

Impact of mechanical and chemical weeding on the floristic diversity of citrus orchards in Tlemcen (Northwestern Algeria)

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Abstract:

This study was conducted to evaluate the impact of weeding (chemical, mechanical and control) on the floristic composition of citrus orchards in the region of Tlemcen (Northwestern Algeria). A comparative approach between two methods of weeding (mechanical vs. chemical) compared to a control (without weeding) was carried out at 3 stations of 100 m² inside the citrus orchard studied. The floristic surveys were performed in the stations at different times (before and after each weeding). In the floristic inventory, 168 surveys were carried out and a total of 88 species were identified belonging to 71 genera and 30 botanical families. This adventitious flora was dominated by the Mediterranean elements (64%), the therophytes (51%) and dicotyledons (64%). Statistical elaboration of floristic data by means of multifactorial ANOVA revealed the existence of a significant spatial-temporal difference in the mean species richness between the stations (control vs. chemical and mechanical). In addition, the species richness before weeding tended to be higher than that after it. Weeding methods practised by crop growers need to be reconsidered. The benefits that weeds can provide should be considered as well as the damage caused by the different weeding techniques.

Keywords: Biodiversity, weeds, weeding, citrus, Algeria.

Introduction

The presence of weeds in cultivated crops can affect the production and quality of the crop by competing for light, moisture, nutrients and space [1], in addition to the technical problems associated with their presence [2]. The problems caused by weeds are also related to the evolution of the adventitious flora under the pressure of cultural techniques [3]. High crop productivity requires control and proper use of weeds [4]. Mechanical weeding is the classic method to control weeds but in modern agriculture, chemical weeding of major crops has become a routine part of cropping techniques. Various socio-economic and environmental factors require an increased rationalization of chemical weed control to avoid reliance on unproductive treatments. At the plot scale, the criteria for any weed control programme should be the risk of weed damage to crop plants and potential damage to the harvest.

Any weed control programme must be part of a technical farming itinerary and be planned in economic terms, whereas the weed nuisance is evaluated using experimental data measured in population biology in an artificially created environment. A farmer is advised to manage weeds for useful purposes as service plants [4]. The repeated use of chemical weeding and of mechanical weeding provokes resistance in the weeds and considerably disturbs the role of the pedo-fauna in biofertilisation [2]. Thus, weed control in recent decades has led to the intensive use of herbicides that cause serious pollution problems and damage to biodiversity [5]. Chemical fertilizers are the main factors in maintaining soil fertility, but greater application with inadequate management reduces the availability of soil organic matter [6] and reduces the number of weeds [7]. In the face of this degradation of the soil and plant species, many developing countries need to rethink their management methods. They must restrict the use of herbicides and promote agroecosystems [8].

Good management of the adventitious flora certainly depends on good knowledge of the flora and its member species. For this purpose, several studies have been conducted in different regions in Algeria [9-11]. In general, the presence of a weed has both an ecological (soil and climate) and an agronomic (cultural practices) dimension. It is through the change of this environment that it is possible to quantify the impacts on agriculture [12]. Changes on agricultural practices influence the composition and evolution of weed communities [13, 14]. The impact of humans on the weed communities causes some characteristic species to disappear from poor environments (oligotrophiles) in favour of nitrophilic species. Specialist species also disappear in relation to generalist species and the massive decline in species and species diversity affects even common species [15].

Several management strategies have been developed. These include that of Bertrand and Doré [16], who discussed the control of weed flora through an integrated production system; Chauvel *et al.*, [17] who also studied the integrated management of weed flora, which greatly limited the use of herbicide treatments, thus contributing to the control of the seed stock of weeds; and Quennesson and Oste [18] who have worked on weed management through soil cover by exploiting allelopathy and plant competition relationships for resources. Many studies indicate that weed diversity can have positive impacts on the functioning of agroecosystems [7, 19, 20]. In addition, weeds can have beneficial properties on the biodiversity index and can also be a host to auxiliaries [21].

Chemical and mechanical weeding can affect the floristic diversity and they can decrease the species richness after each weeding. The point is not only that mechanical weeding favours therophytes and chemical favours geophytes. The objective of this work is to study the adventitious flora associated with citrus orchards by comparing the impacts of mechanical and chemical weeding on their floristic composition compared to a control without weeding.

Materials and methods

Presentation of the study area

Located at latitude 34°58'19"N, longitude 0°20'36"W and altitude 364m (Figure 1), the area under study is part of the plain of Hennaya in the agricultural basin of the region of Tlemcen (Northwestern Algeria) where citrus cultivation predominates. The climate of this region is Mediterranean, semi-arid with moderate winter under a semi-continental influence and with a seasonal regime of precipitation of the HPAE type (Hiver, printemps, automne et été). The dominant soils are brown, with a loamy to sandy-loamy texture, balanced, low in organic matter, and slightly alkaline with a low P₂O₅ reserve. Table 1 describes the studied orchard.

Experimental protocol

The experimental approach was designed to compare two weed control methods against a control without weeding. According to the minimal area recommended by Sorensen [22] to study perennial crops, three stations of 100m² were chosen inside the experimental plot located in a citrus orchard (Figure 1). Stations were subjected to mechanical weeding (M = y: 34.972006°; x:-1.343233°), chemical weeding (C= y: 34.972580°N; x: 1.342573°W) and control without weeding (Ct = y: 34.971189°N; x: 1.343983°W), respectively. The surveys were carried out in each station according to the method described by Braun-Blanquet [23] and Guinochet [24],

seasonally (autumn and spring). The quadrat technique consists in placing a square of 1m². All the species present inside this square were sampled to be identified and each species encountered was assigned a presence-absence index. A total of 168 surveys were conducted during the period from August 2016 to September 2017.

For chemical weeding, the product used is a total, systemic and non-selective herbicide in the form of a water-soluble concentrated liquid, in which the active substance is glyphosate™ as isopropyl amine salt (IPA) 48% w/v. The treatment was carried out using a knapsack sprayer. Mechanical weeding was done by a weeder (an agricultural machine used for removing weeds from an area), The treatments were carried out in two periods, the first in autumn (October) and the second in spring (April).

Systematic approach

New flora of Algeria and southern desert regions [25], the ‘portative flora’ of France, Switzerland and Belgium [26], flora and vegetation of the Sahara [27] and the flora of cultivated fields [28] were used for the identification, chorology determination and biological spectrum of inventoried species.

Statistical analysis

In order to evaluate the impact of the method of weeding on the weed flora, the collected data were statistically processed (ANOVA) using the *R* software by considering three factors: species (n=88; from all surveys), plots (n=3; chemical, mechanical vs. control) and time (n=2; before vs. after weeding) and the interactions between factors. Each species was codified by the first three letters of the genus, the first two letters of the species, and a number was assigned to each floristic survey.

Results and discussion

Floristic composition

From the 168 floristic surveys conducted in citrus orchards, 88 species have been inventoried. All the species encountered are angiosperms, including 8 families, 23 genera and 32 monocotyledonous species. There are 22 families, 48 genera and 56 dicotyledonous species (Figure 2).

The 88 species registered in this inventory belong to 71 genera and 30 botanical families. These families account for 73% of the weed flora of phytogeographic crops Oranais [11] and 76% of

the adventitious agrosystems flora of eastern Morocco [29]. *Poaceae*, *Asteraceae*, *Apiaceae* and *Fabaceae* were the dominant families (Table 2). These four botanical families alone represented 55% of all the species encountered. Some families were accidentally encountered such as *Palmaceae*, *Oleaceae*, *Moraceae* and *Orchideae* (Table 2).

Ethological spectrum

Raunkiaer [30, 31] proposed the bases for a biological classification of plants. The criterion of bud position during the most unfavourable season to the plant remains in the case of weeds the basic criterion of a biological classification [28].

Figure 3 shows the ethological spectrum established for all species. Therophytes are the majority and represent 51% of the inventoried flora. This contribution is lower than that previously established at 69% for citrus flora in eastern Morocco [29] and for that reported by KaziTani et al. [11] at 75%, respectively.

Despite the importance of therophytes, hemicryptophytes occupy an important place (22%) and geophytes rank third with a contribution of 17% of the total inventoried species. The phanerophytes, chamaephytes and nanophanerophytes represent 5%, 3% and 2%, respectively (Figure 3). In the same context, the perturbation index calculated by Loisel and Gamila [32] allows the researcher to quantify the therophytization of a medium by the following formula:

$$PI = [(Number\ of\ Chamephytes + Number\ of\ Therophytes) / Total\ number\ of\ species]$$

For the experimental area, the perturbation index is of the order of 54.54%. Therefore, the experimental area is almost half conserved, tending to a medium still in equilibrium with the biotic and abiotic conditions of the environment.

Biogeographic distribution

The phytogeographic study is an essential basis for any attempt to conserve biodiversity [33]. It represents a true model of interpretation of the phenomena of regressions [34]. Regarding the chorology, the weed flora of Tlemcen citrus groves consists of heterogeneous elements of various origins: Mediterranean, northern and southern (Table 3).

Species with Mediterranean distribution *sensulato* (including bi-regional and tri-regional) have a contribution of 64% (Table 3). This rate is close to that obtained in a previous study for weed communities of phytogeographic crops Oranais in which 58% of the taxa are Mediterranean [11],

52% for perennial crops in the Mitidja plain [35], 59% for the weeds of eastern Morocco [29], and 62% for the weed flora of western Morocco agrosystems [36]. As for the endemic elements of North Africa, they are represented by a single species (*Pistacia atlantica* Desf.), which accounts 1.13% of the total flora. However, for Algerian endemics, there is also a single species (*Hedysarum naudinianum* Coss.).

Spatio-temporal evolution

The results obtained by analysing the method of weeding (chemical, mechanical and control) for the three stations (plots) showed that the richness of species differs between plots according to the weeding applied: C and M with respect to the Ct (Figure 4). In fact, 81% of the inventoried species were present in the control station (Ct), 56% in the station with mechanical weeding (M) and 43% in the chemical (C) weeding station. Due to the level of significance of the F-test is less than 0.001 (Table 4) for plots, this indicates that there are very significant differences ($p=0.000$) between the different weeding methods. The significant difference for the typology of the three stations reveals the impact of the weeding mode on the floristic composition of the weed flora of citrus groves.

Considering the time of weeding, the species richness before weeding tended to be higher ($p=0.06$) to that after weeding for the Ct and the two methods of weeding. A graphical representation using the *R* software is added to identify the spatio-temporal change in mean species richness (Figure 4).

At the level of the chemical weeding station, it has been recorded the presence of perennial weeds in favour of annuals. Most perennials are found in the watering basin at the foot of trees. Paradoxically, annual weeds dominate in the station subjected to mechanical weeding. Therophytes and geophytes represent the most advanced groups in the Raunkiaer classification [37]. From the agronomic point of view, the geophytes and species with vegetative propagation are clearly abundant in a soil not regularly worked [38]. The tillage operations favour the annual appearance of therophytes, however, through the redistribution of the seed stock. This biological type is perfectly adapted to productive and disturbed habitats [39]. In the study area, farmers rarely use chemical weeding (herbicides). Mechanical weeding is the norm [40].

The species-plot interactions confirm the dissimilarity of the species richness and nature of the species recorded in the three stations, including their frequency of occurrence (Table 4). The species mainly present in all floristic surveys were: *Oxalis pescaprae* L., *Convolvulus arvensis*

L., *Cynodon dactylon* (L.) Pers. and *Cyperus rotundus* L. Otherwise several species were indifferent to the method of weeding and were present in the three stations (C, M and Ct) of the experimental plot (*Solanum nigrum* L., *Malva sylvestris* L., *Avena sterilis* L., *Sinapis arvensis* L., *Chenopodium album* L., *Daucus carota* L., *Fumaria capreolata* L., *Portulac aoleracea* L. and *Setaria viridis* (L.) P. B.).

As for the species-plot interaction and time, it turns out that the difference is highly significant with a *p-value* (<0.001) (Table 4), the method of weeding resulted to be an important factor that influence on the floristic diversity of the three plots under study and condition results at weeding.

Conclusion

The objective of this study is to evaluate the impact of mechanical and chemical weeding on the floristic diversity of citrus orchards vs. a control (without weeding) at different weeding times (before and after). The floristic surveys carried out during 2016-2017 have identified 88 species belonging to different botanical families. The results show that the agricultural practices influenced the weed flora of the citrus orchards. This is mainly due to the method of weeding, which affected the weed flora's composition and the frequency of species composing it. In general, four species occupied the first places; they are the most common perennial weeds present in Algeria: *Oxalis pescaprae* L., *Convolvulus arvensis* L., *Cynodon dactylon* (L.), and *Cyperus rotundus*L. The notion of biological type is also a point to consider because, in agronomy, it is closely related to the cultural context. Superficial and irregular weeding favours perennial weeds. The therophytes are adapted to productive and disturbed habitats because they are the only ones capable of growing between two weeding operations. Thus, farming techniques affect the composition, evolution and dynamics of the weed flora. The impact of the weed control method on the floristic diversity of citrus orchards cannot be the only factor governing the floristic composition and the dynamics of the adventitious flora. Other agricultural practices may have an effect and may need to be studied.

Consequently, this study requires other more precise studies to illuminate the questions studied. We recommend continuing the study for at least three years to see if there is reproducibility, expand the study area and complete the present study with an inquiry into the current situation of citrus growing in Algeria on all plans, and more specifically on the use of chemical inputs. The biological properties of weeds may make some species useful for the pharmaceutical and food industries.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Legend: (C: Chemical weeding; M: Mechanical weeding; Ct: Control).
Figure 1. Location of the experimental area.

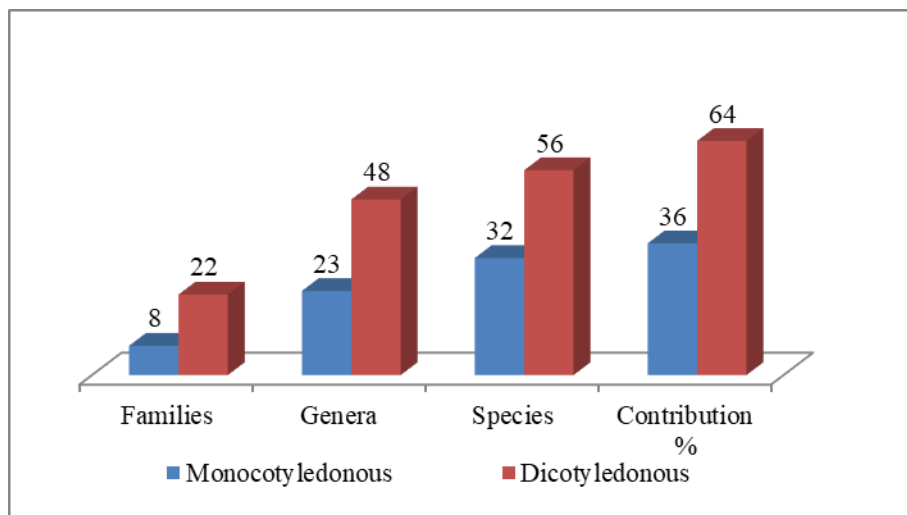


Figure 2. Floristic composition of the experimental area.

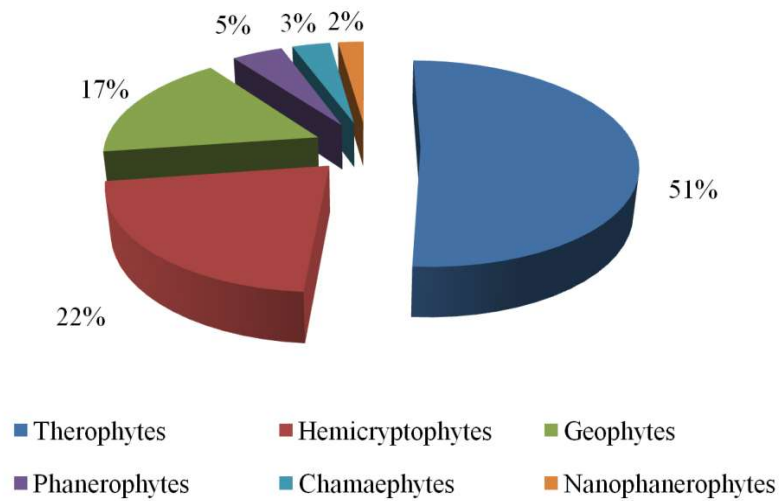
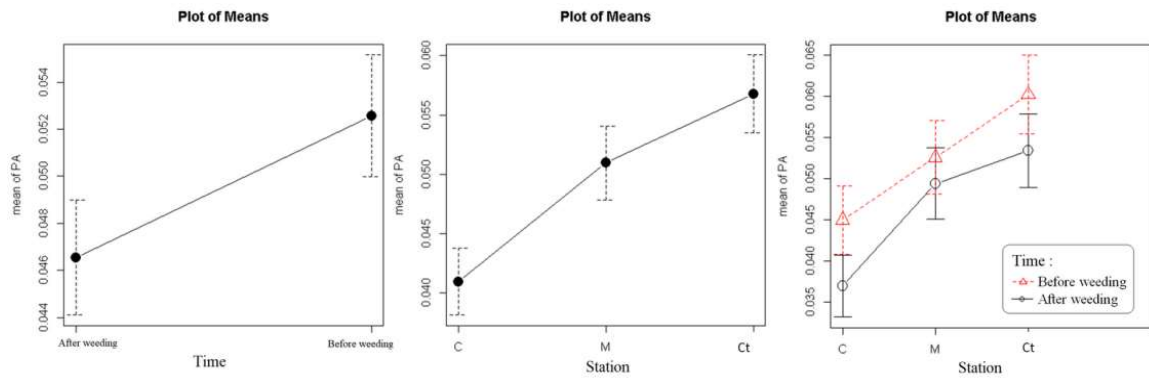


Figure 3. Global ethological spectrum of weeds.



Legend (C: Chemical weeding, M: Mechanical weeding, Ct: Control, PA: Presence/Absence).

Figure 4. Spatio-temporal evolution of species richness according to treatment.

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Table 1. Description of the studied orchard.

| | | | |
|------------------------------|---------------------|-----------------------------------|---------------------------------------|
| Status of Landholding | Private family farm | Irrigation mode | Drip irrigation |
| Age of the orchard | 14 years | Origin of irrigation water | OuedSekkak |
| Area of the orchard | 4 hectares | Types of fertilizing | Mineral and Organic |
| Density of plantation | 400 trees/hectare | Phytosanitary treatments | Insecticide Fungicide Acaricide |
| Row spacing | 5 metres | Weeding mode | Mechanical weeding |
| Altitude | 400 metres | Product destination | Regional market |
| Cultivated variety | Thomson | Soil texture | Loamy balanced |

Table 2. Total distribution of botanical families according to their specific contribution.

| Botanical families | Genera | Species | Contribution (%) |
|---------------------------|---------------|----------------|-------------------------|
| <i>Poaceae</i> | 12 | 19 | 21.59 |
| <i>Asteraceae</i> | 10 | 14 | 15.9 |
| <i>Apiaceae</i> | 9 | 9 | 10.22 |
| <i>Fabaceae</i> | 6 | 6 | 6.81 |
| <i>Liliaceae</i> | 4 | 4 | 4.54 |
| <i>Chenopodiaceae</i> | 2 | 3 | 3.4 |
| <i>Cyperaceae</i> | 1 | 3 | 3.4 |
| <i>Convolvulaceae</i> | 1 | 2 | 2.27 |
| <i>Malvaceae</i> | 1 | 2 | 2.27 |
| <i>Orchideae</i> * | 2 | 2 | 2.27 |
| <i>Polygonaceae</i> | 2 | 2 | 2.27 |
| <i>Anacardiaceae</i> | 1 | 2 | 2.27 |
| <i>Labiataeae</i> | 2 | 2 | 2.27 |
| <i>Solanaceae</i> | 2 | 2 | 2.27 |
| <i>Amaranthaceae</i> | 1 | 1 | 1.13 |
| <i>Primulaceae</i> | 1 | 1 | 1.13 |
| <i>Araceae</i> | 1 | 1 | 1.13 |
| <i>Aristolochiaceae</i> | 1 | 1 | 1.13 |
| <i>Boraginaceae</i> | 1 | 1 | 1.13 |
| <i>Geraniaceae</i> | 1 | 1 | 1.13 |
| <i>Moraceae</i> * | 1 | 1 | 1.13 |
| <i>Fumariaceae</i> | 1 | 1 | 1.13 |
| <i>Iridaceae</i> | 1 | 1 | 1.13 |
| <i>Araliaceae</i> | 1 | 1 | 1.13 |
| <i>Oleaceae</i> * | 1 | 1 | 1.13 |
| <i>Oxalidaceae</i> | 1 | 1 | 1.13 |
| <i>Portulacaceae</i> | 1 | 1 | 1.13 |
| <i>Rubiaceae</i> | 1 | 1 | 1.13 |

| | | | |
|---------------------|---|---|------|
| <i>Brassicaceae</i> | 1 | 1 | 1.13 |
| <i>Palmaceae</i> * | 1 | 1 | 1.13 |

Legend : * *Accidental families*

Table 3. Biogeographic origin of weeds and their contribution.

| Geographic origin | Number of species | Contribution % |
|---|--------------------------|-----------------------|
| Mediterranean | 30 | 34.09 |
| Cosmopolitan | 6 | 6.81 |
| European-Mediterranean | 5 | 5.68 |
| Mediterranean-Iranian-Turanian | 4 | 4.54 |
| Atlantic-Mediterranean | 4 | 4.54 |
| Sub-cosmopolitan | 3 | 3.40 |
| Eurasian | 3 | 3.40 |
| Paleo-Subtropical | 3 | 3.40 |
| Paleo-Temperate | 3 | 3.40 |
| Mediterranean Circum | 2 | 2.27 |
| Ibero-Moroccan | 2 | 2.27 |
| Eastern Mediterranean | 2 | 2.27 |
| Western Mediterranean | 2 | 2.27 |
| Thermo cosmopolitan | 2 | 2.27 |
| Temperate-Subtropical | 2 | 2.27 |
| Macaronesian-Mediterranean | 1 | 1.13 |
| Mediterranean-Asian | 1 | 1.13 |
| Submediterranean | 1 | 1.13 |
| Spain-North Africa | 1 | 1.13 |
| Eurasiatic- Mediterranean | 1 | 1.13 |
| Tropical-Subtropical | 1 | 1.13 |
| Endemic | 1 | 1.13 |
| Circumboreal | 1 | 1.13 |
| West Mediterranean-Subatlantic | 1 | 1.13 |
| South African | 1 | 1.13 |
| Endemic. North African | 1 | 1.13 |
| European-Siberian-Mediterranean | 1 | 1.13 |
| European-Asian-North American | 1 | 1.13 |
| Macaronesian-Mediterranean-Iranian-Turanian | 1 | 1.13 |
| North tropical | 1 | 1.13 |

Table 4. Multi-factor ANOVA (Response: Presence / Absence).

| Presence/Absence | | | | | |
|-----------------------|-------|-----|---------|----------------|------|
| | SumSq | DF | F value | P value | Code |
| Species | 90.5 | 87 | 26.1716 | $< 2.2e^{-16}$ | *** |
| Plot | 0.64 | 2 | 8.0620 | 0.0003167 | *** |
| Time | 0.14 | 1 | 3.4075 | 0.0649198 | NS |
| Species : Plot | 12.25 | 174 | 1.7708 | 0.000000002172 | *** |
| Species : Time | 16.67 | 87 | 4.8204 | $< 2.2e^{-16}$ | *** |
| Plot : Time | 0.02 | 2 | 0.1969 | 0.8212916 | NS |
| Species : Plot : Time | 10.79 | 174 | 1.5599 | 0.000003800582 | *** |

NS = Not significant; * = Significant ** = Highly significant; *** = Very highly significant at 5% probability level, 1% and 1 ‰, respectively.