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Determination of the critical period of weed competition and its impact on yield and yield components of rapeseed (*Brassica nupus* L.).

Kharman Mohammed Pirdwad[1], Ali Mala Khedir Galalaey[2]
[1,2] Department of Field crops and Medicinal Plants, College of Agricultural Engineering Sciences, University of Salahaddin, Erbil, Iraq.

[*] *Corresponding author: E-mail:* *kharman.pirdawd@su.edu.krd*, *ali.galalaey@su.edu.krd*

ABSTRACT

During the growth season 2023–2024 Grdarasha Field was the site of the field experiment in the Erbil region at Salahaddin University's College of Agricultural Engineering Sciences. The GPS reading was 415.8 meters above sea level, with latitude 36.10116 ◦N and longitude 44.00925 ◦ E.W. The purpose of the factorial experiment was to estimate the critical period of weed control (CPWC) in *Brassica napus* L. and the impact of various types of periodic weed interference on winter canola growth, yield, and yield component. Three replications and one factor of treatments were used to arrange the treatments in a randomized complete block design (RCBD). Weeds were manually removed from the crop at 0, 15, 30, 45, 60, 75, and 90 days following the emergence of canola. In each block, one weed free and weed infested control was for all the growing season. The findings indicated that 1000 seed weight and number of siliqua per plant was unaffected by periodic weed interference, and that the leaf area, plant height, main and lateral branches, number of seeds per siliqua, siliqua length, harvest index, biological yield and seed yield all significantly dereased as the duration of weed interference increased. Seed yield was significantly impacted and diminished by prolonged weed interference. According to the study, after (90 days after emergence) duration 6 and weed-infested plots produced much less, at 886.5 kg and 599.0 kg per hectare, but weed-free plots produced 3177.5 kg per hectare. The occurrence of weeds during the entire growing season led to a reduction of 74.71 percent in seed yield when compared to the plots that without of weeds .

The critical period for competition between weeds and the canola crop was identified as occurring between the 4 to 6 leaf stages at duration 2 (30 days after emergence).

KEY WORDS: Weed, Canola, CPWP, Yield Components.

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تحديد الفترة الحرجة لمنافسة الحشائش وأثرها على المحصول ومكونات المحصول في نبات الكانولا (*Brassica napus* L.)

خرمان محمد بيرداود[1]، علي ملا خضر كه لالي[2]
[1،2] جامعة صلاح الدين، كلية علوم الهندسة الزراعية، قسم المحاصيل الحقليةو النباتات الطبية، اربيل، العراق.

الملخص

خلال موسم النمو 2023–2024، كان حقل غردارشا موقعًا للتجربة الحقلية في منطقة أربيل، في كلية علوم الهندسة الزراعية بجامعة صلاح الدين. وكانت قراءة نظام تحديد المواقع **(GPS) 415.8** مترًا فوق مستوى سطح البحر، عند خط العرض 36.10116° شمالًا وخط الطول 44.00925° شرقًا. كان الهدف من التجربة العاملية تقدير الفترة الحرجة لمكافحة الادغال **Critical Period of Weed Control (CPWC)** في نبات الكانولا (*Brassica napus* L) ودراسة تأثير أنواع مختلفة من التداخل الدوري للادغال على نمو الكانولا وإنتاجيتها ومكوناتها. تم استخدام ثلاث مكررات وعامل واحد من المعالجات لترتيب التجارب باستخدام تصميم القطاعات العشوائية الكاملة **(RCBD)** تم إزالة الحشائش يدويًا من المحصول عند 0، 15، 30، 45، 60، 75، و90 يومًا بعد ظهور الكانولا. في كل قطاع، تم تخصيص معاملة خالية من الحشائش وأخرى مصابة بالحشائش طوال موسم النمو. أشارت النتائج إلى أن وزن 1000 بذرة وعدد القرون لكل نبات لم يتأثرا بالتداخل الدوري للحشائش. ومع ذلك، انخفضت مساحة الأوراق، ارتفاع النبات، الفروع الرئيسية والجانبية، عدد البذور لكل قرن، طول القرن، مؤشر الحصاد، الغلة البيولوجية، وإنتاجية البذور بشكل كبير مع زيادة مدة تداخل الحشائش. تأثرت إنتاجية البذور بشكل كبير وتراجعت مع زيادة مدة التداخل. وأظهرت الدراسة أنه بعد 90 يومًا من ظهور النبات، كانت الإنتاجية في القطع المصابة بالحشائش أقل بكثير، حيث بلغت 886.5 كجم و599.0 كجم لكل هكتار، مقارنةً بالقطع الخالية من الحشائش التي حققت 3177.5 كجم لكل هكتار. وأدى وجود الحشائش طوال موسم النمو إلى انخفاض بنسبة 74.71٪ في إنتاجية البذور مقارنةً بالقطع الخالية من الحشائش.

تم تحديد الفترة الحرجة للتنافس بين الحشائش ومحصول الكانولا بين مرحلتي 4 إلى 6 أوراق، وذلك عند مدة 30 يومًا بعد ظهور النبات.

الكلمات المفتاحية: الادغال، الكانولا، **CWPC**، حاصل ومكوناتها.

INTRODUCTION

Rapeseed (*Brassica napus* L.) constitutes a significant oilseed crop of considerable economic relevance globally, primarily cultivated for the extraction of edible vegetable oils, the production of bio-diesel, and as livestock feed (Mohamed, 2017) It has the potential to be an extraordinarily significant oilseed crop due to its oil content, which ranges from approximately 40-45%, and its protein composition, which is between 38-40%. This oilseed also possesses elevated levels of the amino acids methionine, cysteine and lysine, (Amjad, 2014). Rapeseed, similar to other species within Brassicaeae family could be an intercrop due to its extensive clearings, rapid growth and early canopy closure. The competition posed by weeds during the initial growth stages of oilseeds can be a significant challenge, as noted by (Khan et al., 2003).

The presence of weeds and their competition with crops are two major issues that impact crop yield and quality (Hager et al., 2002). Weeds compete with crops throughout their growth, but are most aggressive at certain times. During these times they can cause the greatest losses in crop yield. The timing at which weeds grow and how long they compete with plants can significantly affect seed yield. Additional days of early development enable plants to better compete against weeds, thereby providing them with a competitive edge (Mohler, 2001).

Effective management of weeds in the early season is crucial for safeguarding the potential yield of crops, especially during the seedling stage of canola, when the plants exhibit limited competitive strength. To create a good weed management system (IWM), it is important to carefully study how weeds affect crops. The critical weed control phase (CPWC) is an important part of a weed control program. This refers to the time in the growing season when weeds must be removed to prevent them from taking away nutrients and space from plants, which can lead to lower crop yields (Jhala et al., 2014).

Numerous factors influence the onset and length of the Critical Period of Weed Competition (CPWC). The crop and weed types, as well as the surrounding environment (Tursun et al., 2016) farming methods, and the methods for calculating the CPWC .

The purpose of this article was to look into how various times when weeds compete with rapeseed crops for growth, yield and yield component and estimate the crucial time for weed control in rapeseed as well.

MATERIALS AND METHODS

The research was conducted in the Erbil region, specifically at the Grdarasha Research Field, which is part of the College of Agriculture at the University of Salahaddin Erbil. The study utilized used Global Positioning System measurements, with coordinates at 415 meters above sea level, located at 36°4‘N latitude and 44°2’E longitude. This investigation conducted during the winter growing season of 2023 to 2024. For soil analysis, a representative composite sample was created by combining soil samples collected from 0-30 cm soil depth in the experimental field from 0-30 cm soil depth in the experimental field.

Selected physical and chemical characteristics of the soil analyzed prior to planting*

Soil properties	**Particle size distribution**			**Texture class**	**pH**	**EC dSm^{-1}**	**O.M%**	**Total (N)**	**Available (P) ppm**	**Available (K) ppm**
	Sand %	**Silt %**	**Clay %**							
0-30 cm	46.1	21.2	32.7	Sandy clay	7.6	0.2	1.2	0.14	4.7	172

Two crossed ploughs were used to prepare the experimental plots, and a rotavator was used to level the land and soften the soil, On November 15th 2023, the seeds were manually sown at a rate of 4 kg per hectare for rapeseed.

`A factorial experiment was carried out that used three replicates and followed a randomized complete block design (RCBD) separated by nine plots. Each plot measured 1.5 × 1.5 meters and consisted of four rows. Rows are spaced 40 cm apart (Hashim, 2016). To facilitate movement, the blocks are spaced 1 meter apart. The experiments involved taking care of the crops by removing weeds by hand at various intervals: 0, 15, 30, 45, 60, 75, and 90 days after the rapeseed plants started to grow. The study also looked at plants with weeds and plants without weeds.

After that randomly selected ten plants from each experimental unit were inspected based on the following traits were assessed on the labeled plant samples .

Growth traits:

1. Total leaf area per plant (LA) cm^2 plant^{-1}:

Samples of plant leaves were taken from all experimental units. The leaves were duplicated on A4 sheets with their known area and weight, the leaves were precisely traced and weighed. The area was calculated on portion and optionality scale, to get the leaf area of whole plant by multiplying the numbers of leaves by mean area of one leave (Pattons, 1984) .

2. The assessment of plant height (cm): was completed by measuring from the highest point of the plant to the soil's surface.

3. Number of Main branches per plant.

4. Number of lateral branches per plant.

Yield and its components:

1. Number of siliqua per plant.

2. Length of siliqua.

3. Number of seeds per siliqua: To find out how many seeds are in each siliqua (25), we randomly picked siliques from each plant in the experiment and counted them by hand. Then, we calculated the average number of seeds in each siliqua.

4. 1000seeds' weight (gm): One thousand seeds were weighed.

5 .Seed yield (kg ha^{-1}): Seeds from the central rows of the plants were harvested, ground, and sifted, after which their weight was measured. This weight was subsequently transformed into units of (kg ha^{-1}).

6 .Biological yield (kg ha^{-1}): The plants were gathered from the middle rows of each experimental unit were allowed to dry before being weighed. The yield was subsequently transformed to kg ha^{-1}.

7 .Harvest index (HI) (%): was determined based on the methodology outlined by Parsons and Hunt (1987) using the following formula :

$$\boldsymbol{HI = (Seed\ yield)/\ (Biological\ yield)\ \times\ 100}$$

8 -Weed Index (WI): The weed index represents the percentage reduction of yield attributed to the occurrence of weeds, in comparison to an un-weeded control. A higher weed index indicates a more significant loss. The difference between the yields of the treated and weed free plots is divided by the yield of the weed free plots to determine this index multiplying the result by 100. The result is expressed as a percentage.

$$\boldsymbol{WI = (X - Y)/\ (X)\ \times\ 100}$$

Where X and Y represent the yields of treated and weed-free plots, respectively.

Statistical Analysis:

Duncan's New Multiple Range Test (DNMRT), as defined in SAS (2001), was working to determine the wealth of determinable characteristics and to conduct the reasoning of difference inside the foundation of a randomized complete block design (RCBD).

RESULTS AND DISCUSSION

The CPWC for general weed interference was calculated using populations of natural and mixed weed species. Before canola was planted, weeds started to appear; these can be seen in the table below.

Table 1. The most prevalent weed species in the winter Rapeseed field in 2023–2024.

Common name	Scientific name	Family	Grown season
Narrow leaf weeds			
Wild barley	*Hordium spontaneum* L.	Poaceae	Annual Winter
Rigid rye grass	*Lolium rigidum* L.	Poaceae	Annual Winter
wild oats	*Avena fatua* L.	Poaceae	Annual Winter
Johnson grass	*Sorghum halepense* L.	Poaceae	Perennial
Broad leaf weeds			
Common name	**Scientific name**	**Family**	**Grown season**
Spurge	*Euphorbia helioscopia* L.	Euphorbiaceae	Annual Winter
wild carrot	*Daucus carota* L.	Apiaceae	Biennial
Docks	*Rumex dentatus* L.	Polygonaceae	Perennial
Milk thistle	*Silbyum marianum* L.	Asteraceae	Annual Winter
Indian sweet clover	*Melilotus indicus*	Fabaceae	Annual Winter
Red chickweed	*Anagallis arvensis* L.	Primulaceae	Annual Winter
Cheese weed	*Malva parviflora* L.	Malavaceae	Annual Winter
Common henbit	*Lamium amplexicaule*	Lamiaceae	Annual Winter
shepherd's-purse	*Capsella bursa-pastoris*	Brassicaceae	Annual Winter
split-leaf lettuce	*Lactuca scariola*	Asteraceae	Annual Winter
drug fumitory	*Fumaria officinalis*	Papaveraceae	Annual Winter
Spurge	*Euphorbia antiquorum*	Euphorbiaceae	Annual Winter
Black mustard	*Brassica nigra* L.	Brassicaeae	Annual Winter
White top	*Cardaria draba* L.	Brassicaeae	Perennial
field bindweed	*Convolvulus arvensis*	Convolvulaceae	Perennial
Cleavers	*Galium aparine*	Rubiaceae	Annual Winter

Plant Height (cm):

Periods of weed competition greatly influenced the height of the rapeseed plants. Table (2) analysis of variance results revealed notable variations in plant height across all competitive periods.

Canola and weeds did not significantly compete until the 4-leaf stage of canola because there were sufficient resources available throughout the early growth season, resulting in the maximum plant height (163.44 cm) being achieved in the weedy-free treatment and the lowest value (80.44 cm). Kaur et al. (2013) also reported comparable findings, indicating that the use of two hands for weeding in rapeseed resulted in an increase in plant height reaching 136.4 cm at 25 and 45 days after sowing (DAS). In contrast, under weedy conditions, the plant height measured only 116.6 cm.

Leaf Area (cm^2 $plant^{-1}$):

Leaf area was studied for its important role in the accumulation of necessary carbohydrates during the seed filling stage of crops. The maximum leaf area recorded was 57.20 cm^2 per plant in the weed-free condition maintained throughout the season, whereas the minimum was 13.13 cm^2 per plant in the weedy check. This variation can be linked to the prolonged presence of weeds and the shortened time of weed-free conditions, which intensified competition between the weeds and canola, ultimately leading to a decrease in leaf area. A comparable outcome was discovered by Martin (2000) observed that as the duration of weed coexistence with the canola crop increased, the leaf area index of the crop decreased.

Number of Main Branches per plant.

One important factor influencing the number of main branches in each plant was the duration of crop weeds competition. The weed-free plot and Duration 1 (15 DAE) had the largest number of major branches (4.7733 and 4.1067) per plant, while the weedy check plot had the lowest number (1.22). The increase in branch number can be attributed to the lack of competition for nutrients among plants (Al-jumaili and ALmohammedi, 2023). This was supported by Akhter et al. (2016), who observed fewer branches in weeded plots compared to increase branching in plots with two-hand weeding.

Number of Lateral Branches per Plant:

Lateral branches number in each plant differed significantly between the weed-free and weed-infested treatments. The greatest number of lateral branches, a totaling 12.11, was noted in the weed-free plots, whereas the lowest count of 3 was recorded in the weedy plots. This disparity can be attributed to intense competition for light and space between the crops and weeds, which intensified with prolonged weed interference. Conversely, in areas where weed-free conditions were maintained for an extended period, there was an increased opportunity for lateral growth, leading to a higher quantity of secondary branches. These findings align with the research conducted by Brandler et al. (2021) note that the decrease in secondary branch production is linked to competition affecting canola plants.

Table 2. Impact of various periodic weed interference on Canola growth parameters.

Treatment	Trait			
	Plant height (cm)	Leaf area ($cm^2 plant^{-1}$)	Main branch per plant	Lateral branch per plant
Control	112.55^{b}	13.13^{d}	1.22^{b}	3^{b}
Weed Free	163.44^{a}	57.20^{a}	4.77^{a}	12.11^{a}
Duration 1 (15 DAY)	124.33^{ab}	43.88^{ab}	4.10^{a}	8.33^{ab}
Duration 2 (30 DAY)	123.89^{ab}	37.28^{bc}	3.88^{a}	7.99^{ab}
Duration 3 (45 DAY)	107.33^{b}	37.44^{bc}	3.62^{a}	5.83^{ab}
Duration 4 (60 DAY)	80.44^{b}	27.40^{bcd}	3.77^{a}	8.66^{ab}
Duration 5 (75 DAY)	94.72^{b}	25.05^{bcd}	3.22^{ab}	5.10^{ab}
Duration 6 (90 DAY)	96.77^{b}	20.79^{cd}	2.88^{ab}	4.77^{ab}

*Means sharing the same letters are not significantly different at $p \leq 0.05$.

Number of Siliqua per Plant:

The amount of siliqua produced by each plant is the key feature that affects the seed production in rapeseed. Siliqua plant^{-1} varied by the weed free and different weed interference durations compared with weedy check but the analysis of variance stated that weed free, different weed interference periods and weed check showed non- significant differences. In contrast to Shaheenuzzamn et al. (2010), who compared the weed-free and no-weeding treatments, the results show that there were 142 pods per plant under weed-free conditions and 110 pods under weeded conditions.

The length of the siliqua (cm^2 plant^{-1})

The highest value 4.50 and 4.45 cm2 plant^{-1} were recorded from Duration 3 (45 DAE) and duration 4 (60 DAE) treatment, while the least value (3.56) cm2 plant^{-1} was recorded from the weed check treatment, respectively. The observed variation is due to the intense competition from weeds during the critical mid-growing phases of the crop. This finding contradicts Zare et al. (2012), they reported that impact of weeds was found to be insignificant ($P>0.05$) on pod length, suggesting that this characteristic is unaffected by the presence of weedy environments.

Number of Seeds per Siliqua:

The prolong of crop weed infestation had a significant effect on the number of seeds per siliqua. Duration 1 (15 DAE) produced the largest number of seeds per siliqua (12.33), while the weedy check plot produced the lowest value (8.82). Increasing of weed interference duration reduce number seed per siliqua due to reduction in light intensity will decrease in photosynthesis and reduce of number of seed per siliqua. Yaghoobi and Siyami (2008) supported this finding, noting that seed per siliqua increased with increasing weed free period duration .

Weight 1000 seed (gm):

As 1000- grain yield weight is also very important yield component in every crop. Significant differences were not observed among different duration of crop weed competition on the weight 1000 seed. Jauhar and Al-Mafrajy (2023) found similar results, showing that periodic weed interference did not affect the number of seeds in soybean pods or their thousand seed weight.

Seed yield (Kg ha^{-1}) :

Statistical evaluation of the data revealed that yield was substantially impacted by duration of crop weed competition. Data on table (4) indicates that the pure stand plots yielded the highest seed production at 3177.5 kg ha^{-1}, whereas the weedy check and Duration 6 (90 DAE) plots recorded the lowest yields of 599.0 and 86.0 kg ha^{-1}, respectively. In the initial weeks after emergence, the roots and shoots of crops and weeds do not compete. After this period, crops can tolerate weeds without significant growth reductions. However, prolonged weed presence in the field will lead to crop yield loss. The evaluation of yield reduction across different weed-infested regions, measured by the weed index, indicated that an extending the length of times without weeds resulted in higher seed yields. The most significant yield losses were observed at 74.7 and 70.2 in the weed control and duration 6 (90 days after emergence), respectively, while the least loss was noted at 2.33 in Duration 1 (15 days after emergence). To put it differently, the presence of weeds until the 4 leaf stage does not substantially impact canola yield, because canola and weeds don't compete much until the four-leaf stage, given that there are adequate resources available during the initial growing period. Comparable findings were documented by Ahmad Khan et al. (2003) and Martin et al. (2001). They demonstrated that weed control increased grain yield, while yield loss increased with the length of time that weeds interfered with canola. Duration 2 (30 DAE) was determined to be the start of the critical weed infestation period (Figure 1 and Table 3)

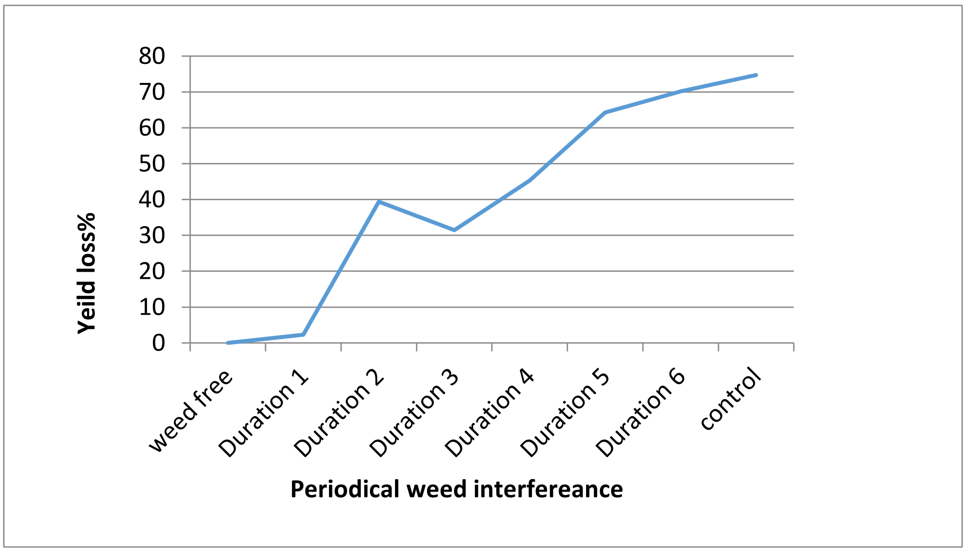

Figure 1. Effect of Periodical weed interference on yield loss.

Biological yield (Kg ha^{-1}):

A notable variation was identified among the various periodical competitions regarding biological yield (Table 4). The highest biological yield, recorded at 18,778 and 18,171 kg ha^{-1}, was seen in the weed-free and Duration 1 (15 DAE) plots, respectively. Conversely, the lowest biological yield of 9,076 kg ha^{-1} was recorded in the weed check plots. The biological output decreased as the length of time that weeds were allowed to interfere and the time without weeds diminished. Comparable results were documented by Hamzei et al. (2007), who noted that maximum biological yield of 2296.4 kg ha^{-1} under weed-free condition.

Harvest Index (HI) :

Among Different duration of weed competition showed that significant effects on the harvesting index (HI) expressed in percentage (HI %). Data on the (Table 4) indicates that the maximum HI (15.90 %) was seen in the weed free plots, while the lowest HI (9.79 %) was documented during the weed inspection. The harvest index decreased in the presence of weeds. This decline was associated with the increased vegetative growth of the cultivars, which was greater than their generative growth which was due to the improved movement of photosynthetic substances to the shoots (Zare et al., 2012).

Table 3. Impact of various periodic weed interference on yield and its components.

Treatment	Traits						
	No. of siliqua per plant	Siliqua length (cm)	No. of seed per siliqua	Weight 1000-seed (gm)	Seed yield (kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest index %
Weed Check	126.6^{a}	3.56^{b}	8.82^{c}	2.72^{a}	599.0^{c}	9076^{b}	6.791^{d}
Weed Free	385.6^{a}	4.22^{ab}	11.84^{ab}	3.78^{a}	3177.5^{a}	18778^{a}	15.90^{a}
Duration 1 (15 DAY)	206.1^{a}	3.88^{ab}	12.33^{a}	3.85^{a}	2244.5^{ab}	18171^{a}	12.35^{abc}
Duration 2 (30 DAY)	145.89^{a}	3.89^{ab}	9.41^{bc}	3.32^{a}	1384.5^{bc}	13907^{ab}	10.33^{bcd}
Duration 3 (45 DAY)	166.3^{a}	4.50^{a}	11.84^{ab}	3.76^{a}	1815.0^{bc}	12598^{b}	14.29^{ab}
Duration 4 (60 DAY)	162.1^{a}	4.45^{a}	11.11^{abc}	3.56^{a}	1302.8^{bc}	12726^{b}	10.611^{bcd}
Duration 5 (75 DAY)	130.3^{a}	4.10^{ab}	9.11^{bc}	3.54^{a}	1035.6^{bc}	14018^{ab}	7.131^{d}
Duration 6 (90 DAY)	124.8^{a}	3.69^{b}	10.12^{abc}	3.08^{a}	886.5^{c}	11244^{b}	8.063^{cd}

*Means sharing the same letters are not significantly different at $p \leq 0.05$.

CONCLUSIONS

In our field, we found high populations of natural weeds. The composition of the weed flora at the experimental site exhibited considerable variability, with grasses being the most prevalent. The presence of Avena fatua has led to a decrease in seed germination in the field due to its potent allelopathic effects, which inhibit the germination of *Brassica napus*. This crop is particularly sensitive to competition from weeds; therefore, it is essential to select cultivars that demonstrate greater tolerance to such competition.

The findings demonstrated that intermittent weed competition significantly affected all measured parameters, with the extent of impact increasing with the duration of weed interference throughout the season, ultimately leading to a reduction in all growth characteristics. The optimal time to apply in-crop herbicides to canola is at the 4-leaf stage.

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