008; Heap 2014; Kashif et al. 2015). Another hard to control species was *Cirsium arvense*, which has a high ability to spread both vegetatively, through its root buds, and sexually, through the effective anemochorous dispersion of its achenes. The fourth species mentioned by farmers as a troublesome weed was the summer-annual *Xanthium italicum*, whose success is easily linkable to an abundant fruit production and zoochory. In order to avoid the use of chemical control, farmers should establish better-planned crop rotations with a higher temporal and spatial crop diversification. This would promote the establishment of more balanced and species-rich communities, which are less competitive and cause less damage to the crop, avoiding the selection of few, highly harmful species (Storkey and Neve 2018).

Syntaxonomic scheme

DIGITARIO SANGUINALIS-ERAGROSTIETEA MINORIS Mucina, Lososová et Šilc in Mucina et al., 2016
ERAGROSTIETALIA J. Tx. ex Poli, 1966
Spergulo arvensis-Erodion cicutariae J.Tx. in Passarge, 1964
Panico-Polygonetum persicariae Pignatti, 1953
cyperetosum rotundi Lorenzoni, 1967, *nom. corr. hoc loco*
sorghetosum halepensis Baldoni, 1995

Other syntaxa quoted in the text (in alphabetic order)

Amarantho-Cyperetum rotundi echinochloëtosum coloni Maugeri et al., 1980 nom. inval.; *Chenopodion botryos* S. Brullo et Marcenò, 1980; *Convolvulo arvensis-Cyperetum rotundi* Carretero et Aguilella ex Ninot, X. Font, Masalles et Vigo, 2010–2011; *Daphno laureolae-Quercetum cerridis* Taffetani et Biondi, 1993; *Diplotaxion erucoidis* Br.-Bl. in Br.-Bl. et al., 1936; *Echinochloo-Setarietum pumilae* Felfoldy, 1942 corr. Mucina, 1993; *Fraxino-Quercion roboris* Passarge, 1968; *Fumario agrariae-Brassicetum fruticulosae* S. Brullo et al., 2001; *Fumarion wirtgenii-agrariae* S. Brullo in S. Brullo et Marcenò, 1985; *Hibisco trioni-Sorghetum halepensi* Mitić et al., 2009; *Malo florentinae-Quercetum frainetto* Biondi, Gigante, Pignattelli et Venanzoni, 2001; *Setario ambiguae-Sorghetum halepensi* Ştefan et Oprea, 1997; *Setario-Echinochloëtum colonum* A. et O. Bolòs ex O. Bolòs, 1956; *Panico-Setarion* Sissingh in Westhoff et al., 1946; *Papaveretea rhoeadis* S. Brullo et al., 2001; *Salicion albae* Soó, 1951; *Setario ambiguae-Cyperetum rotundi* Brullo et al., 2001; *Setario glaucae-Echinochloëtum colonum* A. & O. Bolòs ex O. Bolòs, 1956.

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Appendixes

Appendix I – Sporadic species in Table 1

Rel. 4: *Geranium molle* (+), *Potentilla reptans* (+).
Rel. 7: *Sonchus asper* subsp. *asper* (r).
Rel. 8: *Amaranthus hybridus* subsp. *hybridus* (+), *Medicago arabica* (r), *Raphanus raphanistrum* s.l. (r).
Rel. 10: *Malva neglecta* (r).
Rel. 12: *Bunias erucago* (r), *Coleostephus myconis* (+), *Helminthotheca echioides* (r), *Lolium multiflorum* (+), *Lotus hispidus* (r), *Lysimachia foemina* (r), *Trifolium arvense* subsp. *arvense* (+).
Rel. 15: *Chrozophora tinctoria* (+), *Cichorium intybus* (r).

Appendix II – Date, location, and coordinates (Decimal Degrees) of the relevés in Table 1

Rel. 1: 2019/07/15, Supremo farm, Atina (FR), 41.616843 N, 13.8143009 E.
Rel. 2: 2019/07/15, Supremo farm, Atina (FR), 41.6166946 N, 13.8146228 E.
Rel. 3: 2019/07/15, Supremo farm, Atina (FR), 41.6241718 N, 13.832592 E.
Rel. 4: 2019/07/15, Supremo farm, Atina (FR), 41.6248214 N, 13.8335791 E.
Rel. 5: 2019/07/15, Supremo farm, Atina (FR), 41.6245088 N, 13.8340714 E.
Rel. 6: 2019/07/15, Di Palma Basilio farm, Atina (FR), 41.6247842 N, 13.8354823 E.
Rel. 7: 2019/07/15, Di Palma Basilio farm, Atina (FR), 41.6252718 N, 13.8353528 E.
Rel. 8: 2019/07/15, Supremo farm, Atina (FR), 41.6161071 N, 13.8147192 E.
Rel. 9: 2019/07/15, Supremo farm, Atina (FR), 41.6164056 N, 13.8203945 E.
Rel. 10: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.439898 N, 13.6668126 E.
Rel. 11: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.4400749 N, 13.6669481 E.
Rel. 12: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.440061 N, 13.6669818 E.
Rel. 13: 2019/07/17, Peperdop farm, Pontecorvo (FR), 41.4536843 N, 13.6610711 E.
Rel. 14: 2019/07/17, Peperdop farm, Pontecorvo (FR), 41.4535878 N, 13.6608404 E.
Rel. 15: 2019/07/17, Peperdop farm, Pontecorvo (FR), 41.4530913 N, 13.6607519 E.
Rel. 16: 2019/07/17, Il Ponte farm, Pontecorvo (FR), 41.4406832 N, 13.66496 E.