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ORIGINAL ARTICLE

The total phenolic compound and sorgoleone content as possible indirect indicators of the allelopathic potential of sorghum varieties (*Sorghum bicolor* (L.) Moench)

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Abstract

Sorghum produces allelopathic compounds, including total phenolic compounds and sorgoleone, which exhibit a phytotoxic effect on weeds. The field study, carried out in 2016-2017, was designed as an one-factor experiment, in the randomized block design, in four replications, with Sucrosorgo 506, Rona 1, KWS Freya, KWS Juno, and KWS Sammos, to assess the impact of allelochemicals on weeds. Weed infestation was determined at the beginning of July. Individual weed species were collected from two random places in each plot and weighed. The aim of the laboratory study was to evaluate the total content of phenolic compounds, and sorgoleone in the early stages of plant development (5, 10, and 15 days after emergence) in varieties Rona 1, KWS Freya, KWS Juno, KWS Sammos, Farmsorgo 180, GK Aron, PR 845F, Sucrosorgo 506 and PR849F. The total content of phenolic compounds was determined using the colorimetric method, and the sorgoleone HPLC technique on a Flexar chromatographic set. The highest value of sorgoleone was observed in 15-day-old seedlings of KWS Juno, the lowest in 5-day-old seedlings of Sucrosorgo 506, the highest levels of total phenolic compounds in 5-day-old seedlings of PR 845F, the lowest in 15-day-old seedlings of Farmsorgo 180. The results do not fully confirm the beneficial effect of allelopathic compounds on reducing weed infestation, however, it is important to emphasize the diversity of cultivars used. The statistically insignificant results indicated that most varieties of sorghum plants do not exhibit a significant decrease in yield.

Keywords: allelopathic, compounds, phenolic compounds, sorgoleone, sorghum

Introduction

Sorghum (*Sorghum Moench*) is the fifth most widely cultivated cereal in the world (Mwamahonje and Maseta 2018; Mohamed *et al.* 2022). Currently, there is a significant emphasis on natural methods of weed control, including the phenomenon of allelopathy, which involves the use of chemicals secreted by crop plants into the soil. These substances can either stimulate or inhibit the germination, growth and development of plants in the vicinity. The production of allelopathic compounds depends on factors such as the age of the plant, its genotype, location, environment and cultivation system (Weston *et al.* 2013).

The European Commission's European Green Deal program aims to reduce the consumption of chemicals. This may lead to an increased interest in plants with allelopathic potential. Sorghum residues left in the field, along with water extracts from this plant can be utilized to reduce weed infestation (Khamare *et al.* 2022).

Sorghum produces phenolic compounds in the aerial parts and sorgoleone, an oily brownish exudate contains lipid benzoquinones, which constitutes >90% of the hydrophobic components of sorghum root exudates (Sarr *et al.* 2020). Mainly they are intensely produced during the initial phase of plant growth, and their quantity depends on the variety (Tibugari and Chiduza 2018). The highest concentration of sorgoleone in the soil is found in proximity to the roots (Sarr *et al.* 2021) and according to Hussain *et al.* (2021) limits the growth of weeds. Sorghum varieties also differ in growth rate and leaf area. These characteristics can also affect weed suppression through competition for water, nutrients and light (Traore *et al.* 2022).

The allelopathic potential of sorghum is attributed to phenolic compounds, such as phenols and their derivatives, leached from the above-ground parts and root system, as well as sorgoleone and its analogues secreted by root hairs. The phenolic compounds are highly toxic to the sorghum plant itself, which is why they occur in the form of biologically inactive esters or glycosides (Sołtys *et al.* 2010; Traore *et al.* 2022).

Sorgoleone (2-hydroxy-3[(Z,Z)-8',11',14-pentadekatreno]-*p*-benzoquinone) also known as resorcinol, i.e., its 1,4-hydroxyquinone form, account for 90% of the compounds found in root secretions. The remaining 10% consists of sorgoleone analogues (Pan *et al.* 2018). The low mobility of sorgoleone in the soil is attributed to its very strong binding ability to organic matter, which directly affects its bioavailability (Scavo *et al.* 2019). The production of sorgoleone is influenced by environmental factors. It is produced in lesser amounts when the substrate is excessively moist, hindering the growth of root hairs. Additionally, temperatures below 25°C or above 35°C (Dayan 2006), as well as alkaline soil conditions limit the release of this compound. The largest amount of sorgoleone is produced in an acidic environment with a pH of 4–5 (Głąb *et al.* 2017).

When planning crop rotation it is worthwhile to consider plants with allelopathic potential, which can stimulate or inhibit subsequent crops. The utilization of sorghum as a preceding crop leads to the accumulation of allelopathins in the soil, thereby limiting weed growth (Hussain *et al.* 2021).

The significant allelopathic potential of sorghum is also harnessed in the production of an aqueous extract from the above-ground parts of the plant, known as a sorgaab, which exhibits a phytotoxic effect on weeds due to its phenolic content and controls many weed species (Le *et al.* 2018; Yar *et al.* 2020). The use of sorghum extract can serve as an environmentally friendly, convenient and cost-effective alternative to synthetic herbicides (Saudy *et al.* 2021), and can be utilized for the production of ecological herbicides. Its effectiveness stems from its structural similarity to plastoquinone, enabling sorgoleone to bind to the plastoquinone binding site in the D1 PSII protein. By competing for the natural electron acceptor, sorgoleone replaces it and inhibits the re-oxidation of plastoquinone A (QA) by plastoquinone B (QB) (Fetting 2020). This process occurs in photosystem II (PS II) and directly affects photosynthesis. Similar mechanisms are observed in certain synthetic diuronic and phenolic herbicides (Sołtys *et al.* 2010).

Sołtys *et al.* (2010) indicate that some species cultivated after sorghum exhibit different sensitivities to allelopathins remaining in the soil. Barley, wheat, corn, soybean, tomato, red pepper, radish, and Chinese cabbage demonstrate tolerance to both pre- and post-emergence applications of sorgoleone formulations. Conversely, lettuce and cucumber plants are more sensitive to its effects (Uddin *et al.* 2010). On the other hand, sorgaab and post-harvest residues of sorghum can be effectively utilized by barley crops (Jassim *et al.* 2022). The use of natural sorghum extracts as bio-herbicides alone may not provide weed control at the same level as synthetic herbicides. Therefore, combining a natural extract with a reduced dose of a synthetic herbicide can enhance herbicidal effectiveness while minimizing environmental pollution (Farooq *et al.* 2018).

This research hypothesis posited that sorghum cultivars differ in the content of allelopathic compounds and exhibit varying abilities to compete with weeds. The aim of this study was the evaluation of total phenolic compounds and sorgoleone content in sorghum plants and their impact on weeds.

Materials and Methods

Field experiment

The sorghum varieties used in the experiment were Rona 1, KWS Freya, KWS Juno, KWS Sammos, Farmsorgo 180, GK Aron, PR 845F, Sucrosorgo 506 and PR849F. The field experiment was carried out in 2016–2017 in the fields of the Złotniki Experimental and Didactic Station (52°29'N, 16°49'E) Research and Education Center Złotniki (REC Złotniki), belonging to the Poznań University of Life Sciences, as one-factor, in the randomized block design, in four replications. A field trial was carried out on loamy sand soil (66% sand, 13% clay, 21% silt) containing 1.1–1.5% organic matter, and pH 5.7 classified as Luvisols (Smreczak and Lachacz 2019). The tested factors were the variety Sucrosorgo 506, Rona 1, KWS Freya, KWS Juno, KWS Sole, and KWS Sammos. The area of the experimental plot was 28 m^2 (2.8 m × 10 m) and included 4 rows of sorghum, with a row spacing of 70 cm. The distance between plants in a row depended on the variety and the manufacturer's recommendations, namely, 7 cm (density of about 204,000 plants per ha) for the varieties Sucrosorogo 506, Rona 1, KWS Juno, and 4.5 cm (317,000 plants per ha) for KWS Freya, and KWS Sammos. Tillage included disc harrows, moldboard plowing in the autumn, and shallow surface cultivation by cultivation units in the spring. Mineral fertilizers were applied according to plant needs, taking into account the nutrient content of the soil and included 60 kg P · ha^{-1}, 90 kg K · ha^{-1}, and N at 110 kg · ha^{-1} before planting. Sorghum sowing was carried out using a Monosem precision seeder. Sowing in both years was done on May 16 and harvested on October 20, and 23 from the two middle rows of each plot. The previous crop for sorghum was winter rape and spring barley. Weather conditions during sorghum growth seasons are presented in Table 1.

Table 1. Meteorological conditions at the REC Złotniki during sorghum growth season in the years 2016–2017

Month	Years of study			
	precipitation [mm]		air temperature [°C]	
	2016	2017	2016	2017
May	43.0	56.8	15.4	13.7
June	83.6	68.2	18.3	17.4
July	148.8	168.0	18.8	18.0
August	40.6	82.0	17.5	18.9
September	5.6	45.6	16.5	13.3
October	105.0	91.8	8.0	10.6
Total/Average	426.6	512.4	15.8	15.3

The weed infestation was determined at the beginning of July. All individual weed species were taken from two randomly selected places, (0.7 × 1.0 m quadrat frame), divided into species, and weighed. Next, they were averaged and expressed on a 1 m^{-2} basis (Haliniarz *et al.* 2020). Each year, the weed flora of experimental fields mainly consisted of *Chenopodium album* L. (CHEAL), and *Brassica napus* (BRSNN) at densities of 513–850 g · m^{-2} and 547–846 g · m^{-2} , respectively.

Preparation of plant material for analysis

Fifteen randomly selected sorghum seedlings were collected from each plot 5, 10, and 15 days after emergence (DAE). The seedlings were separated into roots and above-ground parts, which were weighed, placed separately in foil bags and frozen for further analysis.

Analysis of total phenolic compounds

The total content of phenolic compounds in the plants was determined using the Folin-Ciocalteu (F-C) method (Noreen *et al.* 2017).

The frozen material was lyophilized, weighed, then ground in a ceramic mortar and stored in 5 ml tubes at −24°C until analyzed. Approximately 100 mg of the ground sample was mixed with 4 ml of methanol, which had been purged with a stream of nitrogen. The mixture was then extracted for 3 hours on a shaker at 100 rpm, and the sample was centrifuged for 5 minutes at 4000 rpm. From the resulting supernatant, 20 μl was transferred to a 5 ml screw cap vial, to which 1.58 ml of distilled water, 100 μl of F-C reagent and 300 μl of saturated sodium carbonate solution were added. The solution was mixed, the vial was capped and it was heated for 30 minutes at 40°C.

After the samples had cooled down, the absorbance readings were taken using a Smart Spec Plus spectrophotometer (Biorad, Sweden) in PMMA (Brand, Germany) 1.5 ml semi-micro cuvettes. The absorbance was measured at a wavelength of 765 nm. The blank used to zero the spectrophotometer reading was the reagent sample. Based on the absorbance measurement of the gallic acid dilutions, a calibration curve was calculated. The calibration curve showed linearity in the range 0–0.8%, and correlation coefficient of r^2 = 0.998.

Determination of sorgoleone content

The determination of sorgoleone content in the roots was carried out using the HPLC technique on a Flexar chromatographic system (Perkin Elmer, Waltham, MA, USA), which consisted of an autosampler, pump, oven, PDA detector and a solvent manager. Chromera CDS system was used to quantify. The sorghum roots along with the filter paper on which the plants sprouted were immersed in 5 ml of methanol for 30 seconds to elute the sorgoleone. The resulting extract was transferred to a 25 ml beaker. This immersion procedure was repeated two more times and the resulting extracts were combined. The crude extract was then evaporated under a stream of nitrogen. The residue was dissolved in 1 ml of methanol and filtered through a 0.22 μm pore size filter (Nylon 66) into a 2 ml autosampler vial. The sample was stored at 4°C until analysis.

After sorgoleone extraction, roots were allowed to dry for 10 min., weighed, dried in an oven at 105°C overnight, and weighed again to determine dry weight. Sorgoleone analysis was performed in duplicate. A 20 μm sample was injected on a Genesis C18 RP column, 150 mm, internal diameter 4.6 mm and 5 μm grain size (Grace, USA). The elution was carried out in an isocratic system using a solvent mixture of 75% acetonitrile and 25% water acidified with 0.1% acetic acid, with an eluent flow of 0.6 ml · min^{-1}. Sorgoleone detection was performed at a wavelength of 280 nm. The total analysis time for each sample was 30 minutes. The presence of sorgoleone was confirmed by comparing the retention time and the UV spectrum

(190–350 nm) of the pure standard sample with the analytical sample. To determine the sorgoleone concentration, the external standard method was used.

A pure standard of sorgoleone obtained from the United States Department of Agriculture – Agricultural Research Service (USDA-ARS), Natural Products Utilization Research Unit was used to plot the calibration curve.

The statistical analysis of the results was performed using the statistical program Statistica 13 (StatSoft Polska). The data were subjected to one-way ANOVA, and Tukey's test (HSD) was used at the significance level of $p = 0.05$ to isolate homogeneous groups. To refer to a relationship between allelochemical content in sorghum varieties and CHEAL, BRSNN, and total weed control, Pearson correlation coefficients were calculated. To check the influence of weed fresh mass on sorghum yield and to predict the outcome of future events, linear regression was used.

Results

Results of the statistical analysis of the relationship between phenolic acid content and time after sorghum plant emergence indicated that significant relationships were present in all tested varieties (Fig. 1). The PR 845F variety had the highest average content of phenolic compounds (25.96 mg · g^{-1}). Additionally, this cultivar consistently recorded the highest values of the compound on each analysis date. The varieties Farmsorgo 180, KWS Juno, KWS Sammos and KWS Freya had the lowest average content of phenolic compounds. The highest content of phenolic acid was recorded in 5-day-old seedlings, which then decreased as the sorghum plants grew. The lowest content of phenolic compounds was found in 15-day-old seedlings. Farmsorgo 180 had significantly the lowest content of phenolic compounds compared to the other tested cultivars.

Results of statistical analysis of the relationship between sorgoleone content and time after sorghum plant emergence indicated that there were significant relationships in Rona 1, KWS Sammos, KWS Juno, PR 849F, and Aron, but not for Farmsorgo 180, KWS Freya, PR 845F, and Sucrosorgo varieties (Fig. 2). The content of sorgoleone in the studied sorghum cultivars exhibited significant differences. The KWS Juno variety had the highest mass of the tested compound in dry matter (average 46.01 mg · g^{-1}). On the first day of measurement, there was no significant difference in sorgoleone content between this cultivar and the others. However, on the 10th and 15th days of the measurement, the content of sorgoleone in KWS Juno was significantly higher than in the other varieties. The sorghum cultivars exhibited varying patterns of sorgoleone production over the course of the measurements. In the Aron and Rona 1 cultivars, the content of sorgoleone decreased with each subsequent measurement. On

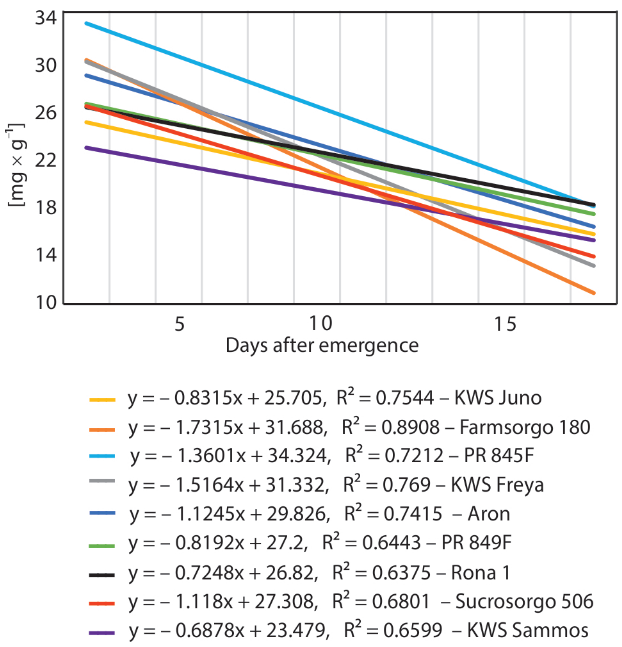

Fig. 1. The phenolic acid content in the dry matter of the aboveground parts of sorghum;
HSD 0.05 (5 DAE) = 6.84; (10 DAE) = 5.37; (15 DAE) = 1.98; DAE – days after emergence

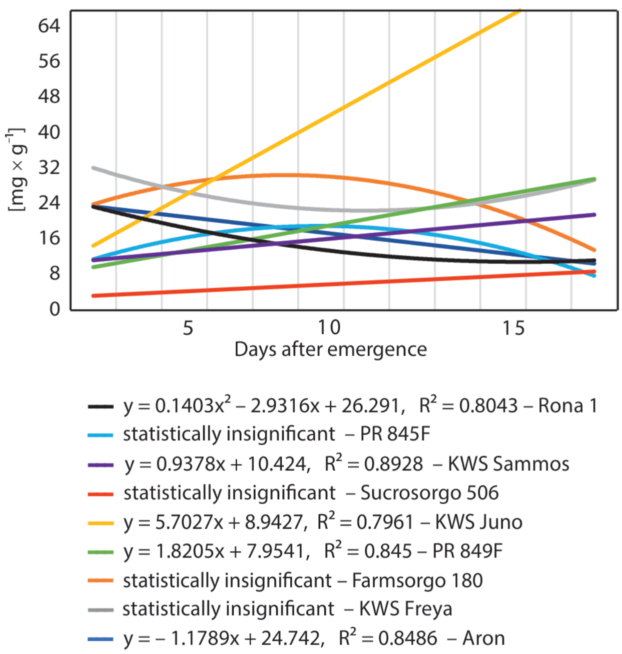

Fig. 2. The sorgoleone content in the dry matter of sorghum roots;
HSD 0.05 (5 DAE) = 1.13; (10 DAE) = 1.39; (15 DAE) = 1.33; DAE – days after emergence

the other hand, in the KWS Juno, PR 849F, and KWS Sammos cultivars the content of sorgoleone increased over time.

The results of the analysis of the effect of the content of total phenolic compounds and sorgoleone on the most numerous weeds, that appeared each year during field study in sorghum are presented in Table 2. The table contains all correlation coefficients, but based on the results of the statistical analysis made only some statistically significant relationships stick. Some positive relationships, even though they show a high correlation, are not crucial because their significance has not been shown. The effect of the content of compounds on the occurrence of weeds varied depending on the sorghum cultivars, the date of assessing the content of compounds, and the year of the study. The results of the analysis indicated the impact of phenolic acid from KWS Juno at 15 DAE on CHEAL (*Chenopodium album*) plant weight reduction in 2016 (very high positive correlation, $r \geq 0.90$), and sorgoleone on BRSNN at 5, 10 and 15 DAE but in 2017 there was a negative correlation. In addition, a significant and very positive effect of phenolic acid on the reduction of total weed weight in 2016 was also found.

The results of the conducted analysis also do not indicate a clearly positive effect of allelopathic compounds contained both in the above-ground parts and in the roots of the sorghum variety Rona on the reduction of the weight of CHEAL, BRSNN and total weeds. However, only in CHEAL and total weeds, a statistically significant relationship was found between the content of phenolic compounds in 2016.

Correlations between allelopathic compounds included in varieties KWS Freya, KWS Sammos, and Sucrosorgo 506 and CHEAL, BRSNN, and total weed mass reduction, despite a few positive relationships, were not statistically significant.

The F statistic confirms a statistically significant linear relationship only between the yield of KWS Juno and Rona 1 and the fresh weight of total weeds (Fig. 3). However, it was found that the estimated model can explain only 29–41% of the variability of

Table 2. The correlation coefficients between the content of phenolic acids and sorgoleone in sorghum plants and weed fresh mass

		Allelochemicals											
		phenols			sorgoleone			phenols			sorgoleone		
Variable	Year	5 DAE	10 DAE	15 DAE	5 DAE	10 DAE	15 DAE	5 DAE	10 DAE	15 DAE	5 DAE	10 DAE	15 DAE
		KWS Freya						KWS Juno					
CHEAL	2016	0.358	0.146	−0.697	−0.856	−0.855	−0.884	−0.258	0.864	0.996*	0.754	0.725	0.699
	2017	−0.409	−0.756	0.485	−0.336	−0.337	−0.327	−0.687	−0.067	0.411	0.751	0.730	0.710
BRSNN	2016	0.094	−0.343	0.038	−0.302	−0.301	−0.327	−0.410	0.444	−0.042	0.222	0.278	0.323
	2017	−0.793	−0.782	0.449	−0.688	−0.689	−0.635	0.923	−0.310	−0.536	−0.965*	−0.970*	−0.970*
Total	2016	0.362	0.374	−0.736	−0.636	−0.637	−0.654	−0.031	0.961*	0.644	0.359	0.366	0.371
	2017	−0.781	−0.930	0.545	−0.692	−0.693	−0.648	0.785	0.046	0.281	−0.369	−0.428	−0.475
		Rona						KWS Sammos					
CHEAL	2016	0.226	0.999*	0.085	0.167	0.166	0.528	−0.165	−0.189	0.622	−0.120	0.147	0.067
	2017	0.842	−0.290	0.646	−0.635	−0.634	−0.212	0.261	0.672	0.868	−0.303	−0.024	−0.109
BRSNN	2016	0.094	0.341	−0.472	−0.755	−0.754	−0.585	0.735	0.345	−0.194	0.881	0.711	0.771
	2017	0.094	0.341	−0.472	−0.754	−0.755	−0.585	0.219	−0.309	−0.595	0.713	0.471	0.550
Total	2016	0.411	0.964*	0.157	−0.068	−0.068	0.391	0.683	0.349	0.673	0.738	0.908	0.867
	2017	0.339	0.268	−0.249	−0.877	−0.876	−0.585	0.294	−0.239	−0.540	0.763	0.532	0.608
		Sucrosorgo 506											
CHEAL	2016	0.164	0.235	0.262	−0.448	−0.085	−0.084						
	2017	−0.424	−0.914	0.905	0.404	0.881	0.880						
BRSNN	2016	0.701	0.028	0.024	0.586	0.584	0.584						
	2017	0.701	0.028	0.024	0.586	0.584	0.584						
Total	2016	0.329	0.400	0.079	−0.423	−0.171	−0.170						
	2017	−0.185	−0.688	0.834	0.306	0.809	0.809						

*statistically significant at 0.05; DAE – days after emergence

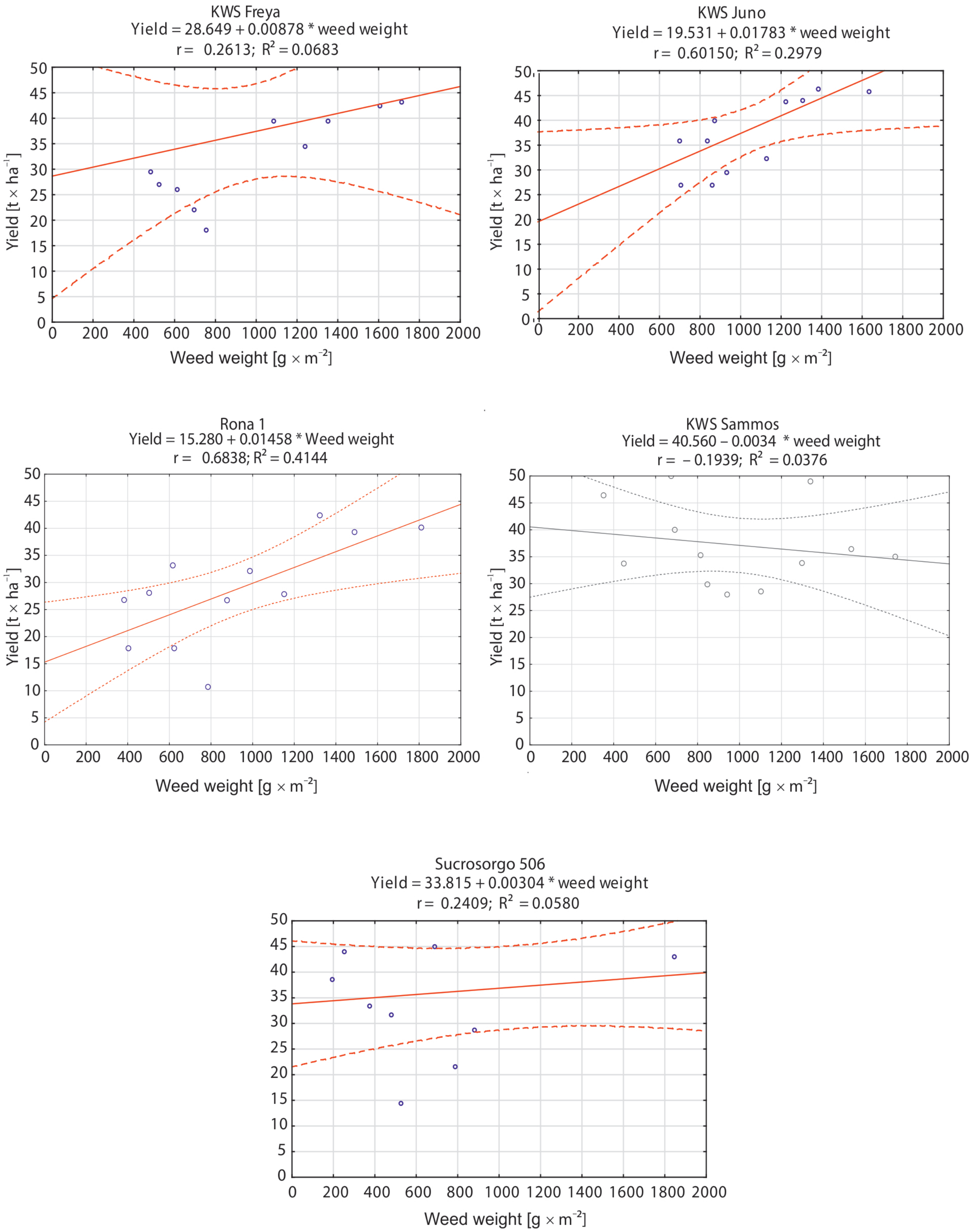

Fig. 3. Dependence of the sorghum fresh mass yield on total weed infestation

the dependent variable, i.e., the yield in relation to weed infestation expressed by weed mass. In KWS Freya, KWS Sammos, and Sucrosorgo 506 cultivars, no statistical relationship was found between the fresh weight of weeds and the yield of these cultivars. The results of the analysis indicate that weed infestation had a positive effect on the yield of most cultivars, with the exception of the KWS Sammos cultivar, which reacted with a decrease in yield as a result of competition with weeds. In all cases, however, certain trends should only be suggested, as these changes have not been statistically confirmed, and in the case of KWS Juno and Rona 1 varieties, the model only slightly explains the course of variability.

Discussion

Of biotic and abiotic factors, weeds are considered to be the main factor affecting the reduction of sorghum yield. Depending on the weed infestation of a plantation and weather conditions, losses can range from 15% to as much as 97%, therefore it is important to keep the plantation free of weeds, especially in its initial stage of growth (Idziak *et al.* 2013).

Weed infestation occurring later in the growing season of sorghum reduces its productivity to a lesser extent, but may hinder harvesting. They compete most strongly with corn and sorghum plants, among others *Ch. album, B. napus* volunteer, *Echinochloa crus-galli* or *Viola arvensis* (Waligóra *et al.* 2020). Weed communities which appeared in the sorghum field during our own research consisted mainly of *Ch. album* and *B. napus,* and to a lesser extent *Fallopia convolvulus, V. arvensis, Geranium petitum* i *E. crus-galli* .

According to Cholajda *et al.* (2021) the use of chemical plant protection products is to be reduced by 50% by 2030. Phasing out active substances in pesticides may contribute to greater interest in plants with allelopathic potential, including, e.g., sorghum. Phenolic compounds inhibit cell elongation, inhibit ion uptake and depolarize the cytoplasmic membranes of root system cells (Li *et al.* 2015). Sorgoleone inhibits or limits the growth of both monocotyledonous and dicotyledonous weeds such as *Solanum nigrum* L., *Amaranthus retroflexus* L., *E. crus-galli* L., and *Eragrostis spectabilis* (Pursh) Steud. The phytotoxic effect of sorgoleone is mainly based on the inhibition of photosynthesis and the synthesis of carotenoids (Sarr *et al.* 2020). The use of an aqueous extract from the aboveground part of sorghum, so-called sorgaab, containing a mixture of phenolic compounds, is indicated as a means of reducing weed infestation. Some reports suggest a positive effect of "sorgaab" not only on weed reduction but also on yield increase (Kostina-Bednarz and Płonka 2023).

The amount of secreted allelopathic compounds depends on the variety of sorghum. The largest amount of sorgoleone is produced by young sorghum seedlings. In the study of Uddin *et al.* (2010), the highest weight of sorgoleone in dry root weight was found in 10-day-old seedlings. The results of our research confirm that the content of sorgoleone depended primarily on the variety of sorghum and its developmental stage, but a unified trend for all varieties was not seen. In the case of KWS Juno, a strong increase in the content of sorgoleone was found in 15-day-old seedlings, similarly, although less clearly, to the cultivars PR 849F and KWS Sammos. The reverse trend was observed in the varieties Aron, Farmsorgo 180, PR 845F, and Rona 1, and confirmed varietal and genotypic differences in terms of sorgoleone content in sorghum roots (Tibugari *et al.* 2018). At the same time, they noted that commercial sorghum varieties produced this compound at a lower level than its wild forms, which suggests that breeding and protecting the crop from excessive weed infestation may contribute to the disappearance of the genes responsible for the production of sorgoleone. Wild forms of sorghum, which are constantly exposed to the stress factor of weeds, stimulate the plant to produce allelochemicals. Planters create high and stable yielding varieties, e.g., sugar sorghum, with a high accumulation of sucrose in the stems (McKinley *et al.* 2018). Therefore, it can be assumed that the breeding work on varieties with the desired characteristics could have contributed to the disappearance of the gene conditioning the synthesis of sorgoleone (Tibugari *et al.* 2018).

The values of the correlation coefficients between the content of total phenolic compounds and sorgoleone in sorghum plants generally indicate their limited effect in relation to CHEAL and BRSNN, although it should be emphasized that there is quite a large varietal difference. This research indicates the limiting effect of sorgoleone contained in the KWS Juno variety, and the strong effect of CHEAL in the KWS Freya and Sucrosorgo varieties. Experiments confirm the limiting effect of sorgoleone on the development of monocotyledonous and dicotyledonous weeds, the latter of which are more sensitive to this substance. The higher the concentration of the discussed allelopathins, the more visible the inhibition of weed growth (Hussain *et al.* 2021).

Sorghum varieties differ in terms of morphology, rate of growth and development, and, as our own research has shown, in the mass of secreted allelopathic substances. The optimal growth of sorghum can be disturbed by the presence of weeds that compete with the crop for nutrients and other factors. The sorghum yield, apart from the species composition of weeds, their distribution and density, may also be influenced by the sowing density of sorghum and the selection of cultivar. Sorghum varieties can be characterized by different competitiveness for weeds not only due to differences in their appearance, development physiology, but also due to different allelopathic potential.

The presence of weeds in the sorghum canopy, regardless of the variety and the content of allelopathic compounds in the plants, affects the yield of sorghum. Contrary to expectations, the presented relationships indicate a beneficial effect of the presence of sorghum yield in most varieties, however, these changes have not been statistically confirmed. This reaction of sorghum plants can likely be explained by the competition between sorghum plants and weeds for water and nutrients. With moderate weed infestations, sorghum may better utilize the available resources in its habitat.

According to Stefan *et al.* (2021), crop weed relationships are very dependent on local abiotic conditions, with the surprising result that crop yield does not always have to correlate with weed suppression or weed diversity under harsher environmental conditions.

Conclusions

The evaluated cultivars significantly differed in the amount of sorgoleone produced by their roots. The highest value was observed in 15-day-old seedlings of the KWS Juno variety, while the lowest was found in 5-day-old seedlings of Sucrosorgo 506. There were significant variations in the content of phenolic compounds between the tested cultivars. The highest levels were detected in 5-day-old seedlings of cv. PR 845F, whereas the lowest levels were observed in 15-day-old seedlings of cv. Farmsorgo 180.

The results of this study do not fully confirm the beneficial effects of allelopathic compounds present in sorghum plants on reducing weed infestation, However, it is important to emphasize the diversity of cultivars. Weeds present in cultivated fields can limit the yield of cultivated plants, particularly when they are sown with wide inter-row spacing. The extent of yield reduction largely depends on the number of weeds. Although the obtained test results were statistically insignificant, they indicate that most varieties of sorghum plants, when facing moderate weed infestation, do not exhibit a significant decrease in yield, therefore, further studies on the weed communities and crop-weed relationships in relation to different environments should be conducted.

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