EFFECT OF PESTICIDE MOLECULES ON THE PHYSICO-CHEMICAL PROPERTIES OF SOIL CULTIVATED BY *BRASSICA NAPUS* RAPESEED (FLOWERING STAGE AND ROSETTE STAGE)

MEROUANI, I.[1] – KETIF, A.[1*] – DRAIDI, K.[2] – HABBACHI, W.[3] – ROUBAL, A.[1]

[1]*Laboratory of Soil and Sustainable Development, Department of Biology, Badji Mokhtar Annaba University, POBOX 12, 23000 Annaba, Algeria*
(e-mail: ines.merouani@univ-annaba.dz; aminaaroubal@gmail.com)

[2]*Research and Environment Center, Environment and Biodiversity Research Division, Department of Biology, Badji Mokhtar Annaba University, POBOX 12, 23000 Annaba, Algeria*
(e-mail: khalildraidi@yahoo.fr)

[3]*Applied Neuroendocrinology Laboratory, Department of Biology, Badji Mokhtar Annaba University, POBOX 12, 23000 Annaba, Algeria*
(e-mail: habbachi.waffa@yahoo.fr)

**Corresponding author*
e-mail: amel.magister75@hotmail.fr

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Abstract. This study examines the impact of pesticide treatments on soil properties at two growth stages of rapeseed (rosette and flowering). Results show a significant reduction in organic carbon content in treated plots, primarily due to increased mineralization of organic matter. An increase in assimilable phosphorus was observed, linked to pesticide-induced nutrient mineralization. Soil acidification was noted, particularly in treated soils, likely due to organic acid release and root exudation. At the flowering stage, a decrease in phosphorus was observed, suggesting increased uptake by plants. The statistical study showed that during both growth periods, the German variety SY GLORIETTA exhibited greater resistance to pesticide treatments. The study highlights the complex interactions between pesticides, soil nutrients, and plant growth, with significant effects on soil fertility and pH dynamics.
Keywords: *soil fertility, SY GLORIETTA variety, agricultural sustainability, soil pollution*

Introduction

Soil is one of nature's most crucial resources, acting as a reservoir of nutrients and moisture essential for plant growth (Saikia et al., 2023). It is also a dynamic ecosystem that harbors approximately 25% of the world's biological diversity (Decaëns et al., 2006) and provides vital services such as biomass production, biogeochemical cycling, and regulation of water flow and climate (Chen et al., 2020).

However, despite these critical ecosystem services, modern agriculture increasingly relies on the use of phytosanitary products. This growing dependence on chemicals is progressively intensifying the pressure on soil health and its ability to maintain these essential functions (Tudi et al., 2021). The use of pesticides per hectare of cultivated land has risen from 1.8 kg/ha to 2.7 kg/ha. In 2019, global pesticide use totaled approximately 4.2 million tons, with 53% being herbicides, 22% fungicides and bactericides, 17% insecticides, and 8% other types of pesticides (FAO, 2020).

Excessive pesticide use can significantly alter the physical and chemical properties of soil, undermining its fertility and essential ecological functions. These chemicals can affect the soil's pH, making it either more acidic or more alkaline, which disrupts

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plants' ability to absorb nutrients effectively. Moreover, repeated pesticide applications can damage soil structure by disturbing vital organisms such as earthworms and microorganisms, which are crucial for maintaining soil stability. This disruption can lead to soil compaction and reduced drainage capacity (Agnihotri, 2023; Liu et al., 2018). Additionally, pesticides can interfere with decomposition processes, decreasing the organic matter content and further reducing the soil's ability to retain water. As a result, the soil becomes more vulnerable to erosion and drought (Sim et al., 2022).

To address soil fertility challenges, sustainable agricultural practices must be adopted, focusing on crops that benefit soil health. Winter oilseed rape (*Brassica napus* L.) is vital for both economic and environmental reasons. It is a key source of edible oil and an important ingredient in biodiesel, aiding the shift to renewable energy. Additionally, rapeseed offers high-quality animal feed and various by-products, making it a versatile crop (Zhao et al., 2013). In this context, this study aims to assess the effects of three pesticides (Colzor Trio, Callisto, and Toprex) on soil properties cultivated with seven varieties of *Brassica napus* (rapeseed) from three different origins.

Materials and methods

Study area

This study was conducted at the Technical Institute of Field Crops of Guelma province, located in the northeastern part of Algeria, as showen in (*Fig.1)*. During the year 2022.

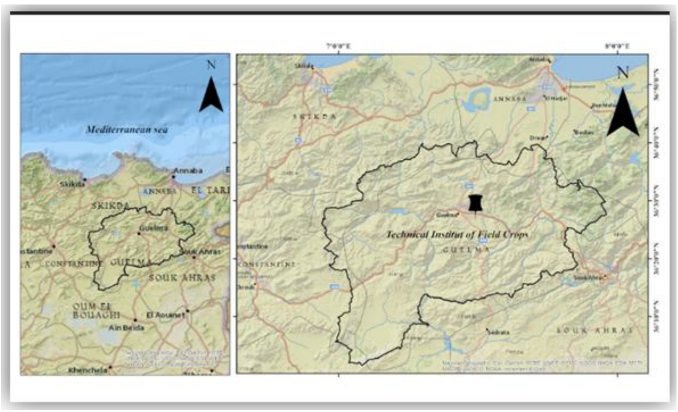

Figure 1. *Geographical location of the study area*

Plant growth stages

This study was carried out during two vegetative developmental stages of rapeseed:

Rosette stage (BBCH scale code-30_39): February 20, 2022.

Flowering stage (BBCH scale code-60_69): March 27, 2022.

The rosette and flowering stages of *Brassica napus* are pivotal for determining both crop yield and quality:

- *Rosette stage*: This is a key vegetative growth phase in which the plant accumulates essential nutrients, and its roots and foliage develop. Optimal growth at this stage enhances the plant's resilience to low temperatures and competition from weeds. It lays a solid foundation for successful reproductive development by ensuring robust vegetative health (Campos et al., 2012).

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- *Flowering stage*: Representing the reproductive phase, this stage involves floral development, pollination, and fertilization, all of which directly affect seed set and final yield. It is highly sensitive to abiotic stresses like drought and heat, as well as biotic factors such as disease pressures. Environmental conditions during this period significantly influence seed quality and oil composition (Helal et al., 2021; Xu et al., 2021).

The two stages are closely linked, with the success of the flowering phase being strongly influenced by the plant's development during the rosette stage.

Plant material: seven varieties of rapeseed (Brassica napus L.)

The seeds are originating from the mentioned countries in *Table 1*.

Table 1. *Seed varieties characteristics: suppliers, origins, and thousand kernel weight (TKW)*

Supplier	Origin	Varieties	TKW (g)
TICG	**Control (regular seed)**	**LINEAGE**	3.6
SARL SRID	**France**	RGT MUZZICAL	4
		RGT GINFIZZ	4.9
		RGT CUZZCO	6.2
SYNGENTA	**Germany**	SY MATTEO	5
		SY HARNAS	5
		SY GLORIETTA	5

TICG: Technical Institute of Field Crops of Guelma; TKW: Thousand-kernel weight

Sowing density: 50 seeds/m².

The experimental field covers a total area of 3036.80 m², divided into seven plots. Each plot measures 50 m in length and 7.2 m in width, with an inter-block space of 1 m and a 1-m trial border.

Pesticide treatment is applied to only 1/5 of the surface area of each plot. The remaining area, outlined in red, serves as the untreated control (*Fig. 2*).

Figure 2 presents the experimental protocol used in the study, detailing the distribution of the different rapessed varieties tested.

Pesticides

During this experiment, we used two herbicides and one fungicide approved for use on rapeseed.

(a) COLZOR TRIO

Colzor Trio is an herbicide approved for winter rapeseed in pre-emergence application. It offers:

- A broad spectrum of efficacy, targeting dicotyledons such as cornflower, shepherd's purse, poppy, cleavers, mayweed, and speedwell, as well as annual grasses like ryegrass and brome

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- A perfectly balanced combination of three complementary active ingredients enhancing its overall performance
- CLOMAZONE (C12H14CLNO2) 30 g/l
- DIMETHACHLOR (C13H18CLNO2) 187.5 g/l
- NAPROPAMIDE (C17H21NO2) 187.5 g/l

This formulation ensures optimal crop protection from the earliest growth stages.
Dose: 4 l/ha.
Formulation: EC (emulsifiable concentrate).

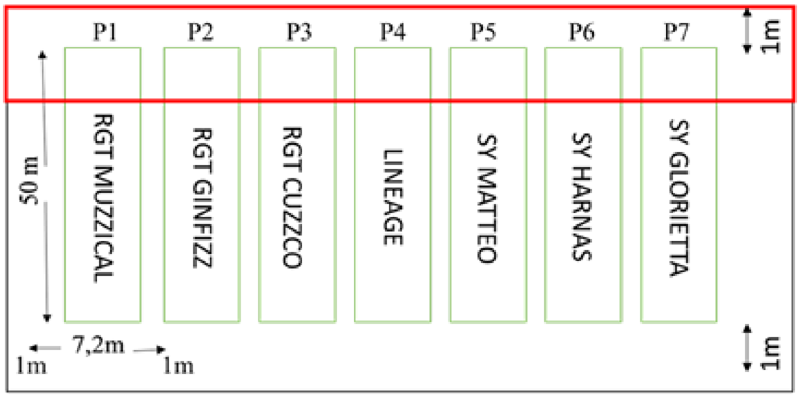

Figure 2. *Experimental protocol and distribution of the different rapeseed varieties used. P: plot*

(b) CALLISTO

Callisto is a systemic herbicide with a broad spectrum of effectiveness against grasses and broadleaf weeds containing a single active ingredient Mesotrione (C14H13NO7S) 100 g/l. It acts on sensitive weeds through both foliar and root absorption, while also providing a pre-emergence effect.
Dose: 0, 15 l/ha.
Formulation: SC (Suspension concentrates).

(c) TOPREX

TOPREX provides growth regulation by limiting the development of aerial plant parts while offering protection against fungal.

Is the combination of two active substances, paclobutrazol and difenoconazole, allowing obtaining both a regulatory effect by paclobutrazol (C15H20ClN3O) 125 g/l and fungicide by difenoconazole (C19H17Cl2N3O3) 250 g/l.
Dose: 0, 3 l/ha.
Formulation: SC (suspension concentrates).

Pesticide application

The weeding process for the trial is executed in two phases:

1. *Post-sowing and pre-emergence:* The first intervention is performed 2 to 3 days after sowing using a broad-spectrum herbicide (COLZOR Trio).

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2. *Post-emergence:* The second intervention begins at the 2-leaf stage and can continue until the rosette stage. It generally involves herbicides with a more targeted action, such as CALLISTO, applied at the 6-leaf stage of the rapeseed. At this same stage, the fungicide TOPREX is then applied for optimal protection.

Soil sampling and laboratory analysis :

Soil samples were collected using a manual auger at a depth of 30 cm from the center of each plot, avoiding the edges, and stored in 20 × 30 cm paper bags. Each bag was labelled and marked to ensure proper identification of each sample.

The samples were air-dried, then sieved through a 2 mm mesh to separate the fine fraction from the coarse fraction. A series of physicochemical analyses were performed for each sample in triplicate to ensure precision and reproducibility of the results.

- The pH was measured by a pH-meter (Baise and Girard, 1995) after mixing soil with distilled water (1:2.5 w/v)
- Phosphorus (P, mol/L) was determined colorimetrically following the Murphy and Riley method (1962)
- The organic carbon was determined using the method described by Walkley and Black (1934)
- Hygroscopic humidity: determined by oven drying at 105°C for 24 h (Delcour, 1981)
- Porosity: real density: Measured using a pycnometer (Delcour, 1981)
- Apparent density: Measured using the paraffin-coated method (Baize, 2000)

Statistical analysis

Statistical analyses were performed using R software version 4.3.1. The results are presented as the mean ± standard deviation (SD), and differences among the mean values of the physicochemical parameters of the studied soils were assessed using the Student's t-test. The significance level was set at $p < 0.05$.

The additional statistical analyses are presented in the Appendix, where we used the Scheirer-Ray-Hare test.

Results

Tables presents the analyses of various soil parameters across seven plots (P1 to P7) containing seven different varieties of rapeseed. Two types of treatments are compared: "Treated" (treated with pesticides) and "Control" (untreated). The impact of the treatment is assessed by analyzing the significance of differences between measurements, Treatments with the same letter for each parameter in each column with the same letter are not significantly different using T-test at 0.05.

We assign the higher mean letter (a) and the lower mean letter (b).

Table 2 illustrates the variations in soil physico-chemical parameters during the rosette stage of rapeseed.

Regarding Organic Carbon, the impact of the treatment varies across the sampling points (P1 to P7). A significant decrease in organic carbon content is observed in the P1 and P4 plots compared to the control, while a significant increase is noted in the P2, P5,

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and P7 plots. In contrast, no statistically significant differences between the treated and control plots are observed for P3 and P6.

As for Phosphorus, the results show an increase in available phosphorus in all treated soils compared to the controls. This difference is significant for the P2, P4, and P7 plots, while no notable variation is recorded in the remaining plots.

Concerning pH (pHKCl), the values are generally similar between treated and control soils. The pH ranges from 6.65 to 7.16 in the treated plots and from 6.85 to 7.33 in the control plots. No significant differences in pH are found between the treated and control groups in most plots, with the exception of a small significant difference observed between P4 and P6.

The water pH follows a similar trend, with slightly lower values in treated soil plots. When comparing the two plot types, it is evident that the control plots have higher and more stable pH values (ranging from 7.62 to 8.16), while the treated plots exhibit lower pH values (ranging from 7.55 to 7.82). The difference is significant in most plots, except for P1 and P7.

Regarding hygroscopic humidity and porosity, the values are very similar between treated and control plots, with no significant differences. This indicates that the treatment does not have a notable effect on these parameters. the results of the additional trials (Appendix) confirm these .

Table 2. *Analysis of soil parameters during the rosette stage of rapeseed*

		P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
		Mean ± standard deviation						
Organic carbon	Treated	0.17 ^{b} ± 0.01	0.97 ^{a} ± 0.01	0.72 ^{b} ± 0.01	0.21 ^{b} ± 0.01	0.83 ^{a} ± 0.01	0.45 ^{a} ± 0.01	0.97 ^{a} ± 0.01
	Control	0.98 ^{a} ± 0.01	0.71 ^{b} ± 0.01	0.76 ^{a} ± 0.01	0.63 ^{a} ± 0.01	0.39 ^{b} ± 0.01	0.45 ^{a} ± 0.01	0.48 ^{b} ± 0.01
Assimilable phosphorus	Treated	0.23 ^{a} ± 0.15	0.4 ^{a} ± 0	1 ^{a} ± 0.1	1.26 ^{a} ± 0.05	1.33 ^{a} ± 0.15	0.93 ^{a} ± 0.05	1.76 ^{a} ± 0.15
	Control	0.16 ^{a} ± 0.05	0.2 ^{b} ± 0	0.86 ^{a} ± 0.05	1.03 ^{b} ± 0.05	1.13 ^{a} ± 0.05	0.8 ^{a} ± 0.1	1.2 ^{b} ± 0
pH KCl	Treated	7.16 ^{a} ± 0.15	7.08 ^{a} ± 0.01	7.12 ^{a} ± 0.01	7.1 ^{a} ± 0.1	6.65 ^{a} ± 0.01	7.11 ^{a} ± 0.01	6.98 ^{a} ± 0.01
	Control	7.33 ^{a} ± 0.01	7.05 ^{a} ± 0.01	6.92 ^{a} ± 0.01	6.72 ^{b} ± 0.01	6.66 ^{a} ± 0.01	6.58 ^{b} ± 0.01	6.85 ^{a} ± 0.01
pH water	Treated	7.72 ^{a} ± 0.11	7.55 ^{b} ± 0.03	7.76 ^{b} ± 0.01	7.64 ^{b} ± 0.01	7.82 ^{b} ± 0.01	7.72 ^{b} ± 0.01	7.77 ^{a} ± 0.03
	Control	7.9 ^{a} ± 0.01	8.16 ^{a} ± 0.01	7.85 ^{a} ± 0.01	7.75 ^{a} ± 0.01	7.85 ^{a} ± 0.01	7.82 ^{a} ± 0.01	7.62 ^{a} ± 0.01
Hygroscopic humidity	Treated	8 ^{a} ± 1	7 ^{a} ± 0	6 ^{a} ± 1	5.33 ^{a} ± 1	8 ^{a} ± 1	10.8 ^{a} ± 1	11 ^{a} ± 1
	Control	7.6 ^{a} ± 1	7 ^{a} ± 0	6.67 ^{a} ± 1	6 ^{a} ± 0	8 ^{a} ± 1	11 ^{a} ± 1	10 ^{a} ± 1
Porosity	Treated	86.00 ^{a} ± 0.58	81.00 ^{a} ± 0.58	81.00 ^{a} ± 0.58	64.67 ^{a} ± 0.88	77.67 ^{b} ± 0.88	71.00 ^{a} ± 0.88	77.67 ^{a} ± 0.88
	Control	77.00 ^{b} ± 0.58	70.6 ^{b} ± 0.33	84.00 ^{a} ± 0.58	65.00 ^{a} ± 0.58	88.00 ^{a} ± 0.58	73.00 ^{a} ± 0.58	88.00 ^{a} ± 0.58

Table 3 quantifies the variations in soil physico-chemical parameters during the flowering stage of rapeseed.

The organic carbon content in the treated plots is generally lower than that observed in the control plots, with significant differences noted across all sampling points. Furthermore, an increase in carbon values was observed at this stage compared to the values recorded at the previous stage, both for the treated and control plots.

The values of assimilable phosphorus in the treated plots range from 0.13 to 1.3, while those in the control plots range from 0.1 to 0.97. The treated plots exhibit higher

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values of assimilable phosphorus at most sampling points. These differences are statistically significant for all plots, except for P1 and P6.

A decrease in phosphorus values was noted at this stage compared to the rosette stage.

Concerning pH (pHKCl), the control plots exhibit slightly higher values, ranging from 5.15 to 5.42, while the treated plots show values between 5.03 and 5.27. Although the differences in pH between the treated and control groups are relatively small, they are statistically significant in most plots.

For pH water, the treated plots show greater variability in pH values, with peaks reaching up to 5.96 (P5) and lower values such as 5.13 (P6). The control plots exhibit more stable values, ranging from 5.43 to 5.73, except for P7, which has a value of 5.13. The difference was significant only for P2, P4, and P7.

Both hygroscopic humidity and porosity values are very similar between the treated and control plots, showing no significant differences.

Table 3. *Analysis soil parameters during the flowering stage of rapeseed*

		P1	P2	P3	P4	P5	P6	P7
		Mean ± Standard deviation						
Organic carbon	Treated	$1.15^{b} \pm 0.01$	$1.35^{b} \pm 0.01$	$0.98^{b} \pm 0.01$	$0.46^{b} \pm 0.01$	$0.73^{b} \pm 0.01$	$0.56^{b} \pm 0.02$	$0.93^{b} \pm 0.01$
	Control	$1.47^{a} \pm 0.01$	$1.61^{a} \pm 0.01$	$2.04^{a} \pm 0.02$	$0.86^{a} \pm 0.01$	$0.91^{a} \pm 0.05$	$1.15^{a} \pm 0.01$	$1.13^{a} \pm 0.01$
Assimilable phosphorus	Treated	$0.13^{a} \pm 0.05$	$0.16^{a} \pm 0.05$	$0.86^{a} \pm 0.05$	$1.03^{a} \pm 0.05$	$1.16^{a} \pm 0.05$	$0.16^{a} \pm 0.05$	$1.3^{a} \pm 0.1$
	Control	$0.1^{a} \pm 0.01$	$0.13^{b} \pm 0.05$	$0.57^{b} \pm 0.11$	$0.23^{b} \pm 0.15$	$0.97^{b} \pm 0.05$	$0.1^{a} \pm 0.01$	$0.97^{b} \pm 0.05$
pH KCl	Treated	$5.16^{b} \pm 0.01$	$5.27^{b} \pm 0.01$	$5.03^{b} \pm 0.01$	$5.16^{b} \pm 0.01$	$5.17^{b} \pm 0.01$	$5.18^{b} \pm 0.01$	$5.07^{b} \pm 0.01$
	Control	$5.33^{a} \pm 0.01$	$5.42^{a} \pm 0.005$	$5.17^{a} \pm 0.01$	$5.22^{a} \pm 0.01$	$5.32^{a} \pm 0.01$	$5.26^{a} \pm 0.01$	$5.15^{a} \pm 0.005$
pH water	Treated	$5.72^{a} \pm 0.06$	$5.62^{b} \pm 0.02$	$5.63^{a} \pm 0.02$	$5.54^{b} \pm 0.02$	$5.96^{a} \pm 0.01$	$5.13^{a} \pm 0.06$	$5.95^{a} \pm 0.01$
	Control	$5.43^{a} \pm 0.2$	$5.67^{a} \pm 0.02$	$5.66^{a} \pm 0.04$	$5.73^{a} \pm 0.01$	$5.16^{a} \pm 0.01$	$5.15^{a} \pm 0.01$	$5.13^{b} \pm 0.01$
Hygroscopic humidity	Treated	$8^{a} \pm 1$	$8^{a} \pm 1$	$8^{a} \pm 0$	$7.33^{a} \pm 0.5$	$8^{a} \pm 1$	$7.33^{a} \pm 0.58$	$7.33^{a} \pm 0.58$
	Control	$8^{a} \pm 1$	$7^{a} \pm 1$	$8^{a} \pm 0$	$7.33^{a} \pm 1.5$	$8^{a} \pm 1$	$7.33^{a} \pm 0.58$	$7^{a} \pm 0$
Porosity	Treated	$80^{a} \pm 1$	$81^{a} \pm 1$	$68^{a} \pm 1$	$78^{a} \pm 1$	$65.11^{a} \pm 0.84$	$72.67^{a} \pm 0.58$	$72.33^{a} \pm 0.58$
	Control	$80^{a} \pm 1$	$81^{a} \pm 1$	$68^{a} \pm 1$	$78^{a} \pm 1$	$64.33^{a} \pm 1.5$	$73^{a} \pm 1$	$72^{a} \pm 1$

Discussion

This study assessed the impact of pesticides on the physico-chemical properties of the soil in rapeseed (*Brassica napus*) fields at the rosette and flowering stages. The results reveal significant changes in soil properties that influence its fertility, plant development, and the sustainability of agricultural systems.

A notable reduction in organic carbon content was recorded in the treated plots compared to the control plots, with a generally significant difference ($p < 0.05$) at both study stages. This decrease can be attributed to increased mineralization of organic matter, stimulated by microbial activity or chemical reactions associated with the applied treatments (Brookes et al., 2008; Marzi et al., 2020). The soil exhibited low organic carbon concentration, and similar studies (Amirhassan et al., 2020; Temple et al., 2024; Safiétou et al., 2024) have shown that rapid mineralization of organic matter

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contributes to this low carbon content in soils. At the flowering stage, an increase in organic carbon was observed, which can be explained by enhanced photosynthetic activity supporting flower and pod growth, as well as the development of a denser root system. Root exudates, rich in organic compounds, enrich the soil with carbon and stimulate microbial activity, contributing to better soil fertility and health (Villarino et al., 2021; Pausch, 2018).

An increase in assimilable phosphorus was noted in the treated soils at both the rosette and flowering stages, suggesting that pesticides may interact with nutrient mineralization. This increase is primarily attributed to the mineralization of organic matter, where microorganisms break down organic residues and release phosphorus in a form accessible to plants (Saeid, 2018; Park et al., 2022). Additionally, the release of H^+ ions during biological processes, such as root activity and organic matter decomposition, promotes the dissolution of phosphate minerals, increasing phosphorus availability (Safiétou et al., 2024; Zhang et al., 2021). Compost or manure applications further improve soil biological conditions, stimulating microbial activity and contributing to the recycling of phosphorus (Torri et al., 2017). However, a decrease in phosphorus content was observed at the flowering stage, suggesting increased phosphorus uptake by plants. This decrease could also be due to phosphorus fixation on the clay-humic complex or through calcium bridges, or on iron and aluminum hydroxides, as also reported by Ketif (2016) and Guardado et al. (2007).

At the rosette stage, a slight acidification was observed in the treated soils, likely due to the release of organic acids during the degradation of organic matter (Macias-Benitez et al., 2020; Ketif et al., 2015). At the flowering stage, although pH values did not show major changes, a moderate decrease was noted compared to the previous stage. This phenomenon may be attributed to biological processes or complex interactions in the soil, where the increased nutrient demand at the flowering stage intensifies root exudate release, mobilizing nutrients such as phosphorus. These exudates release H^+ ions into the rhizosphere, contributing to local soil acidification. Additionally, the degradation of applied pesticides releases organic acids or H^+ ions, further reinforcing pH reduction in the rhizosphere (Adeleke et al., 2017).

Previous studies have shown that plant variety can influence pH reduction depending on its root exudate profile and interactions with the environment. Hoffland et al. (1989) demonstrated that rapeseed (*Brassica napus*) caused a significant pH drop in the rhizosphere from 6.5 to 4.1 due to organic acid release.

Changes in humidity and porosity were minimal during the two study stages, with no significant differences for most of the plots. This absence of noticeable change may be due to the relatively short duration of the study. In the short term, pesticides may not alter microbial activity or soil structure enough to measurably affect these parameters. However, more significant effects could be observed in the long term, particularly if active substances accumulate, leading to deeper alterations in soil porosity and humidity (Yargholi et al., 2014; Kalia et al., 2011; Ammeri et al., 2020).

The observed differences between plots highlight the variability in rapeseed variety responses to applied treatments. Specifically, the SY GLORIETTA variety cultivated in plot P7 appears to be the most resistant to the applied treatments, showing better retention of organic carbon, optimal phosphorus assimilation, and pH stability. Additionally, the combination of high porosity and stable hygroscopicity indicates superior adaptation of this variety to the conditions modified by the treatments. To ensure sustainable management, it would be essential to complement these observations with long-term analyses and adopt agroecological practices, such as organic matter addition, to compensate for the observed reduction in organic carbon.

Conclusion

Soil physico-chemical analysis is an essential method that provides crucial information for optimizing management practices and improving soil quality. This study evaluated the impact of pesticides on the physico-chemical properties of soil at different stages of rapeseed development (rosette and flowering). The results indicate that pesticides alter several key soil parameters, disrupting its chemical and physical balance. Specifically, a decrease in organic carbon was observed in the treated soils, particularly at the rosette stage, suggesting a disruption in microbial activity. In parallel, the treated plots exhibited higher concentrations of assimilable phosphorus, indicating an interaction between pesticides and nutrient mineralization. A progressive acidification of the soil was also noted, especially in the treated soils, which was attributed to nutrient absorption, pesticide degradation, and microbial activity.

The SY GLORIETTA variety showed better resistance to pesticide effects, maintaining more favorable growth conditions compared to the other varieties.

In conclusion, the application of pesticides influences nutrient dynamics and the physico-chemical properties of the soil, with more pronounced effects at the early rapeseed growth stage (rosette) and a gradual attenuation at the flowering stage. This variability underscores the importance of a rational pesticide management approach to mitigate their negative impacts on soil fertility and ensure sustainable production. Further research is needed to explore the long-term effects, particularly by assessing the impact on microbial biodiversity and the soil’s capacity to recover after multiple crop cycles under pesticide treatments.

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Availability of data and materials. All data generated in this research work has been included in this manuscript.

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APPENDIX

Variation of the physico-chemical parameters of the studied soil during the two development stages of rapeseed, analyzed using the two-factor analysis of variance method, the Scheirer-Ray-Hare test.

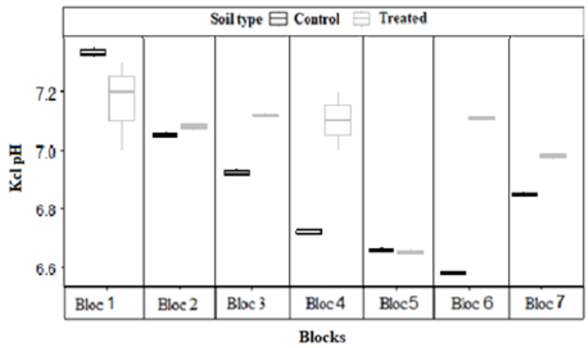

Figure A1. *Variation of organic C during the rosette stage*

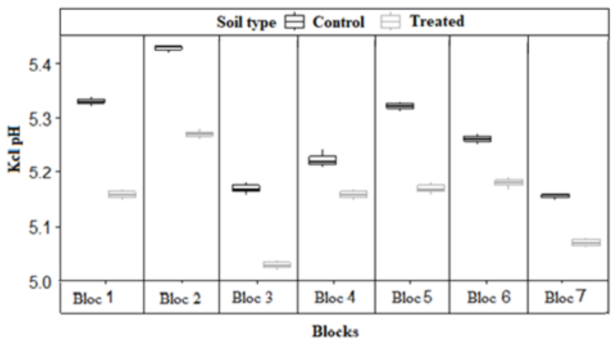

Figure A2. *Variation of organic C during the flowering stage*

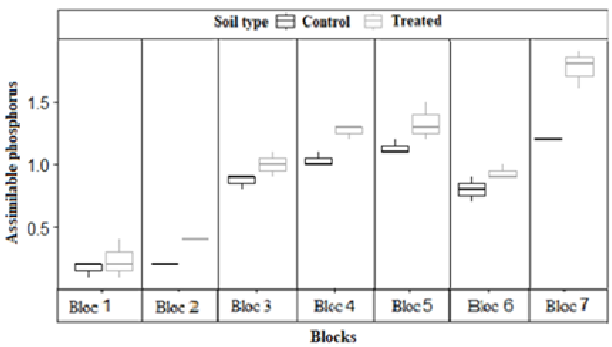

Figure A3. *Variation of assimilable phosphorus during the rosette stage*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_35253539

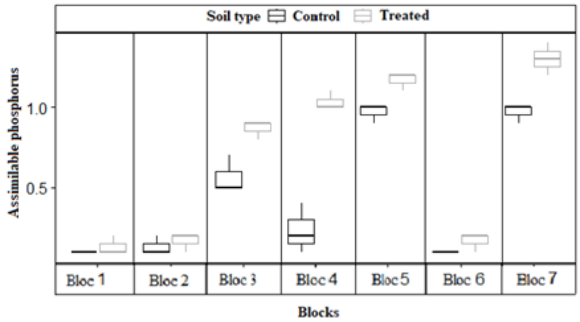

Figure A4. *Variation of assimilable phosphorus during the flowering stage*

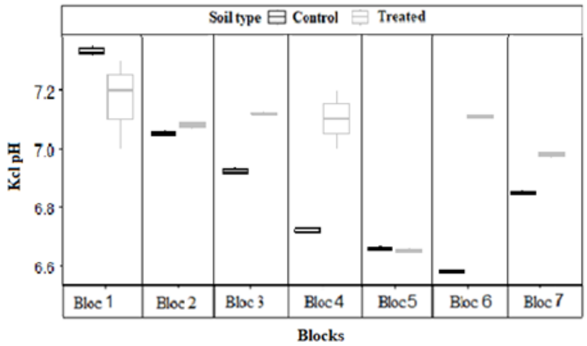

Figure A5. *Variation of KCl pH during the rosette stage*

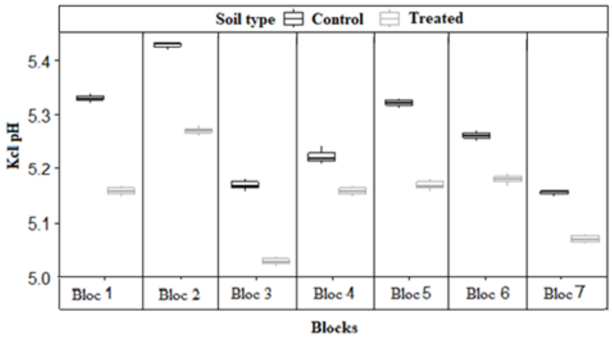

Figure A6. *Variation of KCl pH during the flowering stage*

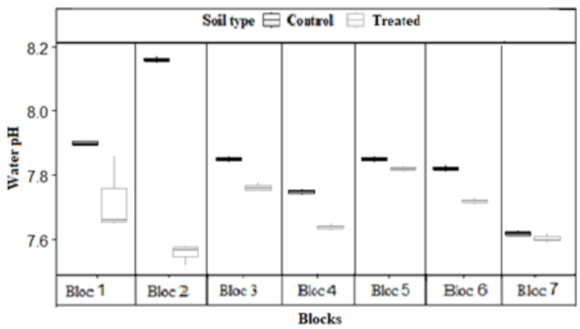

Figure A7. *Variation of water pH during the rosette stage*

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DOI: http://dx.doi.org/10.15666/aeer/2302_35253539

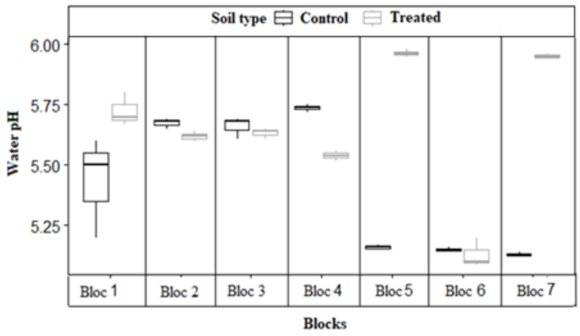

Figure A8. *Variation of water pH during the flowering stage*

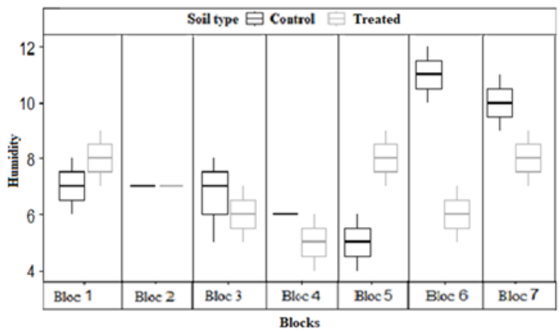

Figure A9. *Variation of humidity during the rosette stage*

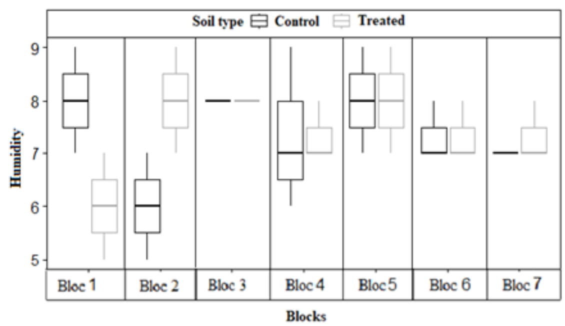

Figure A10. *Variation of humidity during the flowering stage*

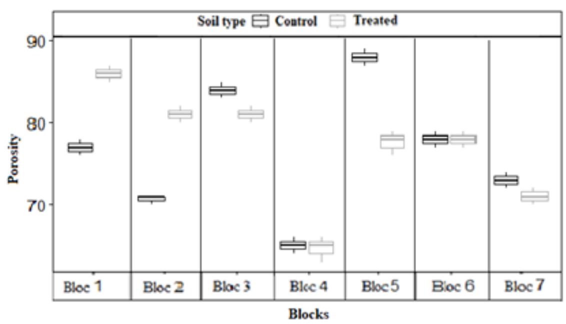

Figure A11. *Variation of porosity during the rosette stage*

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DOI: http://dx.doi.org/10.15666/aeer/2302_35253539

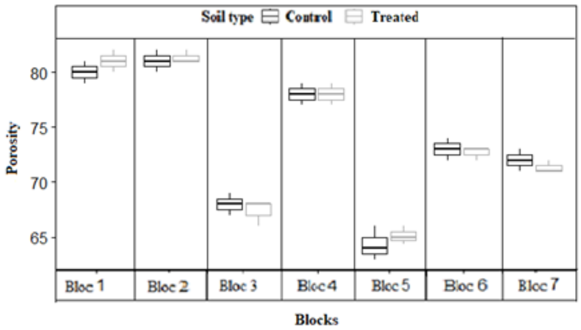

Figure A12. *Variation of porosity during the flowering stage*

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DOI: http://dx.doi.org/10.15666/aeer/2302_35253539