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Najla Sayari
Department of Plant Protection, Higher Agronomic Institute of Chott-Mariem, BP 47, 4042. University of Sousse, Tunisia

Tasnim Gueddes
Department of Plant Protection, Higher Agronomic Institute of Chott-Mariem, BP 47, 4042. University of Sousse, Tunisia

Rym Jaouadi
Research Laboratory of Agricultural Production Systems and Sustainable Development LR03AGR02, Department of Agricultural Production, Higher School of Agriculture of Mograne (ESAM), Mograne, 1121, Zaghouane, University of Carthage, Tunisia

Corresponding Author:
Najla Sayari
Department of Plant Protection, Higher Agronomic Institute of Chott-Mariem, BP 47, 4042. University of Sousse, Tunisia

Effect of hand weeding and chemical treatments on weed flora in Potato crop

Najla Sayari, Tasnim Gueddes and Rym Jaouadi

Abstract
Weed flora that competes with a particular crop species depends upon environmental factors and cropping systems. In this paper we present taxonomic analysis of the weed flora in potato grown conventionally under a semi-arid Tunisian climate, and its shift according to cultural practices particularly hand weeding and chemical treatments. A total of 29 weed species belonging to 16 families and 27 genus have been reported in potato crop. In the total floristic spectrum of potato crops weed flora, *Poaceae* family predominates with 17%, followed by *Amarantaceae* (14%), *Fabaceae* (10%) and *Asteraceae* (10%). In term of biological spectrum, therophytes were the most frequent with 72% followed by geophytes with 14%. *Urtica urens*, *Chenopodium murale*, *Chenopodium album* and *Raphanus raphanistrum* were the most dominant species. Chemical treatment is critical to provide an optimal growing environment for potatoes earlier in the season Results showed that weed biomass decreased when chemical treatments were applied between 2 and 3 weeks after planting. However, beyond 6 weeks after planting, chemical treatments were not effective in controlling weeds. These findings revealed that, under the study site conditions, the critical period for potato crop-weed competition was 4-6 weeks after planting and the crop should be well protected at this stage by creating weed free environment. Early postemergence application of Metribuzin at 0.7 kg *a.i./ha* was more efficient to suppress broadleaf weed species and grasses than pre-emergence application of Linuron at 0.2 kg *a.i./ha*. Furthermore, hand weeding practiced twice: the first at the planting and the second 3 weeks after was more efficient to decreases weed density than that practiced only one time 6 weeks after planting. However, the highest weed control efficiency was recorded when hand weeding was combined with herbicides application.

Keywords: Weed flora, potato-crop, taxonomy, cultural practices, management

1. Introduction
Potato (*Solanum tuberosum* L.) is the third most important food crop in the world after rice and wheat in terms of human consumption (Devaux *et al.*, 2009; FAO, 2014) [9, 11]. In Tunisia, it's considered an important food in the culinary habits of the population which consumes on average 30.3 kg/inhabitant/year. In the period 2016-2021, the production in the country remained relatively stable at over 420 thousand tons. In the crop year 2019/2020, a wide land area of 22 thousand hectares was devoted to growing potatoes in the country (SRD, 2022) [27]. Cape Bon (northeastern Tunisia) is the largest region producing potato in Tunisia. It produces nearly 46 per cent of Tunisia's total production of potato (ONAGRI, 2014) [22].

Despite its importance in the food security insurance, potato cultivation undergoes several constraints. It is subject to many pests' attacks. Weeds represent one of the major problems of this crop since they have always caused heavy yields loss and quality depreciation of the harvested tubers (Hussain *et al.*, 2016; Mehring *et al.*, 2016) [13, 19]. Weeds may also harbor pests and act as carriers of diseases, and likely increase expenses of production for cultivators (Nwosisi *et al.*, 2019) [21]. Accordingly, weed control became a major component in potato production and is achieved using different methods and tools. However, the continuous shifts in weed species and densities caused by changes in cultural practices is a challenge for potato producers (Bhullar *et al.*, 2015) [3].

Changes in cropping system as tillage practices, row spacing, planting date and pest management practices may interact and influence the weed population dynamics (Rana, 2018) [25]. In this context, the present work aims to i) analysis the composition of the weed flora associated to potato crop and ii) study its shift according to cultural practises particularly hand weeding and chemical treatments.

2. Materials and Methods

2.1 Study site

The region of Chott-Meriem is located in the Centre-East of Tunisia, 10 km on the east coast of Tunisia (Longitude 10°38'E, Latitude 35°55'N, altitude 15 m). It's characterized by a typical Mediterranean climate thanks to its proximity to the sea. It belongs to the lower semi-arid bioclimatic stage with an annual rainfall of 200 to 400 mm/year. The climate is characterized by mild rainy winters and hot, dry summers.

2.2 Survey and processing of data collection

Field surveys were conducted during February-June 2021. Ten potato producers in the region of Chott-Meriem were investigated to collect information related to the farming practices carried out to maintain the seasonal potato crop grown under conventional system. The data collected from each producer was recorded on a fact sheet to facilitate their archiving and computer processing. They concern, in particular:

- Observation date: day/month/year;
- Geographical location: GPS point;
- Farmer name, address, level of education, age, etc.;
- Plot size (ha);
- Cultural practices carried out: soil preparation, date of planting, irrigation, fertilization, mechanical or chemical weeding, etc.

2.3 Weed flora assessment

2.3.1 Specific diversity

Weed specific diversity was assessed in ten potato plots. Each plot was completely covered both at the level of the planting lines and in the interlines to identify the existing weed flora. For the reliability of this work, specimens were collected and then identified, pressed and dried to make a herbarium. The identification was carried out in the weed science laboratory of the Higher Agronomic Institute of Chott-Meriem, based on the Tunisia floras documents (Cuénod *et al*., 1954; Pottier-Alapetite, 1979 and 1981; Le Floc'h *et al*., 2010) [7, 23, 24, 17], available catalog (Carême, 1999) [5] and online identification software such as "PlantNet". Nomenclature follows Le Floc'h *et al.* (2010) [17] and has been cross-checked considering online databases, i.e. The Euro+MedPlantbase [10] and the African Plants Database [1]. Names of the families of Angiosperms follow APG III (Haston *et al.*, 2009) [12].

2.3.2 Weed density

Weed density was evaluated in ten plots. At the level of each plot ten samples were taken, in a random way, on the planting lines and interlines. The sampling unit was a quadrat of 0.25 m^2 (0.5*0.5 m). Density was estimated by counting the number of plants/quadrats.

2.3.3 Weed dominance

The dominance of each species, expressed as a percentage of ground cover, was assessed using the Braun-Blanquet abundance-dominance scale (Table 1).

Table 1: Braun-Blanquet abundance-dominance scale (1932) [4]

Coefficient	Ground cover (%)
5	> 75%
4	50–75%
3	25–50%
2	5–25%
1	< 5%

2.3.4 Weed dry biomass

Weeds dry biomass was evaluated in ten plots. For each plot ten samples were collected, in a random way, on the planting lines and interlines. The sampling unit is a quadrat of 0.25 m^2 (0.5*0.5 m). Vegetative samples were oven dried at 70 ºC for 48 hours and then weighed (Demjanová *et al.*, 2009) [8].

3. Results and Discussion

3.1 Weed flora analysis

The inventory of the weed flora associated to potato crop allowed to identify a total number of 29 weed species belonging to 16 families and 27 genus (Table 2). The most represented families were *Poaceae* (17%), *Amarantaceae* (14%), *Fabaceae* (10%) and *Asteraceae* (10%) (Fig 1). Regarding to the life form, therophytes were the most frequent with 86% followed by geophytes with 14%. This result is in agreement with who's of Nikolić *et al.* (2013) [20] who reported that the biological spectrum of weed flora in potato production systems is of predominantly terophytic-geophytic character.

Table 2: Taxonomic review of the weed flora in potato crops (Chott-Meriem, Tunisia, 2021) [27]

Class	Family	Species	Life form
Dicotyledonous	*Amaranthaceae*	*Amaranthus graecizans* L.	Therophyte
		Amaranthus retroflexus L.	Therophyte
		Chenopodium album L.	Therophyte
		Chenopodium murale L.	Therophyte
	Asteraceae	*Sonchus oleraceus* L.	Therophyte
		Chrysanthemum coronarium L.	Therophyte
		Xanthium stramonium L.	Therophyte
	Brassicaceae	*Rapistrum rugosum* (L.) All.	Therophyte
		Raphanus raphanistrum L.	Therophyte
	Caryophyllaceae	*Stellaria media* (L.) Vill.	Therophyte
		Silene rubella L.	Geophyte
	Convolvulaceae	*Convonvulus arvensis* L.	Geophyte
	Fabaceae	*Melilotus sulcatus* Desf.	Therophyte
		Medicago polymorpha L.	Therophyte
		Vicia sativa L.	Therophyte
	Fumariaceae	*Fumaria parviflora* Lamk.	Therophyte
	Lamiaceae	*Lamium amplexicaule* L.	Therophyte

	Malvaceae	*Malva parviflora* L.	Therophyte
	Polygonaceae	*Emex spinosa* (L.) campd.	Therophyte
		Polygonum aviculare L.	Therophyte
	Primulaceae	*Anagalis arvensis* L.	Therophyte
	Rubiaceae	*Galium tricornutum* Dandy	Therophyte
	Urticaceae	*Urtica urens* L.	Therophyte
Monocotyledonous	*Cyperaceae*	*Cyperus rotundus* L.	Geophyte
	Poaceae	*Avena sterilis* L.	Therophyte
		Cynodon dactylon (L.) Pers.	Geophyte
		Hordeum murinum L.	Therophyte
		Lolium rigidum Gaudin	Therophyte
		Setaria verticillata (L.) Beauv.	Therophyte

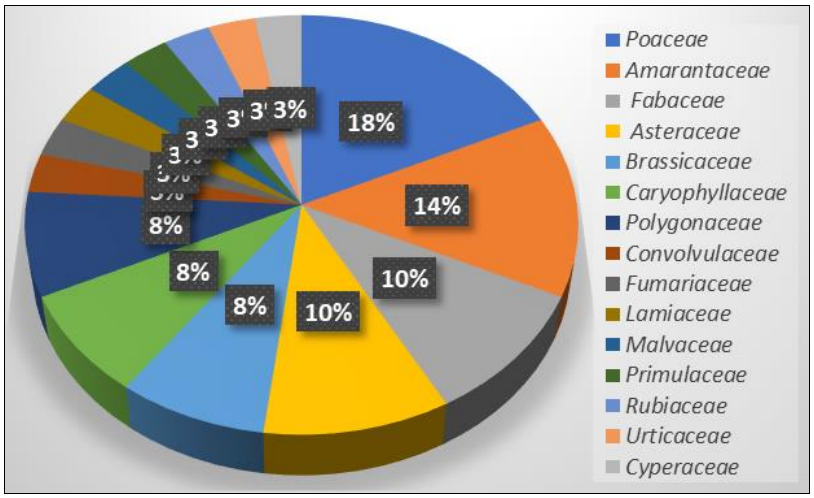

Fig 1: Represented families of the weed flora in potato crops (Chott-Meriem, Tunisia, 2021) [27]

Concerning species frequency, we note that *Urtica urens*, *Chenopodium murale*, *Chenopodium album* and *Raphanus raphanistrum* were the most frequent species in the ten studied plots with a percentage of 90% for each, followed by *Convonvulus arvensis* (80%), *Amaranthus retroflexus* (70%) and *Emex spinosa* (60%).

These results are confirmed by the species abundance-dominance study, as we note that *Urtica urens* was the most abundant species with a ground cover >75% followed by *Chenopodium album* and *Chenopodium murale* with a ground cover of 50-75% for each. On the other hand, floristic records show that monocotyledonous species were present in 50% of the studied plots (plots 3, 4, 1, 8 and 9) with a ground cover of <5%. Perennials, such as *Convonvulus arvensis*, *Cynodon dactylon* and *Cyperus rotundus*, were not very frequent, they were recorded in 30% of the plots (plots 6, 8 and 9) with a ground cover <5%.

3.2 Effects of Chemical and hand weeding practices on weed flora in potato crop

Weed density assessment in the ten studied plots showed that the infestation level was considerable and varies from 39 plants/m^2 in plot 2 to 68 plants/m^2 in plot 8 (Fig 2). This density variation in the different studied plots was probably due to differences in applied agrotechnical practices. In fact, the occurrence and intensity of weeds vary under various agroclimatic regions, cropping systems and management conditions (Singh *et al.*, 2018) [26]. High weed density was confirmed by the species biomass variation (Fig 2). Indeed, we notice that, generally, the biomass was in positive correlation with the density except for plot 8 where we noted that the two variables (density and biomass) were inversely proportional.

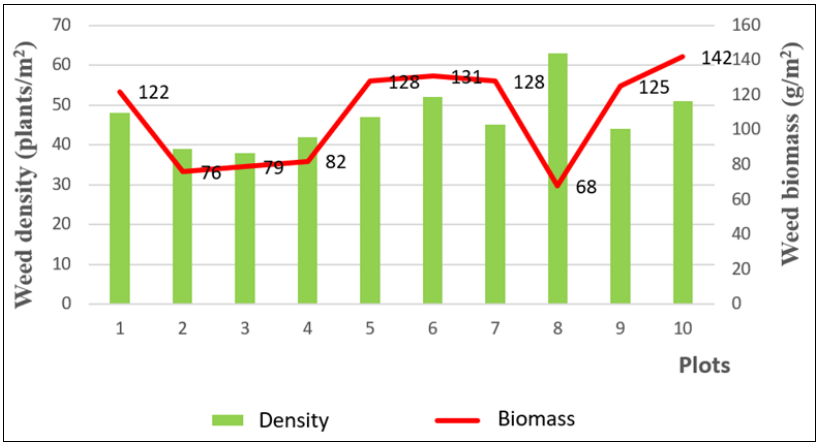

Fig 2: Weed density and biomass variation in the ten studied plots (Chott-Meriem, Tunisia, 2021) [27]

Fundings on weed biomass variation in the ten studied plots could be explained by the effect of applied chemical treatments. In fact, weed biomass decreases when the herbicide treatment was applied between 2 and 3 weeks after planting (WAP) (plots 2, 3 and 4), (Table 3). However, beyond 4 WAP, herbicide treatments do not seem to be effective in controlling weeds, given that weed biomass was higher in plots 1, 7, 8 and 10 which were treated after 6, 5, 5 and 6 WAP. The highest weed biomass was recorded in untreated plots (5, 6 and 9). These results are in agreement with those of Karimmojeni *et al.* (2014) [16] who confirmed that weed biomass in potato crops increases if the weeding (chemical or mechanical) is delayed. Accordingly, we can conclude that, under the studied sites conditions, the critical period of weed competition in potato is first 4-6 WAP. By the way, several studies (eg. Thakral *et al.*, 1989; Manorama, 2004; Singh *et al.*, 2018) [28, 18, 26] confirmed that the most critical period for weed removal in potatoes is about 4 to 6 weeks after planting.

Table 3: Effect of the chemical treatment date on weed biomass

Plot Code	Chemical Treatment Date (WAS)	Weed Biomass (g/m^2)
1	6	122
2	2	76
3	3	79
4	2	82
5	untreated	128
6	untreated	131
7	5	128
8	5	68
9	untreated	125

Herbicides are critical to provide an optimal growing environment for potatoes earlier in the season. Several studies (eg. Bhullar *et al.*, 2015; Kalkhoran *et al.*, 2021) [3, 14] reported that potato growers usually apply herbicide early postemergence. Field surveys showed that 70% of farmers practice the chemical weed control. Table 4 present the characteristics of the herbicides applied in the studied plots. Metribuzin was the most used herbicide generally applied on early post-emergence. These fundings are supported by several previous studies (eg. Karen and Gary 1998; Alebrahim *et al.*, 2012; Correia and Carvalho, 2018; Kalkhoran *et al.*, 2021) [15, 2, 6, 14] which confirmed that Metribuzin is one of the oldest potato herbicides and is still widely used. This relies on the fact that potato growers have few available herbicide options in Tunisia and in many other regions in the world (Bhullar *et al.*, 2015; Kalkhoran *et al.*, 2021) [3, 14].

Table 4: Characteristics of the herbicides applied for weed control in potato

Herbicide	Active ingredient	Dose	Selectivity	Application
Linkey	Linuron	2 Kg/ha	Grasses and dicots	Preemergence
Sencor 600 SC	Metribuzine	0,75 L/ha	Annual weeds, grasses and dicots	Preemergence/Early postemergence
Matecor	Metribuzine	700 g/ha	Grasses and dicots	Preemergence/Early postemergence
Maestro 75 WG	Metribuzine	700 g/ha	Grasses and broadleaf weeds	Preemergence/Early postemergence

Source: List of registered herbicides in Tunisia (2021) [27]

Our study revealed that early postemergence application of Metribuzin at 0.7 kg *a.i./ha* was more efficient to suppress broadleaf weed species and grasses than preemergence application of Linuron at 0.2 kg *a.i./ha*. In fact, it's recognized that Metribuzin is a standard component of preemergence and postemergece weed management programs in potato because it is effective on many broadleaf weeds and grasses (Karen and Gary, 1998) [15]. However, Metribuzine does not provide season-long control and resistance to triazine herbicides has developed in 69 species worldwide, limiting activity and requiring a combination of control practices for these weeds (Singh *et al.*, 2018) [26].

On the other hand, results showed that hand weeding practiced twice: the first at the planting and the second 3 WAP was more efficient to decreases weed density than that practiced only one time 6 WAP. However, the highest weed control efficiency was recorded when hand weeding was combined with herbicides application. In fact, mechanical or hand weeding during the first four weeks of planting followed by chemical control measures is the common practice among majority of the potato producers in the studied sites. Consequently, the recommendation is to manage weeds during initial growth stages and to practice more number of weedings to maximize weed control efficiency in potato. Thus, integrated weed management have been proposed as a viable method for overcoming weed problem in potato crops (Weerarathne *et al.*, 2016) [29].

4. Conclusion

There are many factors that interact and influence the weed population dynamics in cropping system. The inventory of the weed flora associated to potato crop allowed to identify a total number of 29 weed species belonging to 16 families and 27 genus. The most represented families were *Poaceae* (17%), *Amarantaceae* (14%), *Fabaceae* (10%) and *Asteraceae* (10%). Regarding to the life form, therophytes were the most frequent with 86% followed by geophytes with 14%.

Our study highlights that weed management practices have an impact on the weed spectrum. In fact, weed biomass decreases when the herbicide treatment was applied between 2 and 3 WAP. However, beyond 4 WAP, herbicide treatments do not seem to be effective in controlling weeds which allowed to conclude that, for conventional potato crops growing under a semi-arid Tunisian climate, the critical period of weed competition is first 4-6 WAP.

Metribuzin is one of the oldest potato herbicides and is still widely used by potato growers in Tunisia. Our study revealed that early postemergence application of Metribuzin at 0.7 kg *a.i./ha* was more efficient to suppress broadleaf weed species and grasses than preemergence application of Linuron at 0.2 kg *a.i./ha*.

Results showed that hand weeding practiced twice: the first at the planting and the second 3 WAP was more efficient to decreases weed density than that practiced only one time 6 WAP. However, the highest weed control efficiency was recorded when hand weeding was combined with herbicides application.

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Conflict of interest
Authors declared no conflict of interest for this study.

Consent for publication
Authors have given their consent to publish this article.

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