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The Competitive Ability of Weed Community with Selected Crucifer Oilseed Crops

Inés Santín-Montanyá, E. Francisco de Andrés, Encarnación Zambrana and José Luis Tenorio

Additional information is available at the end of the chapter

Abstract

Dedicated production of energy crops on agricultural land is expected to be a crucial source of biomass to be exploited in order to achieve the renewable energy targets in the European Union. Vegetable oils are the main source for the production of biofuel; therefore, an alternative is to use oils from non-food oilseed crops. Oilseed crops examples include rapeseed, crambe and camelina.

Most oilseed crops are considered minor crops and have received much less research attention in numerous areas, including agronomy, development of weed management strategies and determination of environmental benefits and production challenges. The use of these crops may be positive when all the benefits to the cropping system (mainly in terms of soil coverage and inhibition of weeds emergence) are considered. The strongly competitive cultivars and appropriate fertilisation are strategies used to develop appropriate integrated weed management systems. However, currently, there are few data on evaluation of oilseed competition with weed community in a semiarid climate.

We conducted one study aimed at assessing the weed community in five oilseed crops: three rapeseed species (*Brassica carinata* A. Braun., *Brassica juncea* L. and *Brassica nigra* L.), crambe (*Crambe abyssinica* Hochst. ex R.E. Fries) and *Camelina sativa* (L.) Crantz. Seed yields, yield components and plant height of each oil seed species were recorded. We evaluate these species in two irrigation levels (fully irrigated and without irrigation) and three nitrogen fertiliser doses: 0, 75 and 150 kg N ha^{-1}.

Keywords: Fertilisation, Irrigation, Drought, Weed, Yield, Brassica, Competition

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1. Introduction

The crucifer oilseed crops are grown outdoors in nearly all temperate climates where there are fertile soils and adequate soil moisture. Production of these crops has increased, thanks to plant breeding advances and consumer demand. The growth and cultivation of these crops depend on many factors including the crop variety itself, the availability of light and water, the environmental temperature and the concentration of CO_2 – all of which interact in complex ways.

The majority of oilseed crops initially grow very slowly and establish a relatively reduced ground cover; they are therefore very sensitive to the presence of weeds [1]. In addition, the growth requirements of crops include abundant soil moisture, fertile soil and warm temperatures – requirements that also promote the appearance of a large number of weed species. Moreover, many weeds emerge throughout the crop cycle and can reach high infestation densities.

The characteristics of oilseed crops place them at a competitive disadvantage compared to most of the weeds that infest them: weeds grow more quickly and have a greater capacity to obtain resources from the growing environment. The damage caused by weeds competing for water, light and nutrients is well known.

The standard definition of a weed in agricultural land is an undesired plant [2-3]. Weeds cause ecological damage if they successfully colonise habitats or niches occupied by plants of agricultural interest. Weeds have characteristics that favour their dispersion and persistence, thus favouring their success in cultivated fields. These properties have been determined [3] and are summarised below:

- They can reproduce at early stages in their growth and mature rapidly.

- Some have several methods of reproduction; most use either seeds or vegetative propagation.

- They can withstand adverse environmental conditions.

- The seeds of many weeds are often the same size and shape as crop plant seeds, which facilitate their distribution.

- They germinate asynchronously over the year or over several years, allowing them to avoid adverse conditions and to emerge in successive fluxes during the crop growth cycle.

- Weeds have great capacity to compete for water, light and nutrients.

- They are found in numerous habitats.

- Many species of weeds have morphological characteristics that render them more competitive, e.g. they may show greater root development [4], be taller than the crop [5] or have a greater leaf area [6].

2. Factors involved in competition between crops and weeds

Plant species that grow at the same time are bound to enter into competition for resources such as **water**, light and nutrients, all the more so if these resources are limited. Such is the outcome when weeds infest cultivated crops, whether these are indigenous weed species that traditionally grow in the cultivated areas or invasive species from other, more distant habitats. As a consequence of competition, crop growth and/or yield can be reduced and plant morphology can even be altered [7].

When weeds compete with crops for water, they reduce the amount available to the crop, contributing towards water stress. The water deficit is a limiting factor to the production of crops, and the presence of weeds increases the water stress severity [8-9].

Light is a very important resource [10] for which crop plants and weeds compete. In the early stages of crop development, competition for light is practically null, but as the seedlings develop, they begin to shade one another. If the height of the weed is the same as that of the crop, both will be equally competitive. If the weed is smaller than the crop, the latter will be more competitive (this could be an advantage when trying to control weeds). The quantity and quality of light received are important factors affecting crop yield.

The availability of nutrients in the soil also affects the competition between weeds and crops. Soil nutrient supplies are generally limited and have to be shared by both. Those absorbed by the weeds are lost by the crop which must, in the end, reflect this deficit. In poor soils, yields improve with the application of nutrients, especially nitrogen, phosphorus and potassium, which clearly promote plant growth. However, some authors indicate that such applications benefit weeds more so than crops, increasing the farmers' negative impact [11]. In situations in which nutrient supply is limited, some weeds can absorb greater quantities of nitrogen. Some authors report that the ability to extract nutrients from the soil differs among weed species but is usually greater than that of crop plants [12-13-14].

Cultivated species, such as those of the family Brassicaceae, generally absorb great quantities of nutrients, depending on the quantity of seed fruit and dry matter they produce. This in turn is influenced by genetic and environmental variables. In the absence of other limiting factors, the absorption of nutrients and final yield are closely related. Therefore, the nitrogen fertilisation is intimately related to the yields obtained and their quality [14-15].

Mineral nutrition can be a determining factor during certain periods of the crop cycle, especially when the reproductive stage is reached. The quantity of fertilising nutrients to be applied will depend on variety, potential yield, quantities of nutrients already in the soil and growth conditions. The majority of the nutrients in fruits are usually absorbed by the plant during flowering; a period of great nitrogen, phosphorus and potassium requirement runs from the first ten days after flowering to just before seed ripening in Brassicaceae.

Nitrogen is the nutrient that most alters the chemical composition of plants. An inadequate supply to crops can cause a notable fall in production. Adequate supplementation is vital to obtain a good yield. Nitrogen may be one of the first resources for which competition occurs, and this is reflected in smaller leaf growth. Competition between weeds and crops for nutrients is not independent of interaction with other resources. Nitrates are a potential factor for

competition between crops and weeds when water is not a limiting factor. Weeds can reduce the amount of nutrients available to wheat by 30–40 % [16].

Other factors that characterise the relationship between crops and weeds are weed density and the length of time of those weeds persists [5, 17]. With respect to weed density, indices of competition with the crop have been determined.

Weeds emerge in successive fluxes during the crop growth cycle. This property provides them with a very important competitive edge: they can emerge before the crop, alongside it or after it. It is known that the first species to establish itself has the best chance of dominating, so if weeds emerge before the crop, the latter is likely to suffer large losses. However, the simultaneous and even the later emergence of weed has been observed to cause severe damage to crops. Crop losses have often been related to weed emergence times and consequently to the differential growth of weeds and crops.

3. Oilseed crops as potential feedstock and biofuel production

The transport sector relies heavily on diesel fuel, the demand for which is increasing steadily. This has led to the need for alternative fuels which are technically feasible, economically competitive, environmentally acceptable and readily available. Biodiesel, which is synthesised by trans-esterification of vegetable oils or animal fats sources, is an alternative to diesel fuel because it is produced from renewable sources and involves lower emissions than petroleum diesel during manufacture. In today's society, the constant concern of high petroleum prices, environmental considerations, unstable supply and geopolitical issues are all attributable to biofuel production being one of the most controversial and popular topics on the political agenda [1]. Political factors and a number of other incentives at the state level have also attributed to the interest in biofuel production. These factors have arisen at a time of significantly low agricultural commodity prices and have led to a relatively quick expansion in the interest and production of biofuels [18].

In temperate climates, biodiesel could be obtained from sunflower, soya or others; however, crops able to grow in marginal land and with high productivity are required [19]. Several crucifer oilseed crops could be a suitable alternative due to their adaptability to temperate and semiarid climates: a strong pivoting root enables high yields even under low rainfall; they have a strong resistance to diseases and pests and the tendency for pod not to shatter under high temperatures.

Brassicaceae crops, which include canola, rape and mustard, have been used as a rotational crop with wheat and barley. Rapeseed provides an alternative for cereal-based agricultural systems, as it is broad leaved and can be grown as a break crop for a continuous run of cereals [20]. These crops are produced extensively in Europe, Canada, Asia, Australia and the United States [21]. The benefit of rotating oilseed crops with cereal grains is that they allow a wider choice of herbicide use, improving overall system weed control. The addition of oilseed crops also helps loosen hardpan and can be direct-seeded or no-till farmed, reducing soil erosion impacts and breaking disease cycles.

Oilseed crops contain a high oil content which makes them a good candidate for producing feedstock oils for biodiesel. Only 5–6 % of the world production of oil crops is used for seed (oilseeds) and animal feed, while about 8 % is used for food. The remaining 86 % is processed into oil [22]. Biodiesel can be produced from a wide variety of oilseed crops. In Europe, rapeseed oil is the major biodiesel feedstock. In the United States, soybeans are the dominant biodiesel feedstock.

As a result of energy supply concerns, alternative energy sources such as mass biofuel production are in high demand. Large-scale production of biofuel crops will have serious impacts on the agriculture sector in terms of quantities, prices and production locations.

4. Damages caused by weeds in oilseed crops

Herbicides are the dominant tool applied to control weeds in modern agriculture. They are highly effective in controlling most of weed species. However, they are not a complete solution to the complex challenge that weeds present [23]. Recently, public concern has been raised about the environmental pollution caused by overuse of herbicides as well as the increase in herbicide-resistant weeds. Therefore, reliable IWM (integrated weed management) strategies are required [23-24].

Dedicated production of energy crops on agricultural land is expected to be a crucial source of biomass to be exploited in order to achieve the renewable energy targets in the European Union. Vegetable oils are the main source for the production of biofuel; therefore, it is very convenient to use oils from non-food crops [25]. Oilseed crops have great potential for biofuel production and are one of the best alternatives, as, for example, rapeseed, crambe and camelina [26].

Most oilseed crops, including crambe and camelina, are considered minor crops and have received much less research attention in numerous areas, including agronomy, development of weed management strategies and determination of environmental benefits and production challenges [27]. Oilseed crop production generally is rare in the drier semiarid regions due to their poor productivity under drought conditions [28], particularly in comparison with legume crops.

Weeds typically are readily controlled in cereal crops by applying herbicides, but they can be exceptionally difficult to manage in crucifer crop production [1]. Dominant weeds, such as wild mustard (*Sinapis arvense* L.) in the rapeseed crops, can cause major yield losses. A strongly persistent seed bank, competitive growth habit and high fecundity all contribute to its nature as a dominant weed and ensure that it will be a continuing problem [29]. With wild mustard densities of 10–20 plants m², rapeseed yield in Ontario, Canada, was reduced by 20 to 36 %, and similar lambsquarter densities reduced by 20–25% the rapeseed yield [30].

In the field, competition for available water and light is linked to nutrient supply. In addition to yield losses, weeds can reduce oilseed crop quality even at a low density. It has been observed that seeds of rapeseed contaminated with those of wild mustard had increased linolenic and erucic acid levels in the extracted oil and glucosinolate content in the meal [31].

Increased competitive ability among cultivars has been attributed to early seedling emergence, seedling vigour, rapid root growth and rate of leaf expansion, early root and shoots biomass accumulation and canopy closure and plant height [24, 32-33]. The variation in crop competitiveness depends on crop species (intraspecific competition).

Farmers require precise information on the ability of oilseed crops to compete effectively with weeds and on integrated weed-management programs, so as to encourage their adoption.

5. A case of study: The competitive ability of weed community with selected crucifer oilseed crops

Currently, the cultivation of oilseed feedstock to make biofuel is hampered by the lack of knowledge of production practices, including questions about fertilisation and environmental conditions [34]. The use of these crops may be positive when all the benefits to the cropping system (mainly in terms of soil coverage and inhibition of weeds emergence) are considered. The strongly competitive cultivars and fertilisation are strategies used to develop appropriate integrated weed management systems. However, there are little data concerning oilseed production in semiarid climate. We conducted a study to assess the weed presence in five crucifer oilseed cultivars in response to two irrigation levels and three nitrogen doses, over two years of study.

5.1. Study area

The study was conducted at the field-testing lands of the INIA (Figure 1), La Canaleja (Alcalá de Henares, Madrid, Spain: 40º 32'N and 3º20'W; 600 m). The soil was a loamy sandy Calcic Haploxeralf [35] characterised by a lime horizon within a metre of the surface. It had a loamy sandy texture in the two surface horizons (Ap, Bt), changing to sandy with depth (CCa). The soil had 5 % total carbonate, 1 % active limestone and an average pH of 7.8 in the upper 60 cm [36]. At initiation of the experiment, the soil contained low initial organic carbon content (around 7 g kg^{-1}). Mean interannual precipitation at the site is 386 mm (mean of 20 years), 50 % of which occurring from February through June. The study was located on land that grew winter wheat (*Triticum aestivum* L.) in the preceding years.

5.2. Experimental design and treatments

The experimental design was a randomised complete block in a split-plot arrangement (Figure 2). There were 5 cultivars studied, arranged in to two whole plots by two irrigation levels: irrigation (I) and no irrigation (NI). These whole plots were divided into three subplot levels – according to nitrogen fertiliser dosage. The N fertiliser doses were 0 g N ha^{-1}, 75 kg N ha^{-1} and 150 kg N ha^{-1}. Oilseed crops cultivars were *Brassica carinata* A. Braun, *Brassica juncea* (L.), *Brassica nigra* (L.), *Crambe abyssinica* Hochst. ex. R.E. Fries and *Camelina sativa* (L.) Crantz. The five oil crops were sown at the beginning of March in 1 x 15 m2 subplots with an interrow of 0.17 m, and the seed density was 400 seeds m^2. There were four replicates of each assay, and the experiment was repeated in 2 years, 2012 and 2013.

Figure 1. Cultivar trials in the experimental farm "La Canaleja"

5.3. Data collection of crop yield and weed measurements

Every year during the study, plants in all subplots were harvested to determine oilseed yield (g/m^2) and yield components (plant number/m^2; silique (number/plant); silique number/m^2; seed number/silique; 1,000-seed weight (g); straw $(g/m^2))$.

Each year, when 50 % of the plants in the subplots were in flower, data on weed density and number of species were determined from two samples of 0.1 m^2 quadrats per subplot, for each cultivar. Weeds were harvested, and we obtained the fresh weight. Then, the weed samples were placed in a forced air oven at 80 ºC for 48 h to obtain the dry weight.
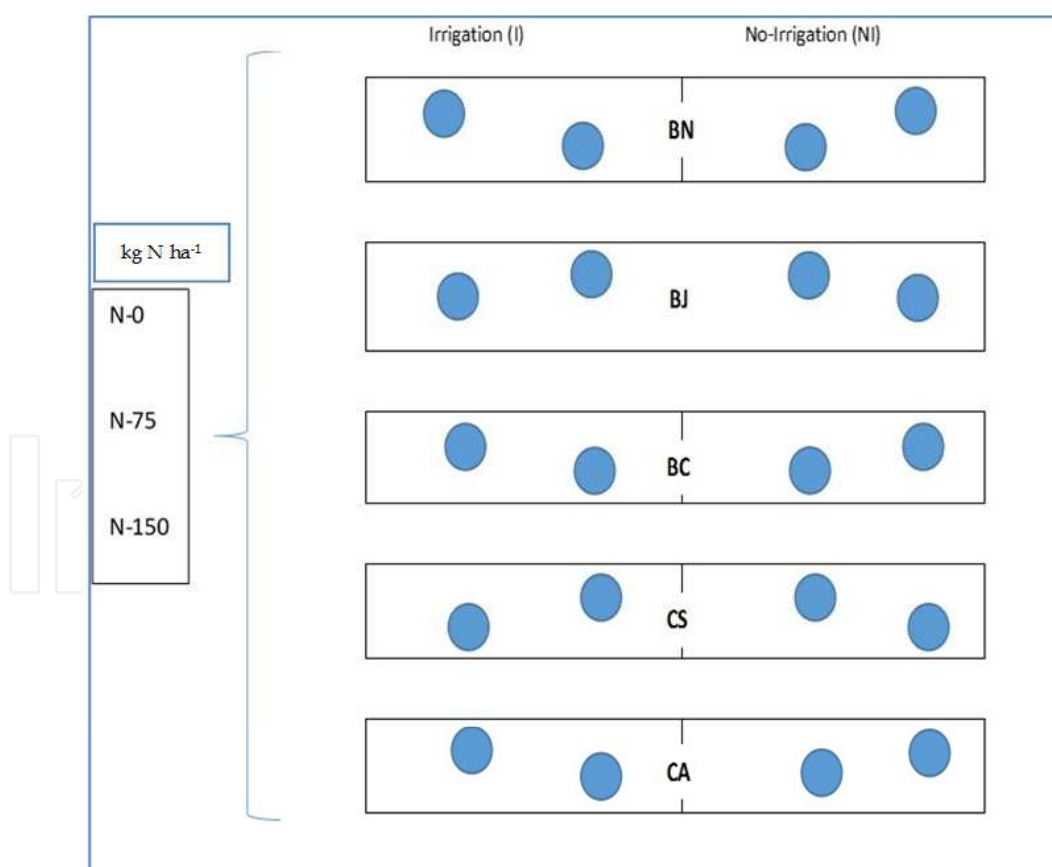
Figure 2. Weeds sampling scheme realised in each subplot **BJ**, *Brassica juncea* (L.); **BC**, *Brassica carinata* A. Braun; **BN**, *Brassica nigra* (L.); **CA**, *Crambe abyssinica* Hochst. ex. R.E. Fries; **CS**, *Camelina sativa* (L.) Crantz

5.4. Statistical analysis

Each year of study, a Proc Mixed GLM procedure was employed to compare the irrigation levels, N doses and oilseed cultivars and interactions, on seed yield components of *Brassica-ceae* crops and all weed data. Means were separated by using the Tukey test at 0.05 probability level (P<0.05). Weed density, fresh weight and dry weight were log transformed prior to analysis to normalise residues. All data were analysed using the SAS package (SAS Institute Inc., 2003) and Statgraphics Plus 5.0 software package (Statgraphics Plus for Windows, Statpoint Technologies, Inc., USA).

6. Results and discussion

Growing season precipitation and temperature varied. In the 2012 growing season, rainfall was very low, with almost no precipitation throughout the months of March and June (77.4 mm) and high temperatures in May. In 2013, rainfall conditions were adequate for the development of crucifer oilseed crops between the months of March and June; the precipitation recorded (158 mm) was twice that of the previous year (Figure 3).
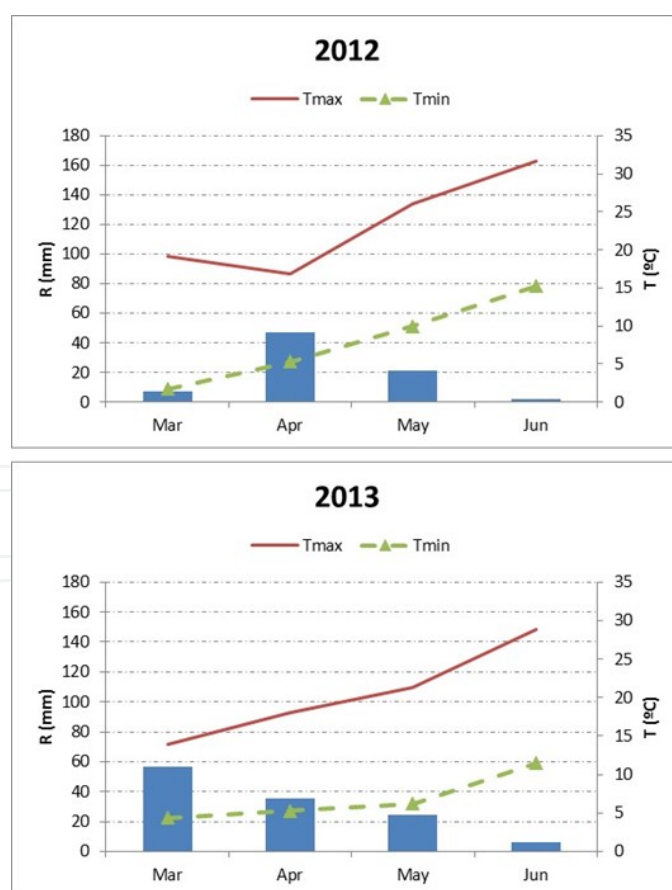
Figure 3. Monthly rainfall and maximum/minimum temperature at the study site in 2012 and 2013

Oilseed crop establishment varied by year in all cultivars of the study. In both years, the yield components of all species increased in response to irrigation (Tables 1 and 2). Our results indicate that the establishment of camelina was particularly higher than other species, evident as greater plant number per m2 and silique number per m^2 in both drought (2012) and wetter (2013) conditions.

		2012											
	Trt.	Plant number /m²		Silique number/ plant		Silique number/m²		Seed number/ silique		1,000-Seed weight (g)		Straw (g/m²)	
		I	NI	I	NI	I	NI	I	NI	I	NI	I	NI
BC	0	105.0	81.3	49.6	45.2	5300	3497	16.2	15.4	2.85	2.78	421.0	301.8
	75	110.0	98.8	75.3	25.2	8340	2422	16.5	11.5	2.53	2.12	716.7	294.3
	150	122.5	66.3	77.8	46.4	8770	2855	15.1	15.8	2.73	2.34	831.1	382.1
		112.5 A	82.1 B	67.5 A	38.9 B	7470 A	2925 B	15.9	14.2	2.70	2.42	656.3 A	326.1 B
BJ	0	268.8	212.5	47.8	15.1	12964	3188	11.2	8.8	1.83	1.62	680.7	261.8
	75	278.8	225.0	40.6	35.8	12309	7570	11.0	8.8	1.78	1.42	640.2	527.2
	150	181.3	116.3	49.5	53.4	8838	6431	10.4	9.4	1.76	1.49	540.6	413.5
		242.9	184.6	45.9	34.8	11370 A	5729 B	10.9 A	9.0 B	1.79 A	1.51 B	620.5 A	400.8 B
BN	0	161.3	160.0	83.0	39.7	13216	5870	8.9	7.1	1.05	0.98	619.0	272.3
	75	146.3	95.0	101.0	45.7	14448	4435	9.4	7.7	0.97	0.80	690.2	288.3
	150	140.0	97.5	83.8	79.0	10254	8194	9.1	7.3	0.97	0.79	823.2	494.0
		149.2	117.5	89.2 A	54.8 B	12639 A	6166 B	9.1 A	7.3 B	1.00	0.86	710.8 A	351.6 B
CS	0	287.5	283.8	70.0	47.5	20079	13377	14.1	14.4	0.85	0.83	494.6	408.7
	75	158.8	206.3	136.8	79.2	21830	14354	13.9	14.3	0.76	0.89	547.7	444.2
	150	142.5	90.0	118.3	160.4	15481	15176	14.1	11.2	0.87	0.70	516.2	449.2
		196.3	193.3	108.3	95.7	19130	14303	14.0	13.3	0.83	0.81	519.5	434.0
CA	0	216	200	147.6	83.4	32476	16874	1.0	1.0	5.02	4.66	241.1	185.9
	75	168	146	265.0	229.3	45156	32909	1.0	1.0	5.30	5.12	282.5	249.9
	150	158	189	225.8	164.7	36071	33043	1.0	1.0	4.83	4.85	279.2	301.3
		180	178	212.8	159.1	37901	27609	1.0	1.0	5.05	4.87	267.6	245.7

Table 1. Oilseed crops yield response to various irrigation levels (I, irrigation, and NI, no irrigation) and nitrogen rates (0, 75 and 150 kg N ha⁻¹), in 2012. Mean values followed by different letters indicate significant differences (P<0.05) according to the Tukey test. BJ, *Brassica juncea* (L.); BC, *Brassica carinata* A. Braun; BN, *Brassica nigra* (L.); CA, *Crambe abyssinica* Hochst. ex. R.E. Fries; CS, *Camelina sativa* (L.) Crantz

In 2012 (Table 1), data obtained of seed yields and yield components of *Brassica* species were significantly affected by drought conditions. Seed yield, compared to irrigated plots, decreased in different proportions in each crop: 70 % decrease for *Brassica carinata*, 65 % for *Brassica nigra*, 60 % for *Brassica juncea*, 50 % for *Camelina sativa* and 30 % for *Crambe abyssinica*. Some

authors [25] reported large decreases in yield in response to drought for a range of cool-season oilseeds, including *Brassica juncea* and camelina. In this sense, cool-season crucifers are not highly tolerant of heat or drought stress, and yields typically are highly variable depending on the year [8, 37-38].

In 2013 (Table 2), data obtained regarding plant number and yield components of *Camelina sativa* and *Crambe abyssinica* were higher than Brassica species. Apparently, these species were better able to use the soil water content and thus gained a competitive advantage over the *Brassica* species. Generally, the species that were high yielding were also high yielding in the presence of weeds in wetter conditions. On the other hand, nitrogen treatments did not significantly affect seed yield of these oil crops in either year of study.

		2013										
	Trt.	\multicolumn{2}{c}{Plant number/m²}	\multicolumn{2}{c}{Silique number/ plant}	\multicolumn{2}{c}{Silique number/m²}	\multicolumn{2}{c}{Seed number/ silique}	\multicolumn{2}{c}{1,000-Seed weight (g)}	\multicolumn{2}{c}{Straw (g/m²)}
		I	NI	I	NI	I	NI	I	NI	I	NI	I	NI
BC	0	143.8	97.5	52.7	37.3	7376	3530	16.8	17.0	2.29	2.11	598.0	293.9
	75	126.3	126.3	44.3	32.2	5445	3820	16.4	15.2	2.19	2.42	393.5	260.0
	150	102.5	96.3	58.3	36.4	5582	3299	18.2	16.4	2.16	2.17	450.2	227.9
		124.2	**106.7**	**51.7 A**	**35.3 B**	**6134 A**	**3550 B**	**17.1**	**16.2**	**2.21**	**2.23**	**480.5 A**	**260.6 B**
BJ	0	161.3	132.5	62.0	41.4	9923	5208	16.1	14.0	2.30	1.68	510.4	275.3
	75	145.0	136.3	36.5	24.6	5431	3318	13.4	13.6	1.93	1.82	258.2	154.7
	150	162.5	110.0	47.7	32.9	8176	3613	13.9	14.0	2.10	1.67	459.1	190.1
		156.3 A	**126.3 B**	**48.7 A**	**33.0 B**	**7843 A**	**4046 B**	**14.4**	**13.9**	**2.11 A**	**1.72 B**	**409.2 A**	**206.7 B**
BN	0	63.8	103.8	196.9	72.2	12633	7491	9.2	9.6	0.77	0.78	296.3	177.1
	75	117.5	98.8	86.4	55.2	10273	5454	9.1	8.5	0.74	0.70	318.2	191.8
	150	86.3	86.3	210.6	98.4	19234	8646	9.6	10.0	1.10	0.88	469.6	199.4
		89.2	**96.3**	**164.6 A**	**75.2 B**	**14047 A**	**7197 B**	**9.3**	**9.4**	**0.87**	**0.78**	**361.3 A**	**189.4 B**
CS	0	253.8	265.0	134.8	92.5	33856	23920	13.8	13.5	0.93	0.81	656.9	380.8
	75	332.5	192.5	115.9	111.0	37782	19185	13.4	13.8	0.97	0.85	823.6	449.9
	150	381.3	312.5	90.7	131.8	34584	39344	14.4	14.4	1.01	0.98	742.1	717.0
		322.5	**256.7**	**113.8**	**111.7**	**35407 A**	**27483 B**	**13.9**	**13.9**	**0.97**	**0.88**	**740.9 A**	**515.9 B**
CA	0	161.3	146.3	278.3	159.7	42800	23361	1.0	1.0	6.17	5.82	376.3	164.9
	75	237.5	235.0	245.6	174.9	54287	41198	1.0	1.0	5.88	5.41	398.2	277.7
	150	223.8	147.5	205.8	174.8	44452	25430	1.0	1.0	5.77	5.64	396.0	180.1
		207.5	**176.3**	**243.2 A**	**169.8 B**	**47180 A**	**29996 B**	**1.0**	**1.0**	**5.94**	**5.62**	**390.2 A**	**207.6 B**

Table 2. Oilseed crops yield response to various irrigation levels (I, irrigation, and NI, no irrigation) and nitrogen rates (0, 75 and 150 kg N ha⁻¹), in 2013. Mean values followed by different letters indicate significant differences (P<0.05) according to the Tukey test. BJ, *Brassica juncea* (L.); BC, *Brassica carinata* A. Braun; BN, *Brassica nigra* (L.); CA, *Crambe abyssinica* Hochst. ex. R.E. Fries; CS, *Camelina sativa* (L.) Crantz

The year had significant effects on weed community in all measured attributes. Overall, drought caused in the dry year (2012) compared to the wet year (2013), the reduction of weed density, number of species and fresh and dry weight of weed community (Table 3). In 2012, we observed in plots with no irrigation (NI) a significantly lower weed density and less species than plots with irrigation (I). The irrigation comparison results obtained the next year (2013) were not significant except for dry weight of weeds. In 2013, the high rainfall in March favoured the germination of weed species in all subplots, and all the parameters measured in weed community were higher than the drought conditions of 2012.

In 2012, increased nitrogen fertilisation rates reduced the measured parameters on weed community. Plots without fertilisation (N-0) showed a higher number of weeds, more species and higher fresh and dry weight compared to N-fertilised subplots. It seems that a reduced rate of fertilisation favours, in drought conditions, the competitive ability of some weeds and their prevalence among the growing crops. This could be attributable to presence of weeds favoured by rooting conditions, and as consequence, weed species are better soil water extractors than the oilseed crops. Due to its slow initial growth, the oilseed crop is exposed to infestation by fast weeds. However, the fertilised subplots (N-75 and N-150) in drought conditions showed that crops were better suited to use the nitrogen supplement than the weed community, and the nitrogen doses were adequate to favour the growth of crops. Also, the N-level increase could induce to break the dormancy of some weed seeds species whose seedlings could have succumbed later due to lack of adequate soil moisture.

The opposite response was obtained in the following (wetter) year of 2013; plots with no fertilisation (N-0) and reduced fertilisation (N-75) presented lower weed community parameter values than high fertilisation (N-150). Wetter conditions facilitate the growth of crops and consequently reducing the competitive ability of weed community.

Table 3 compares five selected oilseed cultivars in terms of weed density, number of species and fresh weight and dry weight of weed community in both years of study. In drought conditions, all weed parameters were significantly greater in *Brassica nigra* than the rest of oilseed cultivars. However, *Brassica carinata* was the cultivar most capable of inhibiting the development of weed community, thus freeing up physical space.

These results highlight that *Brassica nigra* cultivar are not well adapted to our continental climatic conditions, because of its slower growth, and therefore, its yield was lower than the rest of the cultivars. In all cases, the lowest weed infestation occurred in plots where the *Brassica carinata* was grown.

The natural community of weeds present in the assay is comprised by dicotyledonous weed species typical of crop fields in the area (Table 4). High April rainfall favoured early-emergence weeds, such as *Gallium aparine* L., *Lamium amplexicaule* L. and *Papaver rhoeas* L., and a general increase of humidity conditions in the plots favoured the late germination of annual species as *Fumaria officinalis* L., *Anacyclus clavatus* (Gouan) DC. and particularly two crucifer weed species *Descurainia sophia* (L.) Webb. ex Prantl. and *Diplotaxis erucoides* DC.; these species could be especially difficult to control in crucifer oilseed crops.

	2012				2013			
	Weed density	Number of species	FW (g m⁻²)	DW (g m⁻²)	Weed density	Number of species	FW (g m⁻²)	DW (g m⁻²)
Irrigation levels (I)	**	*	n.s.	n.s.	n.s.	n.s.	n.s.	*
I	60,0	2,5	191,7	40,9	218,3	4,3	450,5	80,7
NI	44,0	2,1	159,0	36,0	264,0	4,5	579,7	126,5
SEM	3,2	0,1	15,2	2,8	33,3	0,2	68,6	12,6
N doses (F)	***	***	**	***	n.s.	*	*	*
N-0	65,5	2,9	221,1	50,9	258,7	4,1	492,3	98,6
N-75	48,0	2,1	123,0	26,7	174,0	4,1	360,5	76,9
N-150	42,5	2,0	181,7	37,6	290,7	5,0	692,7	135,4
SEM	3,9	0,1	18,6	3,4	40,8	0,2	84,0	15,4
Cultivars (C)	***	**	***	***	*	n.s.	*	*
BJ	46,6	2,3	110,9	25,4	180,8	3,9	353,0	68,9
BC	39,1	1,6	99,6	23,2	206,6	4,4	326,1	71,5
BN	65,0	3,0	278,5	58,8	250,8	4,5	795,2	153,9
CA	45,8	2,0	189,3	42,5	383,7	4,5	651,1	130,4
CS	63,3	2,6	198,5	42,1	183,7	4,7	450,3	93,3
SEM	5,1	0,1	24,1	4,4	41,7	0,2	85,7	15,8
I x F	***	**	*	**	n.s.	n.s.	n.s.	n.s.
I x C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
F x C	*	*	n.s.	*	n.s.	n.s.	n.s.	n.s.
I x F x C	**	n.s.	**	**	n.s.	n.s.	n.s.	n.s.

SEM: standard error or the mean. BJ, *Brassica juncea* (L.); BC, *Brassica carinata* A. Braun; BN, *Brassica nigra* (L.); CA, *Crambe abyssinica* Hochst. ex. R.E. Fries; CS, *Camelina sativa* (L.) Crantz

Table 3. Analysis of variance results (*, **, ***: significant at the 5, 1 and 0.1 % probability level, respectively) for irrigation levels, N doses and oilseed cultivars each year of study. Mean values for total weed density, number of species and fresh weight (FW) and dry weight (DW) parameters

Scientific name			
Amaranthus blitoides	Datura stramonium	Lactuca serriola	Rapistrum rugosum
Amaranthus retroflexus	Descurainia sophia	Lamium amplexicaule	Roemeria hybrida
Anacyclus clavatus	Diplotaxis erucoides	Lavatera spp.	Senecio vulgaris
Buglossoides arvensis	Fumaria officinalis	Papaver hybridum	Sisymbrium irio
Capsella bursa-pastoris	Galium murale	Papaver rhoeas	Sonchus spp.
Chenopodium album	Heliotropium europaeum	Polygonum aviculare	Stellaria media
Convolvulus arvensis	Hypecoum procumbens	Portulaca oleracea	Veronica hederifolia

Table 4. Weed community composition in the study

The annual distribution of rainfall may limit the effectiveness of the system used to control weeds, predisposing the specialisation of some species under certain crop conditions. Generally, the knowledge of the emergence process of weeds will increase the effectiveness of weed management, assuming an important qualitative advance in the integrated control of weed populations [39].

Previous researchers [40-41] have named management practices and climatic factors as the driving forces to explain weed species composition and richness in Northern and Central Europe. Thus, changes in flora may be the result, among other factors, of complex interactions between agronomic practices (choice of species and fertilisation) and environmental factors [42-43].

7. Conclusions

In summary, the interactions between irrigation, fertilisation and oilseed cultivars will affect weed density and growth. Our results support the idea that the competitiveness of different rapeseed species with weed community varies depending on the weather conditions and nitrogen fertilisation. The slow growth of certain rapeseed species and any consequential areas of bare ground could favour the spread of weeds and render its management rather difficult.

Additional adaptive management measures will be needed in the future to avoid an increased spread of weeds in oilseed crops. Bearing this in mind, our findings highlight the importance to select the adequate oilseed species in each environment. In this regard, farmers have to be given access to and choice of the most appropriate and cost-effective technologies for their particular circumstances.

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