Allelopathic Effect of Barley *(Hordeum vulgare*) and Rapeseed (*Brassica napus*) Crops on Early Growth of Acetolactate Synthase (ALS)-Resistant *Glebionis Coronaria*

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ABSTRACT

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Glebionis coronaria is a serious threat to cereal production in Northern Tunisia. Previous results showed that *G. coronaria* has developed resistance to acetolactate synthase (ALS)-inhibiting herbicides which limits their use in cereal cropping systems. The use of allelopathic crops has been reported as a potential alternative to herbicides to control resistant weed populations. The aim of this study is to evaluate the effect of five allelopathic crops on the early growth of *G. coronaria*. In vitro experiments using aqueous extracts of different crops and in pots experiments with increasing rates of barley (*Hordeum vulgare*) and rapeseed (*Brassica napus*) residues were performed for this purpose. All tested crops showed allelopathic effects on *G. coronaria* and were able to reduce its root length at the concentration of 50 g/L. Barley and rapeseed were the most effective crops, with 70% and 60% of root length reduction, respectively. An aqueous extract concentration study with five increasing concentrations of 12.5, 25, 50, 75, and 100 % was performed with these two crops, and root length was significantly reduced with increasing concentration, being up to 80% with the highest aqueous extract concentration of barley. The in vitro results were supported by the in pots experiment: Shortest roots length and highest dry mass reduction were obtained by the highest barley (0.64 g/kg) and rapeseed (8 g/kg) residue concentrations. This study confirmed the allelopathic potential of both barley and rapeseed in reducing the early growth of ALS-resistant *G. coronaria*, suggesting the effectiveness of these crops if integrated with other control measures for the management of resistant population of *G. coronaria* in cereal fields.

Keywords: Allelopathic crops, aqueous extract, crops residues, root length, weed management

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Allelopathy is defined as the direct or indirect harmful or beneficial effects of one plant on another through the release of chemical compounds into the environment (Rice 1984). Several allelochemical phytotoxic substances isolated from plant tissues and soils inhibit the germination and the growth of other plants in the surrounding environment (Mushtaq et al. 2020). These substances are usually secondary plant products or waste products of the main metabolic pathways of plants (Ashrafi et al. 2007; Chon and Kim 2002). The allelochemicals interfere with the growth of other plants after being released as residues, exudates and leaches from leaves, stem, roots, fruits and seeds (Asgharipour and Armin 2010).

Recently, allelopathy is recognized as an appropriate potential technology to control weeds using chemicals released from decomposed plant parts of various crop species (Naseem et al. 2009). Additionally, allelopathic crops integrated in weed management as cover crops, mulch, smother crops, intercrops or green manures, or grown in rotational sequences, build up soil fertility include organic matter, thereby reducing soil erosion, and improving crop yields (Khanh et al. 2005). The use of plant aqueous extracts alone or in combination with reduced doses of herbicides has been widely reported, to provide effective control of weeds and to reduce the overreliance on synthetic herbicides for weed management (Naby and Ali 2020).

In Tunisia, weed flora is highly diversified and composed of annual, perennial and parasitic species that cause important yield losses, which is estimated up to 60% in cereal crops (INGC 2013). Weed management methods commonly used to control weed species in crops are essentially cultural and chemical. However, intensive use of herbicides to control weeds has adversely affected the environment and water quality, and has resulted in the evolution of herbicide resistant biotypes in many weed species, such as *Glebionis coronaria*, which is recently confirmed as cross-resistant to acetolactate synthase (ALS) inhibiting herbicides (Hada et al. 2020). Such concern has triggered interest towards the development of weed management alternatives that minimize the use of herbicides while sustaining crop production.

This study aimed to assess (i) the allelopathic effect of the aqueous extracts from different crops on early growth of *G. coronaria* in laboratory bioassays (ii) the effect of increasing concentrations of aqueous extracts of barley and rapeseed on *G. coronaria* root length, and (iii) the effect of the incorporation of barely and rapeseed residues into the soil on the early growth of *G. coronaria* in pots.

MATERIALS AND METHODS

Plant material.

Seeds of a cross-resistant population of *G. coronaria* to ALS-inhibiting herbicides (R) were collected from a cereal field in Fritissa region located in Bizerte Governorate, Northern Tunisia (37°10’50.91.00’’N; 9°42’026’92. 00’’E). As well, five known allelopathic crops were harvested from the experimental field site of the National Institute of Agronomy of Tunisia - INAT (36°49’49.01’’N; 10°11’02.07’’E). The crops are *Sorghum bicolor* (var. Jawher), *Brassica napus* (var. Trapper), *Secale cereale* (var. Allawi), *Avena sativa* (var. Chapela) harvested at their flowering stage, and *Hordeum vulgare* (var. Rihane) harvested at its vegetative stage.

Preparation of aqueous extract from crops.

Based on the method of Ben Hammouda et al. (2002), plants were carefully washed with tap water and dried on towel paper. The whole plants were oven dried at 60 °C for 24 h. Dried samples were ground into fine powder and stored dry at 4 °C until their use. The aqueous extracts of each crop were prepared by adding 2.5 g of plant powder in 50 ml of distilled water. The extracts were shaken at 200 rpm at room temperature for 24 h, filtered using four (04) layers of cheesecloth to remove fiber debris and centrifuged twice for 40 min at 9,000 rpm at 8°C. The supernatant was filter-sterilized through a millipore filter 0.22 µm. The filtered solutions (stock solutions) were freshly prepared before each experiment.

Preparation of growth medium.

According to the same previous reference, the growth media for the in vitro bioassays was prepared by adding 12 g of agar to 1 L of distilled water. The mixture was then autoclaved for 20 min at 120 °C and left cooling below 50 °C. For each crop aqueous extract, 20 ml of the stock solution (20% w/v) were added to the water agar. Controls received 20 ml of sterile distilled water. Bioassays were conducted in Petri dishes containing each 40 ml of the growth media.

In vitro experiments.

Seeds of the herbicide-resistant population of *G. coronaria* were sterilized using 3% of commercial bleach Sodium hypochlorite (NaOCl) solution for 2 min, and subsequently washed with sterile distilled water. Seeds were then immersed in 70 % of ethanol solution for 30 s and washed again with sterile distilled water. After sterilisation, seeds were allowed to pre-germinate on a moistened filter paper. The photoperiod was set at 16h/8h day and night respectively, under 350 µmol m^{-2} s^{-1} photosynthetic photon-flux density. Germinated seeds with 1-2 mm of root lengths were used for the experiments.

First experiment. Crops were screened for their phytotoxic ability to reduce the root length of pre-germinated seeds of *G. coronaria.* The growth medium was prepared as mentioned above.

Four (04) Petri diches were used for each crop water extract with ten (10) pre-germinated weed seeds on the surface of the water-agar. All Petri dishes were kept in a growth incubator at a temperature of 22°C/20°C day/night with 16h/8h light/dark photoperiod for 7 days. The root lengths of *G. coronaria* were measured and compared to control seeds.

Second experiment. The effects of increasing concentrations of the aqueous extracts of *B. napus* and *H. vulgare* on the weed root length were investigated. Five concentrations of aqueous extract (12.5, 25, 50, 75, and 100 %) were used for this experiment by diluting the stock solution of both crops, with four (04) replications each. For each replication, ten (10) pre-germinated seeds were used and root length of *G. coronaria* was measured after 7 days of incubation in growth incubator at a temperature of 22°C/20°C day/night with 16h/8h light/dark photoperiod.

The rate of root growth inhibition was determined using the following equation:

$$RL_{in} = \left(\frac{RL_c - RL_e}{RL_c}\right) \times 100$$

where RL_{in} is the rate (%) of root length inhibition, RL_c is the root length of the control plants, and RL_e is the root length of the plants placed at the corresponding extract concentration.

Pot experiments.

Pot experiments were conducted to evaluate the effect of the incorporation of crop residues into the soil on the growth of *G. coronaria* seedlings. The amount of residues used in this experiment were determined based on previous estimations of the average crop residues/ha in Tunisian fields (Ben Jeddi, 2005). The residues are about 500 kg/ha and 2000 kg/ha respectively for barley and rapeseed. Three (03) concentrations of residues for each crop (Table 1) were mixed with 1 kg of sand-perlite mixture per pot (1:2 w/w) and allowed to decompose for one week before transplanting the weed seedlings. Each pot of 7 cm-diameter was filled by 100 g of residue-soil mixture. The seeds of *G. coronaria* were pre-germinated as described above, and transplanted into pots at two-cotyledon growth stage. The experiment was conducted as a complete randomized design with 10 replications per residue mixture and crop. Ten (10) pots without residue were used as control. The pots were kept under greenhouse conditions (25°C/20°C day/night with 16h/8h light/dark photoperiod) and regularly irrigated to keep the soil moisture at field capacity. Fourteen days after transplantation, all seedlings were gently uprooted and the lengths of shoots and roots were determined, the weed samples were oven-dried (for 48 h at 70 °C) and the dry weight of each part per plants was recorded.

Statistical analysis.

Prior to each analysis, the normal distribution and homogeneity of the data were checked. All data were subjected to analyses of variance (ANOVA), using the SPSS software (IBM SPSS statistics 20). The comparison of means was performed by the Duncan post-hoc pairwise test at 0.5% of probability.

RESULTS

Effect of the aqueous extracts of crops on the root length of *G. coronaria.*

Results showed a significant reduction in the root length of *G. coronaria* seedlings in the presence of aqueous extracts for all tested crops compared to the control. Significant differences were also observed between the crops. The root reduction arranged from 30 to 74 % (Fig. 1).

The most pronounced inhibitory effect on the root elongation of *G. coronaria* seedlings was observed with barley aqueous extract (around 70%), followed by rapeseed extract (around 60%).

Effect of increasing aqueous extract concentrations of rapeseed and barley on root length of *G. coronaria.*

Results of the root length of *G. coronaria* under increasing concentrations of aqueous extracts of barley and rapeseed showed that reduction of root length (%) increased by increasing the concentration of aqueous extract of crops.

For all tested aqueous extract concentrations, barley have the highest inhibitory effect on *G. coronaria* growth of root length (Fig. 2). At a concentration of 25%, the inhibitory effect of barley exceeded significantly the inhibitory effect of rapeseed. The root length inhibition reaches up to 80% with the highest aqueous extract concentration of barley.

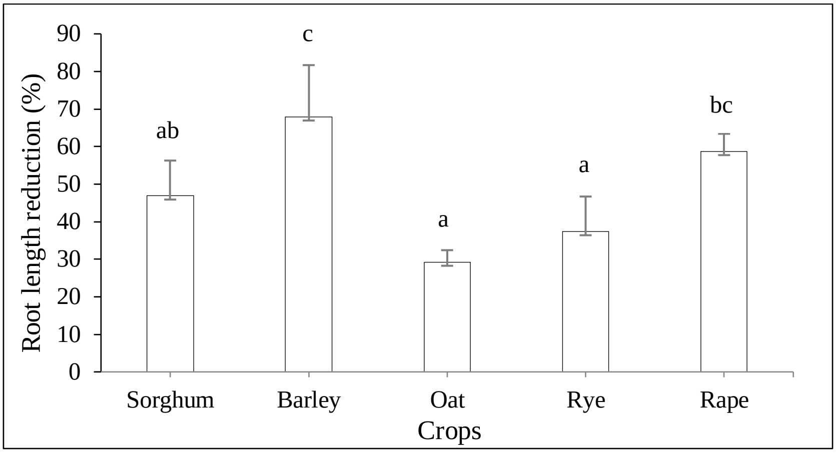

Fig. 1. The root length reduction (%) of *G. coronaria* seedling in the presence of crop aqueous extracts. Bars surmounted by the same letter are not significantly different at $P = 0.05$.

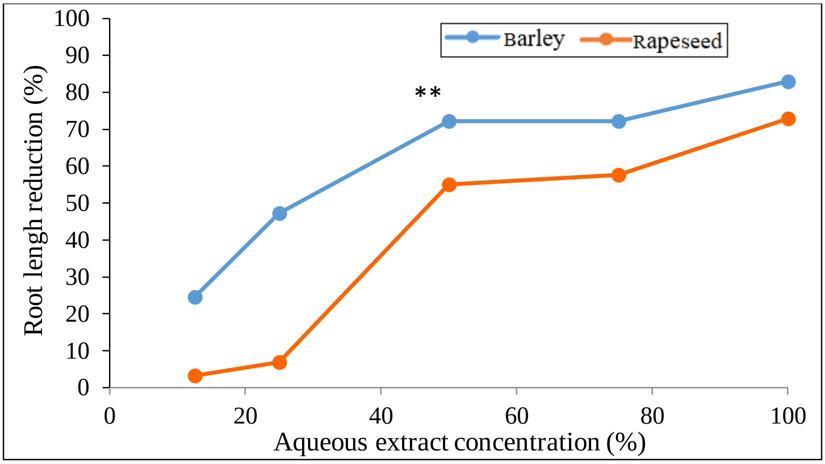

Fig. 2. Root length reduction (%) of *G. coronaria* seedlings at increasing concentrations of aqueous extract of barley and rapeseed. **: Difference highly significant ($P < 0.01$).

Effects of barley and rapeseed residues on *G. coronaria* growth.

Under controlled environment, the results of the experiment carried out in pots showed that the effects varied between crop residues and between the residue amounts. Barley and rapeseed residues caused significant reductions in root length of *G. coronaria* seedlings. However, significant stimulatory effects were observed on the shoot length. The root length was reduced compared to control by 84.5% and 73.2 % with the residues of barley and rapeseed at the concentrations of 0.64 g/kg (B3) and 8 g/kg (R3), respectively (Fig. 3).

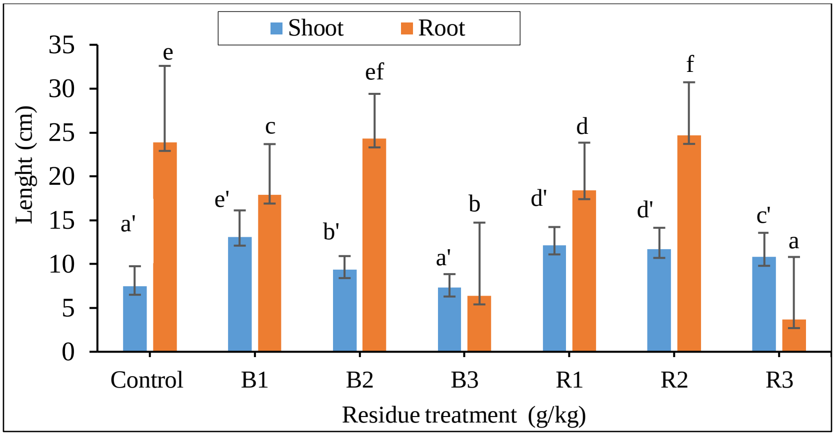

Fig. 3. The effects of increasing concentrations of barley and rapeseed residues on root and shoot length of *G. coronaria* seedlings. Bars surmounted by the same letter are not significantly different at *P* = 0.05. B1: 0.16 g/kg, B2: 0.32 g/kg, B3:0.64 g/kg; R1: 2 g/kg, R2: 4 g/kg, R3: 8 g/kg.

For barley, the lowest amount of residues incorporated in soil (B1 = 0.16 g/kg) caused a significant reduction of seedling root length with an average of 23%, whereas shoot length was significantly stimulated. With the B2 treatment (0.32 g/kg), root length was statistically similar to control and less stimulation was observed in shoot length, suggesting almost no effect of this treatment on *G. coronaria* seedling growth.

A comparative effect was observed between the different amounts of rapeseed residues. The treatment R1 (2 g/kg) inhibited the root length by 25.1% compared to control and stimulated the shoot length by 42.8%. A slight reduction was observed in root length with the treatment R2 (4 g/kg), and shoot length was stimulated by 20.2% with the same treatment.

Results of the dry matter confirm the results of root and shoot length recorded. Indeed, significant differences were found between different amounts of crop residues (Table 2). Both treatments R3 and B3 showed the highest effect on dry matter accumulation of *G. coronaria* seedling. The dry matter reductions were 45.7% and 52.7% with R3 and B3, respectively. With B1, B2 and R2 treatments, the dry matter of *G. coronaria* were increased compared to control.

Table 2. *Glebionis coronaria* average dry matter reduction at 14 days after incorporation in the soil of barley and rapeseed residues at different concentrations

Crop	Treatment	Dry weight (g)	Variation of dry weight (%)
Barley	B1	0.13	144.4 b
	B2	0.16	177.8 a
	B3	0.05	56.6 d
Rapeseed	R1	0.08	88.9 c
	R2	0.15	166.7 a
	R3	0.06	66.7 cd
Control	-	0.09	-

DISCUSSION

Our results revealed that the root length of *G. coronaria* seedlings was affected by a wide range of crops commonly cultivated in Tunisia. Poaceae family are previously reported as one of the most botanical family with pronounced allelopathic potential to suppress weeds (Favaretto et al. 2018; Sánchez-Moreiras et al. 2003; Tantiado and Saylo 2012). Poaceae is an ecologically dominant plant family and it is economically important worldwide, known for its chemical diversity, which represents an important source to allelopathic molecules. In this study, *Sorghum bicolor* reduced *G. coronaria* root length up to 50%, most probably, due to sorgoleone, a lipid benzoquinone released from sorghum plant, that reduces weed growth through its action on the Photosystem II (Hejl and Koster 2004), in a similar way to herbicides of the triazine class (Gniazdowska and Bogatek 2005). *Secale cereal* is usually used as cover crop to compete weeds (Farooq et al. 2011; Nagabhushana 2001) or as a mulch to inhibit the emergence and the growth of weeds (Teasdale and Mohler 2000) by mean of hydroxamic acid (Pérez and Ormeno-Nunez1993), which reduces the need of herbicides (Bhadoria 2011). In the same way, the allelopathic potential of *Avena sativa* was largely explored in weed control. Previous studies reported the inhibiting effect of oat due to phenolics namely scopoletin, a bioactive coumarin known for its allelopathic effect that successfully controls weeds when released into the soil (Belz et al. 2005).

The results showed also that the highest growth inhibition of *G. coronaria* seedlings was caused by barley and rapeseed aqueous extracts and varied with the concentration of the extract.

These results are in agreement with previous research, where the activity of barley extracts was directly related to its concentrations (Ashrafi et al. 2009). The release of water-soluble allelochemicals from vegetative components is thought to be the primary factor contributing to the overall weed suppressive effect of crops (Kremer and Ben-Hammouda 2009). Knowledge on putative barley allelochemicals traces back to Liu and Lovett (1993). Both gramine (N,N-dimethyl1H-indole-3-methanamine) and hordenine (p-[2- (dimethylamino) ethyl] phenol) are the main alkaloids constitutively exuded from barley (Jabran 2017). Phenolic compounds are also among the important allelochemicals produced by barley (Oueslati et al. 2009) that inhibit seed germination and seedling growth of several weed species such as *Echinochloa crus-galli*, *Eclipta prostrata* and *Bromus dianrus* (Bouhaouel et al. 2016; Chon et al. 2004; Oueslati et al. 2009). On the other hand, the family of Brassicaceae receives great attention as source of allelochemicals, often used for weed suppression (Bialy et al. 1990). Most of the species of the Brassica genus, such as rapeseed (*Brassica napus*), produces allelochemicals that inhibits germination and growth of weed species such as *Sorghum halepense* (Uremis et al. 2009b). Brassica glucosinolates play a key role for weed suppression as they can be converted to the corresponding isothiocyanates by the enzyme myrosinase (Petersen et al. 2001). According to Uremis et al. (2009a), higher allelopathic potential could be attributed to the higher isothiocyanates content.

Results from experiment, carried out in pots under controlled environment, showed pronounced effects on roots rather than on shoots, suggesting that the inhibitory effect of barley and rapeseed are more relevant on the underground elongation of *G. coronaria* at this early stage of growth. These results are in line with the finding that water extracts of allelopathic plants generally have more pronounced effects on radicle/root, rather than hypocotyl or shoot growth (Ashrafi et al. 2009; Turk and Tawaha 2002). This may be attributable to the fact that allelochemicals are first in contact with radicle (Ashrafi et al. 2009). Besides the inhibition of root elongation, many of the extracts also altered root morphology, producing distorted and twisted radicles compared to normal seedlings (Bouhaouel et al. 2016; Jennings and Nelson 2002). In addition, results of the pot experiments showed that barley and rapeseed residues leached water soluble allelochemicals that inhibit the growth of *G. coronaria*. However, when incorporated into the soil at increasing rates, crops residues are effective only at first and third level of crop residues (B1, B2 and R1, R3). For both B2 and R2 crop residue levels, no significant effect on the root elongation was observed compared to the control. According to Narwal (1994), allelochemicals that inhibit the growth of some species at certain concentrations might, in fact, stimulate the growth of the same species at another concentration, and it is thus essential to identify the appropriate crop residue level at which growth inhibition occurs, before using allelopathic crops in weed management programs (Ashrafi et al. 2009). In general, the allelochemicals released in the soil affect the growth of weeds through changes in the cell structure, inhibition of cell elongation/division, disruption of membrane structures, and disruption of water and nutrient uptake and the process of photosynthesis (Jabran 2017).

Allelopathic crop residues are widely used for weed management (Tabaglio et al. 2008). For barley crop, the release of water-soluble allelochemicals from vegetative components is thought to be the primary factor contributing to the overall weed suppressive effect of barley used as mulch (Kremer and Ben-Hammouda 2009). Barley residues added to the soil surface of field plots inhibited emergence of *Solanum ptycanthum* by 98% and *Setaria glauca* by 81% at 30 days after planting the weed species (Creamer et al., 1996). Subsequent studies confirmed the effectiveness of barley residues in reducing plant densities of the weeds *Portulaca oleracea* and *Digitaria ischaemum* 60 days after killing the barley with paraquat (Kremer and Ben-Hammouda, 2009). Rapeseed residues are generally incorporated into the soil after harvest in order to control weed. Previous study showed that perennial herbicide resistant *Sorghum halepense* control with over 90% was achieved by rapeseed residues 30 day after its incorporation (Uremis et al. 2009a). Weeds, especially small seeded weeds, could be controlled with the incorporation of rapeseed residues in the soil. Rapeseed residues were reported to inhibit the germination and growth of *Amaranthus retroflexus*, *Solanum nigrum*, *Portulaca oleracea* and *Echinochloa colonum* (Uremis et al. 2009b). For allelopathic residues, it was recommended the combined application of various allelopathic materials to increase the efficiency in weed management, due to the synergistic effect of diverse allelochemicals. The soil surface allelopathic residues could be integrated with no-tillage or reduced tillage (Teasdale and Mohler 2000).

General results from this study showed the allelopathic potential of both barley and rapeseed to reduce the seedling growth of a cross-resistant population of *G. coronaria*. Thus, suggesting the advantage to incorporate these allelopathic crops in resistance management programs. Both crops could be used as water extract, incorporated in the soil or as a part of a rotation program to control herbicide resistant population of *G. coronaria* in field. Further studies should be conduct to investigate the effect of barley and rapeseed in field conditions in order to manage the spreading of resistant population of *G. coronaria*.

RESUME

Hada Z., Jenfaoui H., Khammassi M., Matmati A., et Souissi T. 2022. Effet allélopathique des cultures d'orge (*Hordeum vulgare*) et de colza (*Brassica napus*) sur la croissance précoce de *Glebionis coronaria* résistante aux herbicides inhibiteurs de l'acétolactate synthase (ALS). Tunisian Journal of Plant Protection 17 (2): 55-66.

Glebionis coronaria est une menace sérieuse pour la production céréalière dans le nord de la Tunisie. Des résultats antérieurs ont montré que *G. coronaria* a développé une résistance aux herbicides inhibiteurs de l'acétolactate synthase ALS qui limite l'utilisation de ces herbicides dans les systèmes de production basés sur les céréales. L'utilisation de cultures allélopathiques a été reportée comme une alternative potentielle aux herbicides pour lutter contre les populations de mauvaises herbes résistantes. L'objectif de cette étude est d'évaluer l'effet de cinq cultures allélopathiques sur la croissance de *G. coronaria*. Des expériences *in vitro* avec des extraits aqueux des cultures et en pots avec des quantités croissantes de résidus d'orge (*Hordeum vulgare*) et de colza (*Brassica napus*) ont été réalisées à cette fin. Les résultats obtenus ont confirmé l’effet allélopathique de toutes les cultures testées sur la réduction de la longueur des racines de *G. coronaria* à une concentration de 50 g/L. Les plus fortes réductions de la longueur des racines ont été obtenues avec les extraits de l’orge et du colza avec des pourcentages de réduction de 70% et 60%, respectivement. L’étude de l’effet de cinq concentrations des extraits aqueux (12,5, 25, 50, 75 et 100 %) d’orge et de colza, a montré que la longueur des racines a été significativement réduite avec la concentration la plus élevée de l’extrait de l’orge (jusqu’à 80% de réduction). Les résultats *in vitro* ont été confirmés par l’essai en pot. Les réductions de la longueur racinaire et de la biomasse sèche les plus marquées ont été obtenues avec les plus fortes concentrations de résidus d’orge (0,64 g/kg) et de colza (8 g/kg). Cette étude a confirmé le potentiel allélopathique de l’orge et du colza dans la réduction de la croissance de *G. coronaria* résistante aux inhibiteurs de l’ALS, ce qui suggère l’efficacité de ces cultures si elles sont intégrées avec d’autres mesures dans la lutte contre les populations résistantes de *G. coronaria* dans les champs des céréales.

Mots-clés: Cultures allélopathiques, extrait aqueux, résidus de cultures, longueur des racines, gestion des mauvaises herbes

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ملخص

حاده، زينب وهدى جنفاوي ومسعد خماسي وأحلام مطماطي وثريا السويسي. 2022. تاثير التبادل-المَرَضي للشعير (*Hordeum vulgare*) والسلجم (*Brassica napus*) على النمو المبكر للنبتة الضارة *Glebionis coronaria* المقاومة لمبيدات الأعشاب المثبّطة لأنزيم أسيتولاكتات سينثاز (Acetolactate synthase, ALS).
Tunisian Journal of Plant Protection17 (2): 55-66.

تشكّل النبتة الضارة *Glebionis coronaria* تهديدًا خطيرًا على انتاج الحبوب في الشمال التونسي، إذ أظهرت نتائج سابقة أنّ هذه النبتة قد طورت نوعا من المقاومة لمبيدات الأعشاب المثبّطة لأنزيم أسيتولاكتات سينثاز (Acetolactate synthase, ALS) ممّا يحدّ من استخدام هذه المبيدات للسيطرة على هذه النبتة في أنظمة زراعة الحبوب. ويُذكر أنّ استخدام الزراعات ذات التبادل-المَرَضي (Allelopathy) عُرف كبديل محتمل لمبيدات الأعشاب للسيطرة على مجموعات الأعشاب الضارة المقاومة. وتهدف هذه الدراسة إلى تقييم تأثير خمس زراعات ذات تبادل-مَرَضي فى التحكم في النمو المبكر لنبتة *G. coronaria*. لهذا الغرض، أُجريت تجارب في المختبر باستخدام المستخلصات المائية لهذه الزراعات، كما أجريت تجارب في الأصص باستعمال كميات تصاعدية من مخلفات الشعير(*Hordeum vulgare*) والسلجم (*Brassica napus*). وقد بيّنت المجموعة الأولى من التجارب تأثير جميع الزراعات المختبرة بتخفيض طول جذر نبتة *G. coronaria* عند استعمال التركيز 50 غ/ل، حيث بلغت أعلى معدلات انخفاض طول الجذر نسبة 70% و60% مع مستخلصات الشعير والسلجم، على التوالي. كما أظهرت هذه الدراسة تأثير خمسة تراكيز من المستخلصات المائية (12.5 و 25 و 50 و 75 و 100 %) للشعير والسلجم، أن طول الجذر انخفض بشكل ملحوظ مع أعلى تركيز لمستخلص الشعير (حيث بلغ الانخفاض 80%). وكانت نتائج تأثير مخلفات الشعير والسلجم على النمو المبكر لنبتة *G. coronaria* داعمة للنتائج المخبرية، حيث تمّ ارجاع انخفاض طول الجذور والكتلة الحيوية الجافة إلى أعلى تركيز لمخلفات الشعير(0.64 غ/كغ) والسلجم (8 غ/كغ). وتؤكد هذه الدراسة أنّ لكل من الشعير والسلجم إمكانيات تبادل-مَرَضي تخفّض النمو المبكر لنبتة *G. coronaria* المقاومة لمبيدات الأعشاب المثبطة لأنزيم ALS، ممّا يشير إلى فعالية هذه الزراعات إذا تمّ دمجها مع تدابير زراعية أخرى للسيطرة على مجموعات نبتة *G. coronaria* المقاومة للمبيد في حقول الحبوب.

كلمات مفتاحية: محاصيل ذات تبادل-مَرَضي، مستخلص مائي، بقايا المحاصيل، طول الجذر، إدارة الأعشاب الضارة

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