Agronomy Research **21**(X), xxx–ccc, 2023
https://doi.org/10.15159/AR.23.028

Impact of some herbicides on the growth and the yield of common vetch (*Vicia sativa* L.)

Cs. Juhasz[1], A. Hadhazy[2], W.A.E. Abido[3,*], V. Pal[1,2] and L. Zsombik[2]

[1]University of Debrecen Faculty of Agricultural and Food Sciences and Environmental Management. Kerpely Kálmán Doctoral School. Böszörményi 138, H-4032 Debrecen, Egypt
[2]University of Debrecen, Institutes for Agricultural Research and Educational Farm, Research Institute of Nyíregyhaza, Westsik Vilmos 4–6, H-4400 Nyíregyháza, Hungary
[3]Mansoura University, Faculty of Agriculture, Agronomy Department, Elgomhouria Str., Mansoura City, Egypt
*Correspondence: madawy78@mans.edu.eg

Received: January 23rd, 2023; Accepted: April 2nd, 2023; Published: April 27th, 2023

Abstract. The production and use of common vetch has great potential, but the lack of approved pesticides makes the success of cultivation difficult and unpredictable. The research was carried out on sandy soil at the Nyíregyháza Research Institute of the University of Debrecen in Hungary in April 2022. Five different herbicides, pendimethalin, metolachlor, flumioxazin, bentazon in doses 5 L ha^{-1}, 1.4 L ha^{-1}, 0.06 kg ha^{-1}, 2 L ha^{-1}, respectively, and imazamox in four different doses (0.6, 0.8, 1.0, 1.2 L ha^{-1}) were applied with the consideration of the ranges specified in the Hungarian legislation. The results showed that the highest NDVI (Normalized Difference Vegetation Index) values were obtained with flumioxazin compared to the other treatments. The maximum harvested seed yield (194.1 kg ha^{-1}) was obtained with the application of flumioxazin compared to the control treatment (132.5 kg ha^{-1}). Flumioxazin was also the best as it had the fewest weeds per plot and the lowest phytotoxicity score. Although pendimethalin approached the cleaned and harvested average seed yield of the control plots with 121.3 kg ha^{-1}, it did not feature prominently in the other indicators. With regard to plant trash after cleaning of vetch seed, the highest plant trash (179.4 kg ha^{-1}) was obtained with bentazon. Pendimethalin had the highest percentage ratio between seed yield ha^{-1} and plant trash ha^{-1} (61.8%), followed by flumioxazin (60.7%). The results also showed that there was a positive correlation between NDVI values and seed yield and a positive correlation between NDVI values and plant trash, while there was a negative correlation at the 0.01 level between NDVI values and phytotoxicity.

Key words: flumioxazin, NDVI values, phytotoxicity, weeds, pre-emergent, post-emergent.

INTRODUCTION

The historical background of vetch (*Vicia sp.*) goes back to ancient times. In the 1960s, common vetch (*Vicia sativa* L.) was grown on 75,000 hectares in Hungary. The growing area gradually decreased year by year, and in 2017, 25 hectares with a production amount of 12 tons were documented in Hungary, while in the world the cultivated area of vetch was 353,630 hectares, and the production amount was 711,203 tons in 2020 (FAO, 2022). According to FAO, more than half of total production of vetch species was harvested in Europe between the years 1994 and 2016 (Kutasy, 2019). Based on Hungarian experience, common vetch adapts well to field and crop year extremes. In terms of the pH value of the soil, it can be successfully grown between 4.5–8.2 (Molnár, 2019). The production area of vetch in Hungary correlated with the change in the livestock population, i.e. it decreased. On the positive side, several domestic sources state that it can be grown everywhere in our country. Optimal soils for cultivation are those with medium compaction and humic soils, as well as soils supplied with sufficient nutrients, which is the case in Hungary (Zsombik, 2019). The *Vicia sativa* is usable in many ways, like animal fodder or greening plants, it is one of the leguminous plants, that are able to increase the soil nitrogen content, as well as for human consumption in some part of the world, because it is a cheap substitute of lens (Islam et al., 2003). However, the lack of chemical control and the absence of authorized pesticides may discourage farmers from growing vetch. The active ingredient imazamox is currently allowed to use on Hungarian vetch (*Vicia pannonica* L.). Imazamox is an imidazolinone herbicide used to control weeds in legumes (Bukun et al., 2012). Common vetch is often grown with supporting plants, such as oats (*Avena sativa*), and in this case it is able to suppress weeds better, but in this case, the strong growth of oats may have a negative effect on the yield of the common vetch and other positive effects of the plant (nitrogen fixation) are not as dominant. The diversity, effects and its usability of the plant as well as its historical background, justify the development of plant protection technology for common vetch in Hungary. During our research, we used the experience found in the international literature as a basis for the selection of pesticides. When searching for herbicides, it was a difficulty that most of the literature considers vetch as a weed (Ahmad et al., 1984). Several studies referred to pesticides that were not or no longer on the market in Hungary. It is difficult to find post-emergence herbicides that are effective and do not damage the crop. In the case of common vetch, Balyan & Malik (1991) observed a decrease in dry matter and seed yield with the use of methabenzthiazuron and 2,4-D (2,4-dichlorophenoxyacetic acid). In addition to examining phytotoxicity to common vetch, an important factor was the effectiveness of the given active ingredients in inhibiting the weed species found in the plots. Pendimethalin was phytotoxic to common vetch in a three-year field trial in Spain. In two of the years studied, the active substance reduced the yield of vetch (Caballero et al., 1995). Vasilakoglou et al. (2013) examined the response of several leguminous plants to herbicides. S-metolachlor, pendimethalin and flumioxazin were applied pre–emergence, while imazamox was applied post-emergence in several doses. The results showed that pendimethalin, metolachlor and flumioxazin did not cause phytotoxic effects during the first year of the trial. Pendimethalin at a dose of 1.98 kg ha^{-1} and the active ingredient Metolachlor + terbuthylazine combination at both doses (0.94 + 0.56 and 1.25 + 0.75 kg ha^{-1}) were both effective against the *Chenopodium album* L. Imazamox at a dose of 0.03–0.04 kg ha^{-1} can also be used as an early post-emergence herbicide in common vetch (Vasilakoglou et al., 2013). Two doses of imazamox (0.014 and 0.028 kg 0.4 ha^{-1}) alone and two doses in combination with bentazon (0.11 kg) were applied. Imazamox treatments, including the combination of imazamox and bentazon (0.014 + 0.11 kg 0.4 ha^{-1}), caused significant phytotoxicity in common vetch. Seed yield and germination percentage were similar to the control, but the rate of phytotoxic symptoms ranged from 33–80% (Hinds-Cook et al., 2009). This research could be used to demonstrate that applied sciences are extremely important in life due to their numerous current and past applications (Abido & Zsombik, 2018).

MATERIAL AND METHODS

Study area and experimental design

Our research work was carried out in 2022 April on the sandy soil of the Research Institute of Nyíregyháza, IAREF, University of Debrecen in Hungary. The soil of the experiment is humic sandy soil. The soil pH of our experiment was 7.46. The soil plasticity according to Arany was 26, the amount of water soluble total salt (m/m) was less than 0.02%. The carbonated lime content (m/m) was 0.844%, and the organic carbon content (m/m) was 1.11%. The amount of phosphorus pentoxide was 440 mg kg^{-1}, potassium oxide 252 mg kg^{-1}. The forecrop of the experiment was maize. Common vetch (*Vicia sativa* L.) was sown at the beginning of April 2022 with a seed rate of 138 kg ha^{-1}. The size of each plot was 8.5 m^2. Five different herbicides were used, including imazamox at four different doses. Four replicates were used for each treatment. Herbicide doses were chosen based on application rates already allowed for other crops under Hungarian legislation. Where ranges were given for doses, the mean doses were used. The imazamox was applied in different doses. This ingredient is approved for several cultivars similar to common vetch, e.g. Hungarian vetch (*Vicia pannonica* L.). We have taken into consideration the recommended dose for this species. The common vetch is sensitive to herbicides and there has no herbicide approved in Hungary, yet, therefore we also used lower doses. Table 1 shows the active substances included in the experiment, their dosage and the time of application. The experiment was set up with a Randomized Complete Block Design (RCBD). The herbicides were applied pre-emergent and post–emergent. The pre–emergent and post-emergent treatments were carried out using a Stihl branded Sg 71 type back sprayer. The aim of our research was to investigate the effect of some herbicides on the productivity and weed conditions of common vetch (*Vicia sativa* L.). To monitor plant development, we used the BBCH scale based on UPOV (2012). During the breeding season, the meteorological data were recorded by a Micro Metos 2002 meteorological station.

MEASUREMENTS

Normalized Difference Vegetation Index (NDVI) data collection

Normalized differential vegetation index data were measured twelve times weekly from April 21 to July 7 using by Trimble GreenSeeker HCS-100 hand-held instrument. Two measurements were performed per plot each time. The obtained NDVI values are related to the relative chlorophyll content, the closer the value is to 1, the higher the chlorophyll content (Hatala, 2012). It is important to note that during the measurements, the instrument does not only measure the values of the indirect photosynthetic activity of common vetch (*Vicia sativa* L.), but also the weed values. NDVI values also reflect the phytotoxic effect caused by herbicides on plants.

Table 1. Common name, trade name, chemical name, time of application and rate of application of herbicides under study (Nyíregyháza, 2022)

Common name	Trade name	Chemical name	Time of application	Rate of application
Pendimethalin	Stomp 330 EC	N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine	pre-emergence	5.0 L ha^{-1}
Metolachlor	Dual Gold 960 EC	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(1-methoxypropan-2-yl)	pre-emergence	1.4 L ha^{-1}
Flumioxazin	Pledge 50 WP	2-[7-fluoro-3,4-dihydro- 3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoindole-1,3(2H)-dione	pre-emergence	0.06 kg ha^{-1}
Bentazon	Basagran 480 SL	1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide substituted by an isopropyl group at position 3	post- emergence	2 L ha^{-1}
Imazamox	Pulsar 40 SL	(2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5- oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3- pyridinecarboxylic acid	post- emergence	0.6 L ha^{-1}
Imazamox	Pulsar 40 SL	(2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5- oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3- pyridinecarboxylic acid	post- emergence	0.8 L ha^{-1}
Imazamox	Pulsar 40 SL	(2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5- oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3- pyridinecarboxylic acid	post- emergence	1.0 L ha^{-1}
Imazamox	Pulsar 40 SL	(2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5- oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3- pyridinecarboxylic acid	post- emergence	1.2 L ha^{-1}
Control	-	-	-	-

Phytotoxicity data based on the Dancza (2004) herbicide testing methodology

Phytotoxicity values were also recorded continuously in accordance with the herbicide methodology. The phytotoxicity measurements took place from May 3 to July 7 (9 times). Phytotoxicity was determined based on Dancza (2004) (Table 2), however, the statistical software could not properly handle the % values determined based on this, so for a successful test, an individual ratio had to be prepared.

Table 2. Phytotoxicity percentage and degree of damage according to (Dancza, 2004) (Nyíregyháza, 2022)

Phytotoxicity (%)	Scale values	Degree of damage
0	1	symptom free
1	2	very mild symptom
2	3	mild symptom
5	4	definite symptom
10	5	damaged
25	6	strong damage
50	7	serious damage
75	8	very serious damage
100	9	extinct

Weed measurements

In the herbicide trial, the 50×50 cm sampling frame was used with one replicate per plot, and weed species monitoring and tracking on the plot was also continuous. From the beginning of May to the beginning of June, we recorded the different weed species and their number per plot using a 50×50 cm sampling frame. Weed surveys were continued until the foliage closed (June 10). The following weeds were found: Annual ragweed (*Ambrosia artemisiifolia* L.), White goosefoot (*Chenopodium album* L.), Puruagrass, (*Bolboschoenus maritimus* L.), Common knotgrass (*Polygonum aviculare* L.), Wild radish (*Raphanus raphanistrum* L.), Redshank (*Persicaria maculosa* L.), Wild oat (*Avena fatua* L.), Field horsetail (*Equisetum arvense* L.), Hemp (*Cannabis sativa* L.), Redroot pigweet (*Amaranthus retroflexus* L.), Field pennycress (*Thlaspi arvense* L.), Bindweed (*Convolvulus arvensis* L.), Common chichkweed (*Stellaria media* L.), Giant sumpweed *(Iva xanthiifolia* L.), Scentless mayweed (*Matricaria inodora* L.), Shepherd's purse (*Capsella bursa-pastoris* L.). The number of plants for each weed species recorded during the observation times was added and then averaged in the MS Excel program.

Harvesting and post-harvest data collection

The vetch was desiccated with diquat-dibromid active ingredient on July 20 in order to facilitate the harvest, which took place on August 4. 120 days after sowing, all the plants in each plot ($8.5m^{-2}$) were harvested and air-dried, then threshed, standardizing the amount of the crop to 13% moisture content based on the measured amount. The harvested seeds were cleaned using a Kamas Westrup lab cleaning machine, the size and opening of the sieves used for cleaning were as follows: the upper sieve is 3.75 mm round, the lower sieve is 3.5 mm round. The grain cleaner fractionated grains of different sizes and waste with the help of sieves of different sizes and cleaning air. During the test, we determined the mass of clean grains and plant trash.

Statistical analysis

The basic data was recorded using the MS Excel program (NDVI and phytotoxicity values, degree of weed infestation, waste, seed weight). Descriptive statistical analysis, homogeneity analysis and one-factor analysis of variance were performed using IBM SPSS Statistics v22 statistical software. Homogeneity tests were performed using Duncan's test, and Pearson's correlation tests were performed on the obtained results.

RESULTS

Data from Micro Metos 2002 statistical station

he months of early March to late July, which have the greatest influence on the growing season, were the driest in the last 22 years in terms of rainfall (Fig. 1). Only 125 mm of rain fell during the growing season. In the last 22 years, apart from 2022, only three years had precipitation of less than 160 mm during this period.

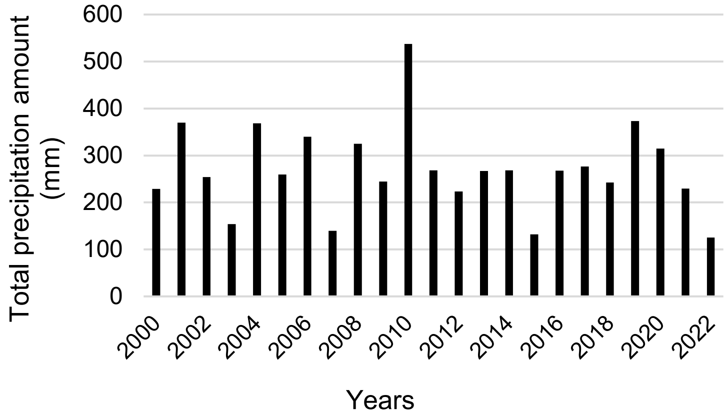

Figure 1. Total precipitation in mm over the last 22 years (Nyíregyháza, 2022).

In April, the amount of precipitation exceeded the average of the last 30 years, which provided suitable conditions for the emergence and early development of the common vetch (Fig. 2). However, there was only 3.9 mm of precipitation in May. In addition to the low amount of precipitation, the temperature values were higher than average. The extreme drought during the flowering phenophase negatively affected the success of generative development, however, it also harmed the development of weeds.

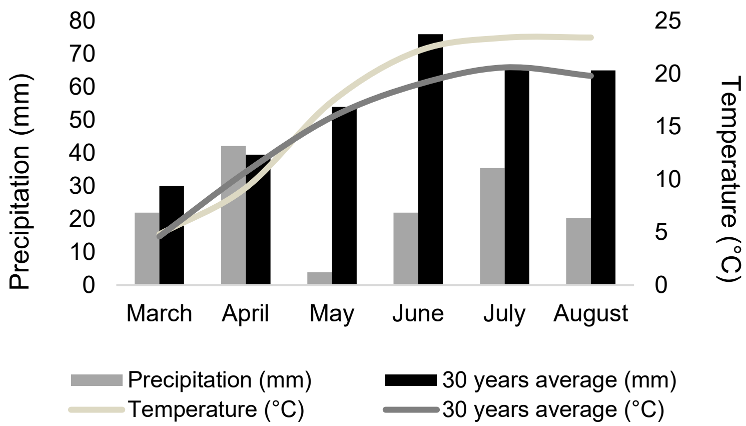

Figure 2. Average monthly precipitation and temperature datas during the growing season compared to the 30 years average (Nyíregyháza, 2022).

Measurement results of the Normalized Difference Vegetation Index (NDVI)

The first time was on April 21, (BBCH stage 10 - pair of scale leaves visible, the plots treated with pendimethalin showed the highest NDVI value (0.193), which was statistically different from the value measured when metolachlor was applied (0.176) as illustrated in Fig. 3.

The second time was on April 26, when the BBCH stage was 12 (2 leaves unfolded), the lowest NDVI value was shown by the metolachlor treatment (0.194). The value of the plots treated with pendimethalin was higher (0.231) than the value of the metolachlor treatment and they were statistically different from each other. Both treatments were statistically different from the value of the control plots (0.249). Fig. 4 illustrates the measured values.

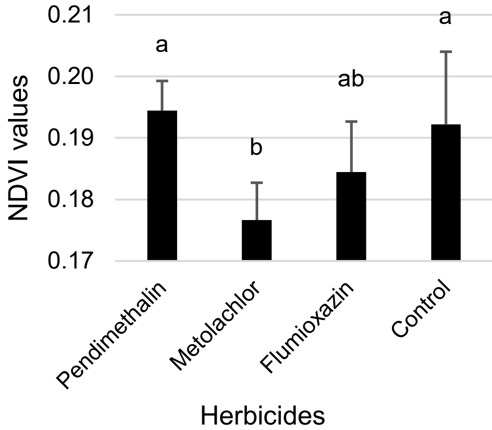

Figure 3. Evaluation of NDVI values in different common vetch herbicide treatments, when pair of scale leaves were visible.

Based on the NDVI values measured on May 3, when the BBCH stage was 19 (9 leaves unfolded), there was no significant difference between plots treated with flumioxazin and control plots, but control plots were statistically different from pendimethalin treated plots and metolachlor treated plots. The measured values are shown in Fig. 5.

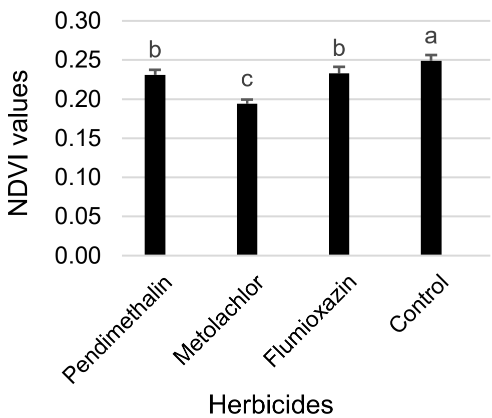

Figure 4. Evaluation of NDVI values in different common vetch herbicide treatments, when was 2 leaves unfolded.

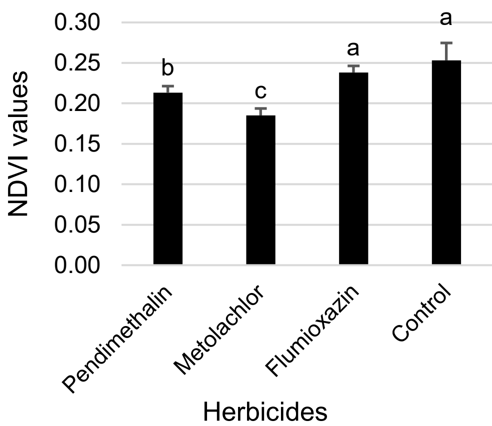

Figure 5. Evaluation of NDVI values in different common vetch herbicide treatments, when was 9 or more leaves unfolded.

Based on the NDVI values recorded on May 11, when the BBCH stage was 30 - beginning of stem elongation, the values of the plots treated with pendimethalin and metolachlor (0.265 and 0.260) treated plots were almost the same and statistically different from the control treatment (0.373). The values recorded for the other treatments are not outstanding here, as the treatment took place two days before, thus the post-emergence herbicides could not yet have exerted their effect here. The measured values are shown in Fig. 6.

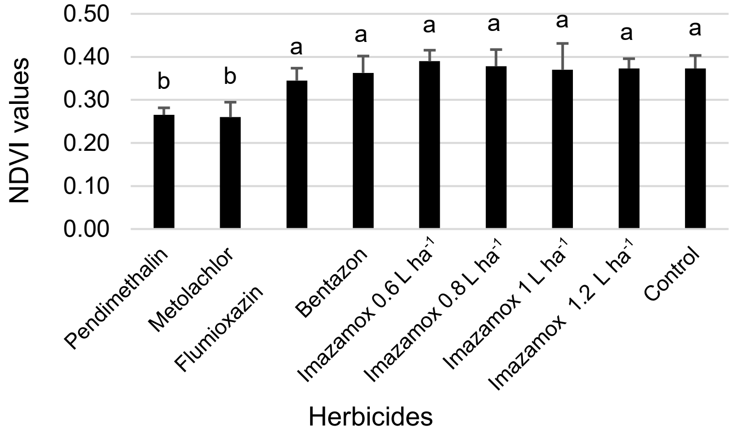

Figure 6. Evaluation of NDVI values in different common vetch herbicide treatments, when stem elongation started.

During the NDVI recording on May 18, when the BBCH stage was 33 - 3 visibly extended internodes, the plots treated with bentazon showed the lowest value (0.350), thus as a result of the post-emergence treatment, the normalized differential vegetation index value decreased compared to the value recorded at the previous recording time. However, the values of other treatments and the control increased. The highest value was measured in the control treatment (0.543) as shown in Fig. 7.

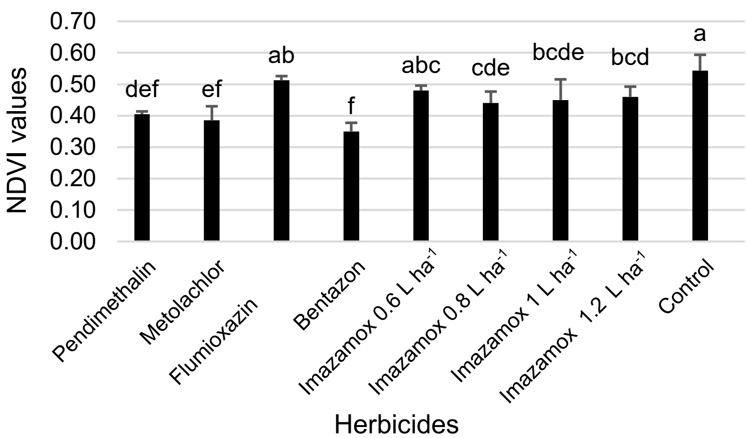

Figure 7. Evaluation of NDVI values in different common vetch herbicide treatments, when there were 3 visibly extended internodes.

The plots treated with flumioxazin showed the highest NDVI value (0.608) at data collection on May 25, when the BBCH stage was 39 - 9 visibly extended internodes (Fig. 8). It was statistically different from the metolachlor treatment, as well as from most post-emergence treatments (bentazon, imazamox 0.8 L ha^{-1}, imazamox 1 L ha^{-1}, imazamox 1.2 L ha^{-1}). The plots treated with bentazon showed the lowest value (0.378) and this treatment was not statistically different from the metolachlor and imazamox treatments.

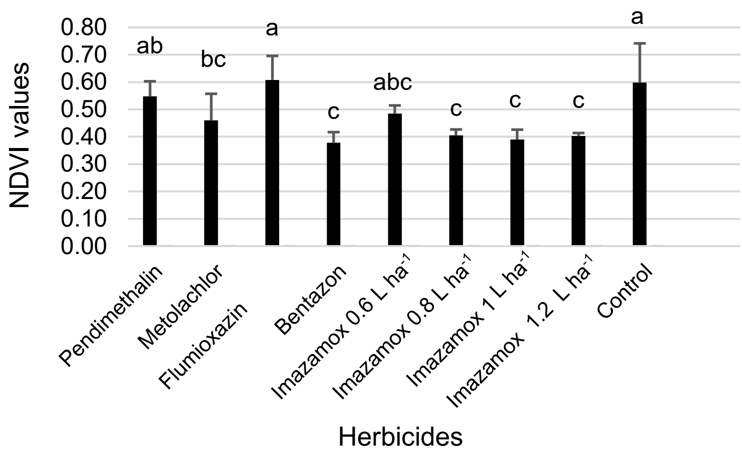

Figure 8. Evaluation of NDVI values in different common vetch herbicide treatments, when there were 9 or more visibly extended internodes.

Subsequently, the NDVI values changed to a large extent, significant differences were measured on May 30, when the BBCH stage was 51 - first flower buds visible outside leaves. The highest values were measured in the plots treated with flumioxazin (0.728) and in the control (0.678), which were statistically different from the values of the bentazon and imazamox 0.8 L ha^{-1}, 1 L $ha^{-1}$and 1.2 L ha^{-1} treatments. Weeds influenced the results in the control. Fig. 9 shows the results on May 30.

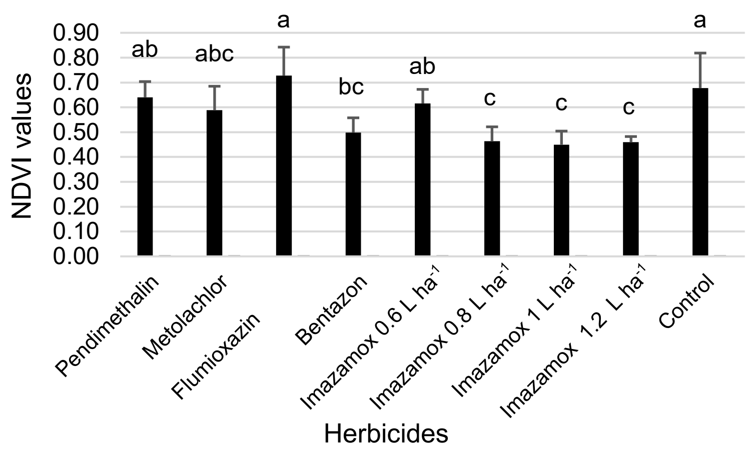

Figure 9. Evaluation of NDVI values in different common vetch herbicide treatments, when the first flower buds were visible outside leaves.

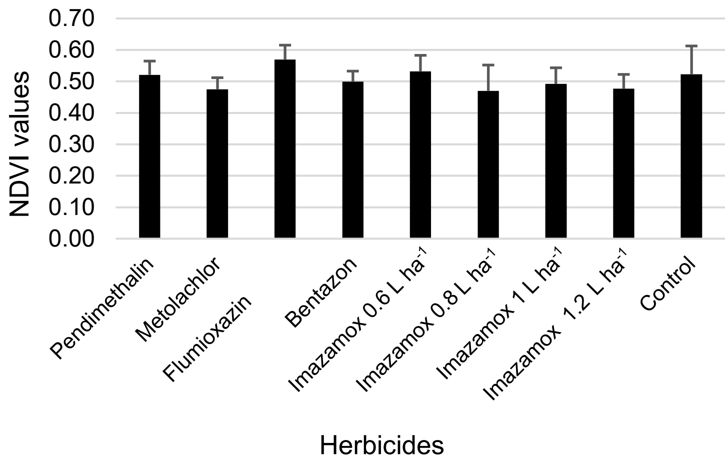

Figure 10. Evaluation of NDVI values in different common vetch herbicide treatments.

Based on the post hoc test of the NDVI data from the average of the twelve measurement times, the data show no statistical difference (Fig. 10). Regardless, it can be said that the plots treated with flumioxazin showed the highest value (0.570), while the plots treated with imazamox 0.8 L ha^{-1} yielded had the lowest value (0.470).

Phytotoxicity test results

Statistical analysis showed that seven out of nine test dates, were statistically different. In the initial period at the beginning of May, when the BBCH stage was 19 - 9 leaves unfolded, pendimethalin and metolachlor applied pre-emergent caused outstanding phytotoxicity values, as detailed in Fig. 11. In vetch, pendimethalin caused clear symptoms, the plant population was more deficient here than in the other treatments, and the treatment resulted in smaller plants. The phytotoxicity caused by pendimethalin and bentazon, as examples is illustrated in Fig. 12. On common vetch, metolachlor also resulted in deficient stands, leaf twisting, paleness, and dwarfed plants. However, plants regenerated over time.

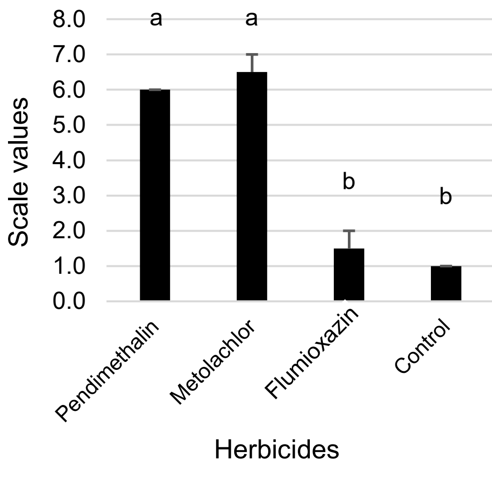

Figure 11. Evaluation of phytotoxicity values in common vetch herbicide treatments, when 9 or more leaves were unfolded.

A) B)

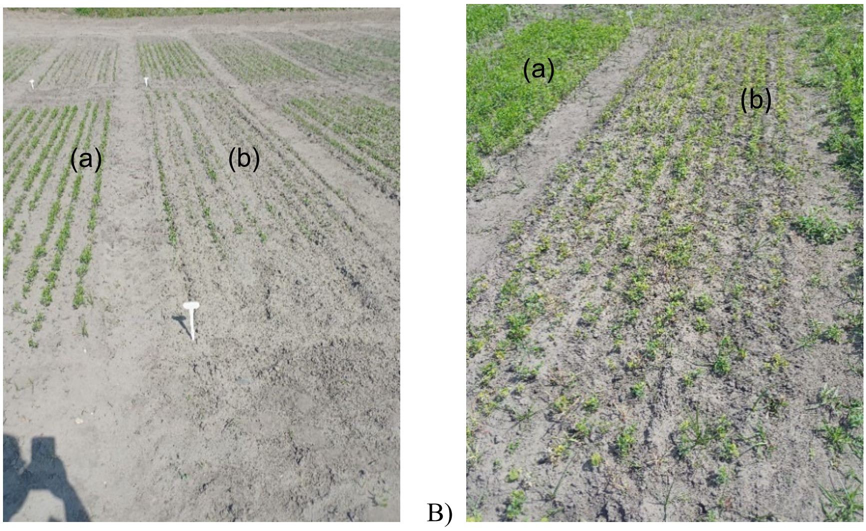

Figure 12. Phytotoxicity caused by pendhimethalin (A) and bentazon (B) on common vetch. (a) plots are untreated, while (b) plots are treated with the herbicides.

Based on data from the end of May to the beginning of June, when the BBCH stage was 39 - 9 visibly extended internodes, bentazon ingredient caused more severe pale yellow symptoms, while the symptoms seen with imazamox were milder. The plots treated with bentazon showed the highest phytotoxicity (6.25). This was followed by imazamox treated with amounts of 1 L ha^{-1}, 1.2 L ha^{-1}and 0.8 L ha^{-1}, and there was no significant difference between them (Fig. 13).

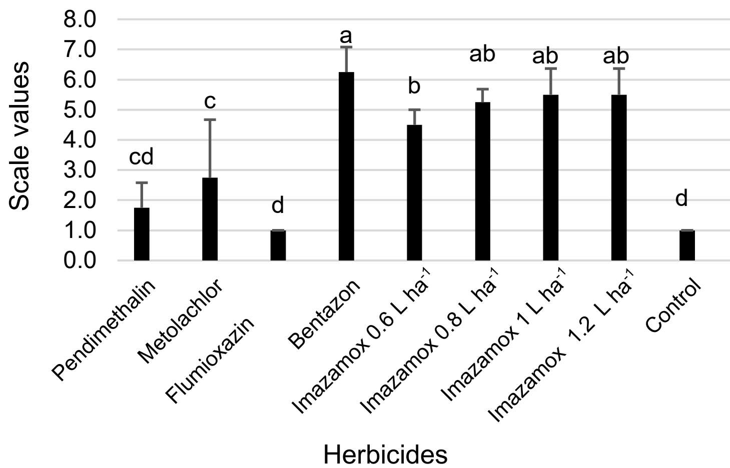

Figure 13. Evaluation of phytotoxicity values in common vetch herbicide treatments, when there were 9 or more visibly extended internodes.

Subsequently, when BBCH stage was 61 - beginning of flowering, the treatment with imazamox 1 L ha^{-1} showed the highest phytotoxicity (Fig. 14), which was statistically different from the phytotoxicity value of flumioxazin (1.75), which was the lowest.

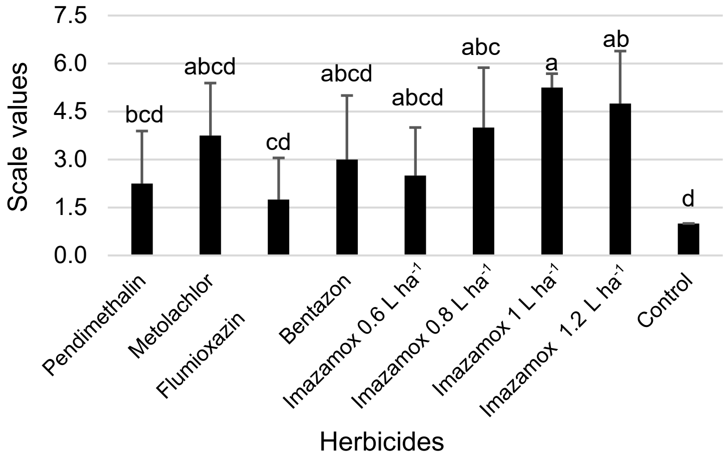

Figure 14. Evaluation of phytotoxicity values in common vetch herbicide treatments, upon the beginning of flowering.

Among the herbicides, the results of plots treated with flumioxazin showed the lowest phytotoxicity value (1.80). The highest phytotoxicity averages resulted from the imazamox 1 L ha^{-1} treatment (Fig. 15).

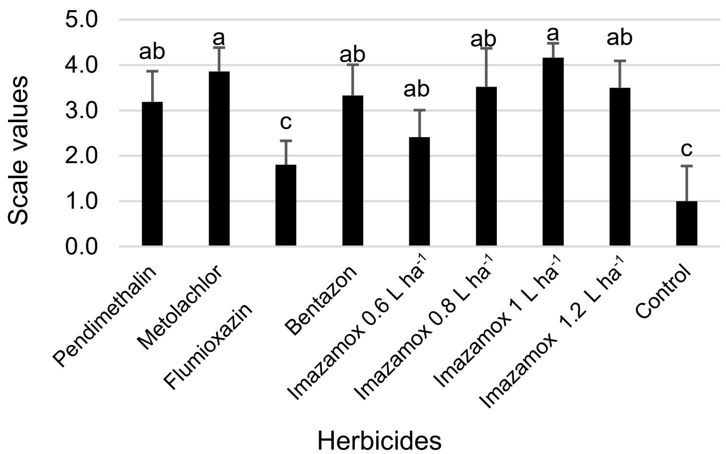

Figure 15. Evaluation of average phytotoxicity values in common vetch herbicide treatments.

Evaluation of the effect of different herbicide treatments on weed characters

We evaluated 16 different weed species occurring in the area. Based on samples collected on five occasions on the Post Hoc test, a significant difference was observed in the abundance of ragweed and white goosefoot. Based on the average of all wild grasses sampled on five occasions, with a value of 2.7 pieces m^{-2}, most of the wild grasses occurred in the control treatment, and the value of the plots treated with pendimethalin was only slightly different from this (2.6 pieces m^{-2}). These plots are significantly different from the other treatments, except for the imazamox 0.6 L ha^{-1} treatment (Fig. 16).

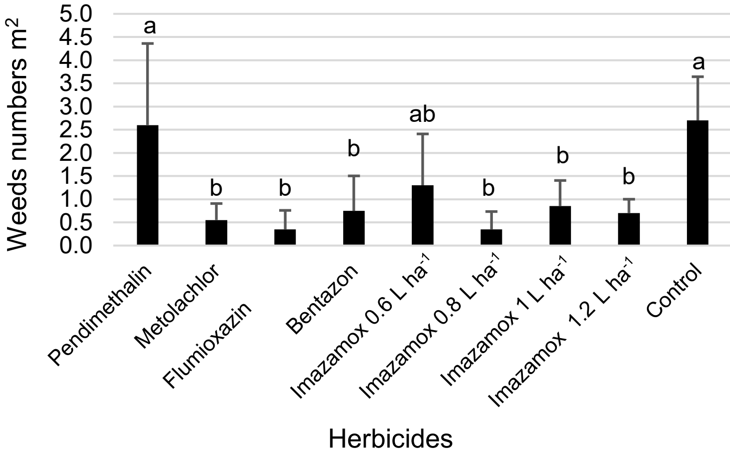

Figure 16. Effect of different herbicide treatments on the number of ragweed (*Ambrosia artemiisifolia* L.) in common vetch.

In the case of the added and then averaged white goosefoot, with a value of 3.75 pieces m^{-2}, the weed occurred in the highest number in the control plots (Fig. 17). Several weed species were present in large numbers, however, the statistical analysis did not show any significant difference between the treatments. Among the weed species occurring in larger numbers, the puruagrass, with a value of 2.5 pieces m^{-2} occurred in the highest amount in the plots treated with imazamox 1 L ha^{-1}, followed by the plots treated with pendimethalin with a value of 2.4 pieces m^{-2}. Redshank occurred in greater numbers with a value of 2.85 pcs m^{-2}, the largest amount occurred in the plots of 0.6 and 0.8 L ha^{-1}of imazamox, but it was second in the plots treated with flumioxazin with a value of only 0.5 pcs m^{-2} lowest, and it did not occur in the plots treated with pendimethalin.

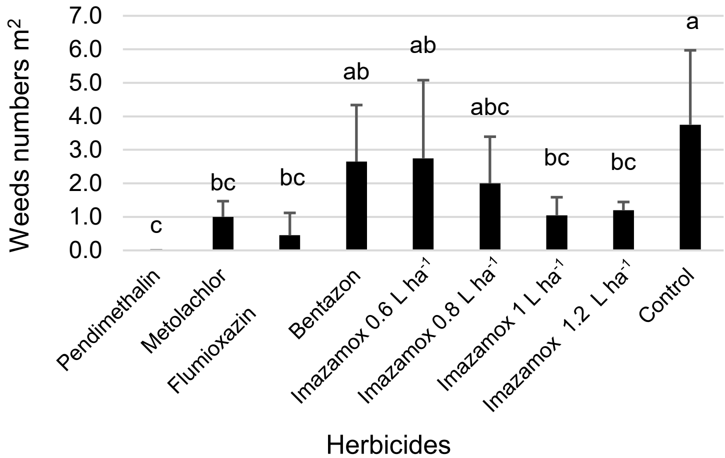

Figure 17. The effect of different herbicide treatments on the number of white goosefoot (*Chenopodium album* L.) in common vetch.

We analysed the total number of weeds at different weed recording times. Based on the data from the first recording on May 4, when the BBCH stage was 19 - 9 leaves unfolded, the metolachlor treatment showed the lowest value of weeds 3 pcs m^{-2}, which was not statistically different from the control value, which was 7.50 pcs m^{-2} as presented in Fig. 18.

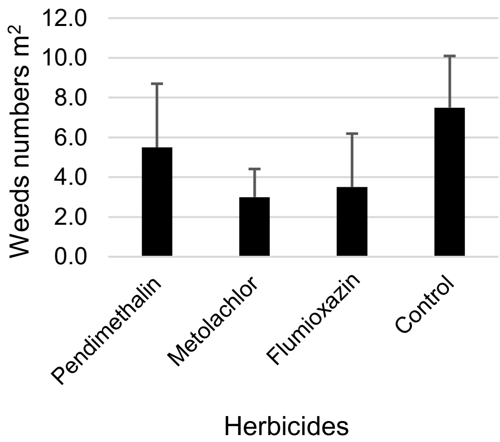

Figure 18. Total weed numbers as a result of herbicide treatments in the common vetch experiment at BBCH 19 phenological stage.

Fig. 19 shows the total number of weeds recorded on May 25, when the BBCH stage was 39, 9 visibly extended internodes. With a value of 12.50 pcs m^{-2}, the control plots had the highest number of weeds; this is statistically different only from the value of the plots treated with flumioxazin (4.75 pcs m^{-2}), which had the lowest number of weeds.

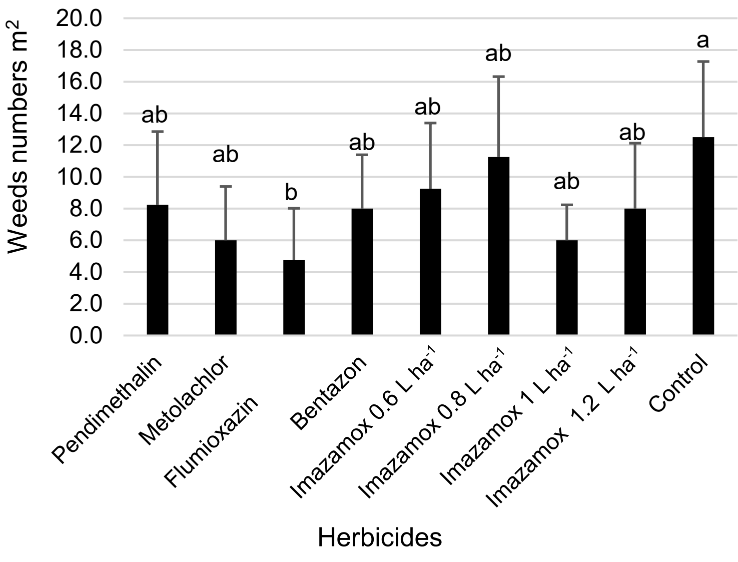

Figure 19. Total weed numbers as a result of the herbicide treatment in the common vetch experiment at BBCH 39 phenological stage.

Based on the data from the total number of weeds survey on June 2, when the BBCH stage was 51 - first flower buds visible outside leaves (Fig. 20), it can be seen that the plots treated with flumioxazin had the fewest number of weeds with a value of 0.50 pcs m^{-2}, followed the plot treated with pendimethalin, followed by the imazamox 1.2 L ha^{-1} treatment, while the most weeds were in the control plots with a value of 12 pcs m^{-2}.

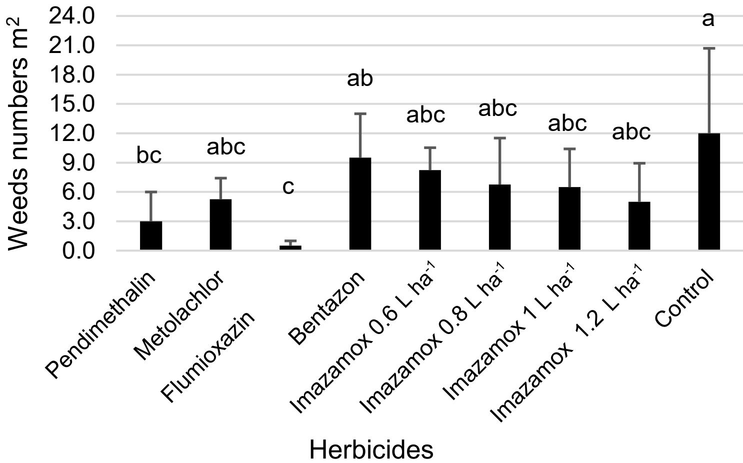

Figure 20. Total weed numbers as a result of the herbicide treatment of the common vetch experiment at BBCH 51 phenological stage.

The last weed collection took place on June 10, when the BBCH stage was 59 - first petals visible, flowers still closed. As expected, the control plots had the most weeds at this time (10.75 pcs m^{-2}). The treatment with 1 L ha^{-1} imazamox resulted in the lowest number of weeds (1.75 pcs m^{-2}), followed by the values of the plots treated with flumioxazin, then the values of the imazamox 1.2 L ha^{-1} treatment, which were not significantly different from each other (Fig. 21).

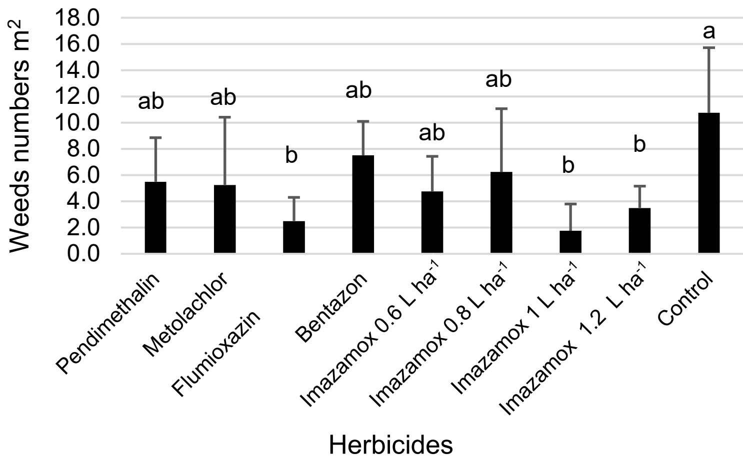

Figure 21. Total weed numbers as a result of the herbicide treatment in the common vetch experiment at BBCH 59 phenological stage.

During the statistical analyses, the average total number of weeds developed according to preliminary expectations, i.e. it was probable that most weeds would grow in the control plots. On average, the control plots had the most weeds (10.4 pcs m^{-2}). This was followed by 8.4 pcs m^{-2} of the plots treated with 0.6 L ha^{-1} imazamox. Flumioxazin was the best performing herbicide with an average of 2.9 pcs m^{-2} as shown in Fig. 22.

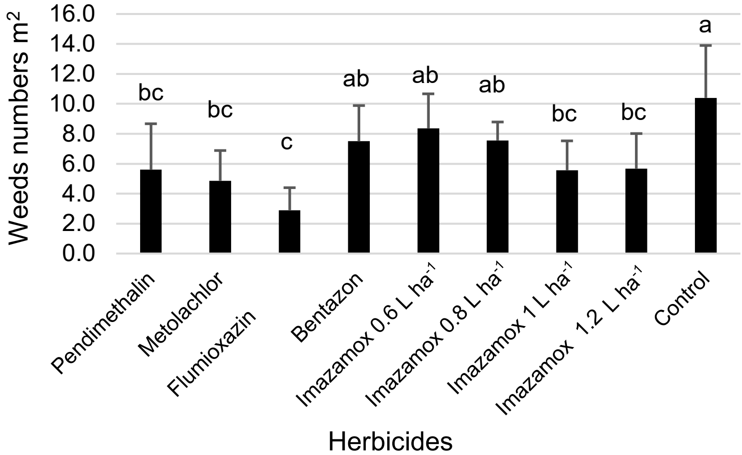

Figure 22. Total weed numbers as a result of the herbicide treatment in the common vetch experiment.

Effect of different herbicides on seed yield of common vetch

It is important to note that the year 2022 was particularly droughty, especially in the eastern parts of the country, thus the harvested crop amounts turned out to be low. In 2022, only 125.2 mm of rain fell between March and July. The lowest yield result was the application of the imazamox at a dose of 1 L ha^{-1} with an average of 34.5 kg ha^{-1}. All plots treated with imazamox had a harvested seed weight below 60 kg ha^{-1}. The imazamox treated plots were significantly different from the flumioxazin treated plots, but the imazamox treated plots and the flumioxazin treated plots were not statistically different from the other treatments and the control. The control plot produced a yield of 132.5 kg ha^{-1}, which was only exceeded by the average results of the flumioxazin treated plots with a yield of 194.1 kg ha^{-1} (Fig. 23).

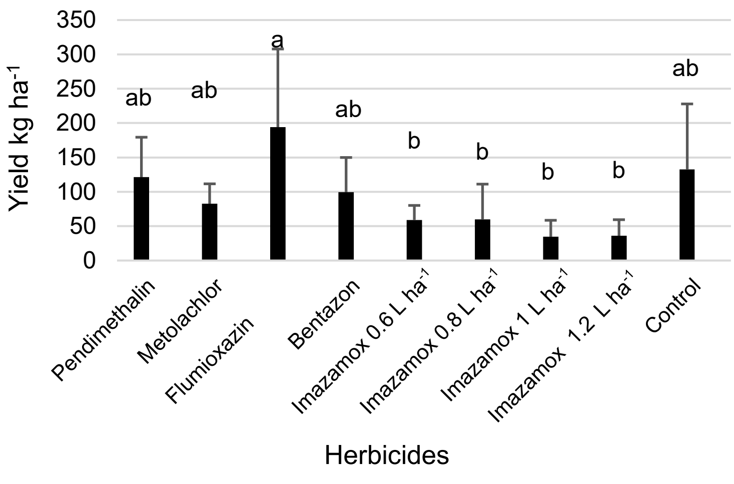

Figure 23. Effect of different herbicide treatments on common vetch yields.

Effect of different herbicide treatments on the amount of plant trash generated during cleaning seeds

Different levels of contamination were measured during the cleaning of common vetch seed lots. The highest contamination was found in the bentazon treated plots with an average of 179.4 kg ha^{-1}. We compared the % of seed yield with the % of plant waste, based on this, pendimethalin was the best with 61.8%, closely followed by flumioxazin (Fig. 24), here the % ratio of seed yield was 60.7%.

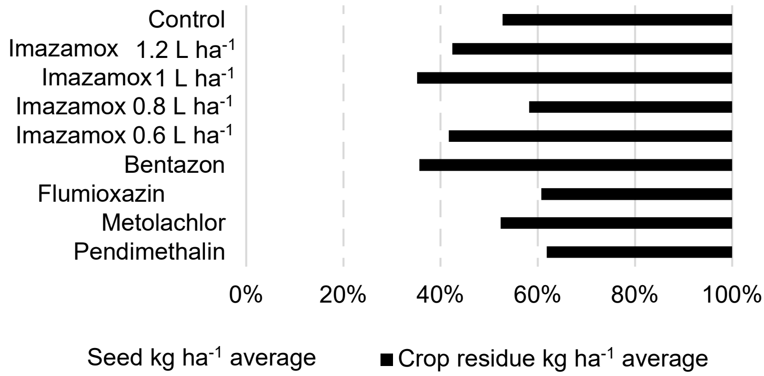

Figure 24. Ratio between quantities of seed and plant waste of common vetch experiment.

Table 3 shows the overall averages of all the parameters studied in the common vetch experiment. Based on the data, the herbicide with the best performance in the experiment was flumioxazin. This herbicide had the highest total average NDVI value (0.570).

Table 3. Averages of total NDVI, phytotox, weeds number, seed yield (kg ha^{-1}) and plant trash (%) as influenced by different herbicide treatments in the common vetch experiment (Nyíregyháza, 2022). Means for groups in homogeneous subsets are displayed. The superscripts indicate if a parameter is significantly different for the treatments

Treatments	NDVI value	Phytotox	Average of weeds m^2	Average seed kg ha^{-1}	Contamination (%)
Pendimethalin	0.521	3.19^{ab}	5.6^{bc}	121.3^{ab}	38.18
Metolachlor	0.475	3.86^{a}	4.9^{bc}	82.6^{ab}	47.62
Flumioxazin	0.570	1.81^{c}	2.9^{c}	194.1^{a}	39.27
Bentazon	0.499	3.33^{ab}	7.5^{ab}	99.4^{ab}	64.35
Imazamox 0.6 L ha^{-1}	0.532	2.42^{ab}	8.4^{ab}	59.0^{b}	58.29
Imazamox 0.8 L ha^{-1}	0.471	3.53^{ab}	7.6^{ab}	59.9^{b}	b41.79
Imazamox 1 L ha^{-1}	0.492	4.17^{a}	5.6^{bc}	34.5^{b}	64.87
Imazamox 1.2 L ha^{-1}	0.477	3.50^{ab}	5.7^{bc}	36.1^{b}	57.58
Control	0.523	1^{c}	10.4^{a}	132.5^{ab}	47.27
Total average	0.5	3.1	6.5	91.0	38.18

Favourable NDVI values were also measured for the imazamox 0.6 L ha^{-1} treatment, but the total average of all weeds pieces in the plots of this treatment was the second highest after the control treatment. The lowest phytotoxicity was observed in the flumioxazin treatment (1.81). In the total average of all weed numbers, the lowest value was for

flumioxazin (2.9 pcs m^{-2}), while the highest value was obtained from the control plots (10.4 pcs m^{-2}). In addition, the highest seed yield was recorded in the flumioxazin treatment (194.1 kg ha^{-1}) followed by the control treatment (132.5 kg ha^{-1}).
For plant trash (kg ha^{-1}), the highest value was found in the plots treated with bentazon (179.4 kg ha^{-1}). Furthermore, the ratio between seed yield and plant trash as (%), based on this, the percentage of plant trash in the plots treated with imazamox 1 L ha^{-1} was the highest (64.87%), followed by the plots which treated with bentazon (64.35%) with no significant differences between them.

Pearson's correlation test

According to Pearson correlation test as shown in Table 4, there was a positive correlation between NDVI values and seed yield at 0.01 level with 0.557, which is a medium strong value, and a positive correlation between NDVI values and plant trash (kg ha^{-1}) at level at 0.01 level with 0.467, which is also a medium strong value. There was a negative correlation at the 0.01 level between mean NDVI values and mean phytotoxicity, at -0.745, which is considered a high strength correlation. There was a positive correlation between seed yield (kg ha^{-1}) and plant trash at the 0.05 level, with a medium correlation of 0.360. Seed yield (kg ha^{-1}) was negatively correlated with phytotoxicity at the 0.01 level, with a medium strength correlation of -0.518. Plant trash was negatively correlated with phytotoxicity at the level of 0.05 and had a medium strength correlation of -0.421.

Table 4. Pearson's correlation between average of NDVI, average seed yield (kg ha^{-1}) average of plant trash (kg ha^{-1}), average of phytotoxicity, average of all total weeds under herbicide treatments in common vetch experiment (Nyíregyháza, 2022)

Results	Average of NDVI	Average seed yield (kg ha^{-1})	Average of plant trash (kg ha^{-1})	Average of phytotox	Average of all total weeds
Average of NDVI	1	.557**	.467**	–.745**	.209
Average seed yield (kg ha^{-1})	.557**	1	.360*	–.518**	.141
Average of plant trash (kg ha^{-1})	.467**	.360*	1	–.421*	–.007
Average of phytotox	–.745**	–.518**	–.421*	1	–.206
Average of all total weeds	.209	.141	–.007	–.206	1

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

The results showed that the seed yield of pendimethalin treated plots was not statistically different from the control plots. Control treatment yielded 132.5 kg ha^{-1}, while the average seed yield of the pendimethalin treated plots was 121.3 kg ha^{-1}. Similarly, in the experiment of Caballero et al. (1995) who indicated that, pendimethalin reduced the yield of common vetch in two out of three years of the experiment. Initially, plants in the pendimethalin treated plots showed clear symptoms, more incomplete stands and smaller plants. Later field studies showed that the plants recovered from these symptoms. Although pendimethalin did not perform outstandingly in terms of weed control, white goosefoot was best controlled by this herbicide, which confirms the findings of Vasilakoglou et al. (2013) that the application of a higher dose of pendimethalin of 1.98 kg ha^{-1} provided the best control of white goosefoot.

The metolachlor treatment on common vetch initially resulted in leaf twisting, wilting, smaller plants and incomplete emergence, but the field survey on May 24, when the BBCH stage was 39 - 9 visibly extended internodes, showed that the plants had almost completely recovered. In terms of herbicidal effect, only flumioxazin performed better than metolachlor. This result is in good agreement with Vasilakoglou et al. (2013), who concluded that a higher herbicidal efficacy (48.8–50%) was recorded with the higher dose of metolachlor + terbutylazine (1.25 + 0.75 kg ha^{-1}), respectively.

Test results on 18th May, when the BBCH stage was 33 - 3 visibly extended internodes, showed that bentazon applied after emergence damaged common vetch. The average phytotoxicity results showed significantly higher values for bentazon as compared to the control treatment. This result contradicts the results reported by Insidecotton (2006) that Basagran at 2 L ha^{-1} did not cause phytotoxicity 3 and 6 weeks after application. In other studies, the application of bentazon resulted in the eradication of common vetch (Dumont & Serpeile, 1981). In a study carried out in 1995, the application of 1 kg ha^{-1} bentazon + 1.5% oil on common vetch leaves showed symptoms of scorch and thinned leaves with a reduced ability to regenerate, whereas in 1997 they were almost fully regenerated and in 1996 they were also damaged but then fully regenerated. In common vetch, the application of both doses of bentazon + oil (1 and 1.2 kg ha^{-1}) in 1995 slightly reduced yields (Americanos & Droushiotis, 1998). In our study, the yields of plots treated with bentazon were also lower than the control.

Application of imazamox resulted in milder symptoms in common vetch based on observations on May 18, when the BBCH stage was 33 - 3 visibly extended internodes. According to Vasilakoglou et al. (2013), imazamox at 0.03–0.04 kg ha^{-1} post-emergence was slightly phytotoxic to common vetch and resulted in 14–16% lower yield than the control treatment (no treatment). Hinds-Cook et al. (2009) found that imazamox treatments caused significant damage to common vetch, but germination percentage and seed yield were similar to those of the control. In a study by García-Garijo et al. (2014), imazamox accumulated mainly in common vetch, where concentrations were more than six times higher than those detected in beans (*Phaseolus vulgaris* L.). Herbicide use can negatively affect symbiosis and biological nitrogen fixation (Zaidi et al., 2005; Vieira et al., 2007). In our study, imazamox at a dose of 1 L ha^{-1} resulted in the highest (worst) average phytotoxicity value of 4.17. Based on the average seed yield per hectare, imazamox 1 L ha^{-1} had the lowest seed yield at 34.5 kg ha^{-1}, closely followed by imazamox 1.2 L ha^{-1} at 36.1 kg ha^{-1}.

CONCLUSION

Based on our findings in the present work, it can be said that flumioxazin herbicide performed best. The highest average NDVI value was observed for this herbicide (0.570), and the plant treated with flumioxazin was also the best performer in terms of seed yield per hectare with an average of 194.1 kg ha^{-1}. In addition, flumioxazin had the lowest average of phytotoxicity value (1.81) and also the lowest average number of weeds (2.9 pcs m^{-2}). Our results showed that the white goosefoot was well controlled by using pendimethalin at the recommended doses. In addition, metolachlor was second only to flumioxazin in terms of total weed number (4.9 pcs m^{-2}), but seed yield was low at 82.6 kg ha^{-1} and phytotoxicity (3.86) was second only to imazamox at 1 L ha^{-1}. All imazamox treatments seed yield per hectare below 60 kg ha^{-1}. Bentazon did not perform prominently either in any of the indicators. Thus, our research suggests that the higher doses of flumioxazin (0.08 and 0.1 kg ha^{-1}) may be worth investigating in the future.

ACKNOWLEDGEMENTS. 'Project no. C1771371 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the KDP-2021 funding scheme'.

REFERENCES

Abido, W.A.E. & Zsombik, L. 2018. Effect of water stress on germination of some Hungarian wheat landraces varieties. *Acta Ecologica Sinica* **3**8(6), 422–428. doi: https://doi.org/10.1016/j.chnaes.2018.03.004

Ahmad, S., Ahmad, I., Barraras, M. & Gill, A.M. 1984. Effect of row spacing and weed control on growth and yield of wheat. *J. Agr. Res., Pakistan* **22**, 113–117.

Americanos, G.P. & Droushiotis, N.D. 1998. Post–emergence herbicides for forage legumes grown for seed production. *Technical Bulletin* **195**. ISSN 0070–2315.

Balyan, R.S. & Malik, K.R. 1991. Growth and development of *Vicia sativa* and Lathyrus aphaca as influenced by herbicide treatments. *Haryana Journal of Agronomy* **7**, 33–38.

Bukun, B., Nissen, S., Shaner, D. & Vassios, J. 2012. Imazamox absorption, translocation, and metabolism in red lentil and dry bean, *Weed Sci.* **60**, 350–354. doi: https://doi.org/10.1614/WS-D-11-00182.1

Caballero, R., Barro, R., Alzueta, C., Arauzo, M. & Hernaiz, J.P. 1995. Weed control and herbicide tolerance in a common vetch–oat intercrop. *Weed Science* **43**, 283–287. doi: https://doi.org/10.1017/s0043174500081182

Dancza, I. 2004. *Herbicide test methodology.* The Department of Plant and Soil Protection of the Ministry of Agriculture and Rural Development, Budapest, 245 pp. (in Hungarian).

Dumont, R. & Serpeille, A. 1981. Essais de desherbage des cultures de pois, feverole, vesce et lupin. In Compte Rendu de la II e Conference du COLUMA. *Paris France* **2**, 379–389.

FAO. (Food and Agriculture Organization of the United Nation). 2022. Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL accessed on 16th February, 2022.

García-Garijo, A., Tejera, A.N., Lluch, C. & Palma, F. 2014. Metabolic responses in root nodules of *Phaseolus vulgaris* and *Vicia sativa* exposed to the imazamox herbicide. *Pesticide Biochemistry and Physiology*. **111**, 19–23. doi: https://doi.org/10.1016/j.pestbp.2014.04.005

Hatala, Z. 2012. *The practical application of precision horticultural technologies*. Szakdolgozat. Debreceni Egyetem. Debrecen, 54 pp. (in Hungarian).

Hinds-Cook, B.J., Curtis, W.D., Hulting, G.A. & Mallory-Smith, A.C. 2009. Postemergence grass control options in vetch grown for seed. https://cropandsoil.oregonstate.edu/sites/agscid7/files/crop-soil/report13-sr10-09-hinds-cook_curtis_hulting_mallory-smith.pdf accessed on 14th December, 2021.

Insidecotton 2006. Managing weeds in vetch rotation crops. http://www.insidecotton.com/xmlui/bitstream/handle/1/995/wep%20i3%20vetch%20management.pdf?sequence= accessed on February 07th 2021.

Islam, M.R., Bari, A.S.M., Rahman, M.H. & Rahman, M.M. 2003. Evaluation of nutritional status of common vetch (*Vicia sativa*) on growing rats. *Bangladesh Journal of Veterinary Medicine* **1**, 57–61. doi: https://doi.org/10.3329/bjvm.v1i1.1920

Kutasy, E. 2019. *Vetch species*. 212–222. In: Alternatív növények. (Szerk: Pepó P.) Mezőgazda Lap– és Könyvkiadó, Budapest. 259 pp. (in Hungarian).

Molnár, T. 2019. The cover crop of the month: common vetch. *Journal of the profession*. 2019/12. Szántóföld. 49 pp. (in Hungarian).
UPOV. 2012. International Union For The Protection Of New Varieties Of Plants. https://www.upov.int/edocs/tgdocs/en/tg032.pdf accessed on 10th March, 2021.
Vasilakoglou, I., Vlachostergios, D., Dhima, K. & Lithourgidis, A. 2013. Response of vetch, lentil, chickpea and red pea to pre– or post–emergence applied herbicides. S*panish Journal of Agricultural Research* 2013 **11**(4), 1101–1111. doi: https://doi.org/10.5424/sjar/2013114–4083
Vieira, F.R., Silva, S.M.M. C. & Silveira, D.P.A. 2007. Soil microbial biomass C and symbiotic processes associated with soybean after sulfentrazone herbicide application. *Plant Soil* **300**, 95–103. doi: 10.1007/s11104-007-9392-4
Zaidi, A., Khan, S.M. & Rizvi, Q.P. 2005. Effect of herbicides on growth, nodulation and nitrogen content of greengram. *Agronomy Sustainable Dev*. **25**, 497–504. doi: 10.1051/agro:2005050
Zsombik, L. 2019. Legume plants in the portfolio of the Agricultural Research Institutes and Agricultural Economics of the University of Debrecen. http://docplayer.hu/142818557–Pillangos–novenyek–a–debreceni–egyetem–agrar–kutatointezetek–es–tangazdasag–portfoliojaban.html accessed on 19th September, 2021. (in Hungarian).