Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 1, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

A COMPARATIVE STUDY OF SOME SOIL HERBICIDES FOR ANNUAL WEEDS CONTROL IN MAIZE

Anyo MITKOV

Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: anyomitkov@abv.bg

Abstract

In 2022 and 2023, a field plot trial with the maize hybrid P 9241 was conducted. The trial was performed on the experimental field of the department of `Agriculture and herbology` at the Agricultural University - Plovdiv, Bulgaria. The evaluated herbicidal products were Adengo® 465 SC (225 g/l isoxaflutol + 90 g/l thiencarbasone-methyl + 150 g/l cyprosulfamide (antidote)), Gardoprim Plus Gold® 550 SC (312.5 g/l s-metolachlor + 187.5 g/l terbuthylazine), Camix® 560 SE (60 g/l mesotrione + 500 g/l s- metolachlor) and Stomp Aqua® (455 g/l pendimethalin). The herbicidal products were applied alone after sowing before germination of the crop. The weed infestation of the experimental field was presented by Digitaria sanguinalis (L.) Scop., Chenopodium album L., Amaranthus retroflexus L., Xantium strumarium L., Abutilon theophrasti Medic, Datura stramonium L., Solanum nigrum L., and Portulaca oleracea L. The infestation with these weeds resulted in a very low average grain yield for the untreated control (270.54 kg/da). The highest herbicidal efficacy as well as the highest seed yields after the alone application of Camix 560 SE was recorded.

Key words*: maize, weeds, herbicides, efficacy.*

INTRODUCTION

A major challenge for humanity is the provision of food for the population and animals. Agricultural crops are the main raw material for the food industry. That is why many scientific studies are focused on sustainable production of agricultural crops (Shopova, 2023; Dimtrova et al., 2019; Nenova et al., 2019; Marinov-Serafimov et al., 2017; Shopova & Cholakov, 2015; Yanev, 2015; Shopova & Cholakov, 2014; Yanev et al., 2014a; Foley et al., 2011).

Maize (*Zea mays* L.) is of the ancient and iconic cereals through the world, owing to its wide range of uses such as human food, animal feed, and biofuel (ethanol production) (Green et al., 2018). Weed management had a major affect on the success of maize growth, because the competition ability of maize is relative low (Andr et al., 2014). In addition to the competition with maize, weeds might also introduce pathogenic bacteria and viruses, which in turn cause critical reductions in yield (Venkataraju et al., 2023). One of the main problems linked to maize crop facing Bulgaria is the weed control. A plethora of annual weed species has been documented to have negative effects on maize yield (Mennan et al., 2003; Meissle et al., 2010; Zhang et al., 2013; Tesfay et al., 2014; Tursun et al., 2015; Mhlanga et al., 2016; Hançerli and Uygur, 2017; Imoloame, 2017; Böcker et al., 2018; Absy, 2019; Delchev, 2022; Idziak et al., 2022; Kakade et al., 2020). Weeds in maize are very competitive for water, light and nutrients (Gołębiowska and Rola, 2008). It is important to reduce their occurrence already in the early stages of development, i.e. from emergence to 8-10 leaves stage (Hruszka, 2003, Sulewska et al., 2008), especially in maize, which is characterized by a slower growth rate in this period (Gąsiorowska and Makarewicz, 2008). According to the report of Oerke and Dehne (2004), a 37% reduction in maize production was observed under weed pressure. In this context, weed control must be done at the earlier periods of growth, whether the corn plant is grown for grain or for silage. The critical weed-free period for maize is between the 3rd and the 6th weeks after emergence (Zimdahl, 2004). Weed competition is manifested by a decrease of maize biomass and yield losses, which is usually between 30% and 50%, depending on the weed density, time and duration of competition, weed spectrum and other factors (Hurle, 1988).

Most often, weed control is carried out by the application of herbicides. When choosing a herbicide, the following requirements must be taken into account: it must be selective to the crop, it must be effective against the weeds, its use must not lead to the accumulation of residual quantities in the plant production and in the soil, it must not deteriorate the quality of the productiont, to be harmless to soil microorganisms and for the environment (Yanev, 2023; Goranovska et al., 2022; Yanev, 2022; Yanev, 2021; Yanev, 2020; Yanev & Kalinova, 2020; Goranovska & Yanev, 2016; Kostadinova et al., 2016; Hristeva et al., 2015; Kalinova & Yanev, 2015; Semerdjieva et al., 2015; Hristeva et al., 2014; Yanev et al., 2014b).

Pre-emergent herbicides are widely used for weed control in maize in Europe, where glyphosate tolerant cultivars are not registered. Thiencabazone is a relatively new active ingredient from the group of inhibitors of acetolactate synthase. According to Stephenson and Bond (2012), isoxaflutole + thiencarbazone provided better weed control than atrazine + S-metolachlor at pre-emergent application in maize. Gardoprim Plus Gold 500 EC (terbuthylazin + S-metolachlor) is a relatively old herbicide (Schulte and Allen, 2000), but is still widely used. For both active ingredients, synergy effects were recorded for control of annual weeds (Schulte et al., 2002). The efficacy of S-metolachlor is strongly influenced by soil moisture and delayed under dry conditions (Jursík et al., 2013). Herbicides applied to the soil reduce the weed population as most of the germinating weeds are suppressed (Mati´c et al., 2011). These weeds mostly consist of annual weeds that reproduce by seed. The effect of herbicides applied to the soil lasts about 40-50 days (Delchev, 2021).

The aim of this study was to evaluate the efficacy of selected herbicides applied pre-emergence for weed control in maize grown for grain.

MATERIALS AND METHODS

In 2022 and 2023, a field experiment with the maize hybrid P 9241 was conducted. The trial was situated in the Training and Experimental Field of the Department of Agriculture and Herbology at the Agricultural University - Plovdiv, Bulgaria.

The experiment was carried out according to the block design in 4 replications with a size of the working plot of 112 m².

A preliminary inspection of the experimental field was performed. In the reporting field eight types of weeds, typical for the crop were identified. The average weed density in the two experimental years, per 1 m² was as follows: *Digitaria sanguinalis* (L.) Scop. - 5 specimens; *Chenopodium album* L. - 5.5 specimens; *Amaranthus retroflexus* L. - 6 specimens; *Xantium strumarium* L. - 14 specimens; *Abutilon theophrasti* Medic - 6 specimens; *Datura stramonium* L. - 5 specimens; *Solanum nigrum* L. - 7 specimens; *and Portulaca oleracea* L. - 5 specimens.

The study included the following treatments: 1. Untreated control; 2. Adengo 465 SC (225 g/l isoxaflutol + 90 g/l thiencarbasone-methyl + 150 g/l cyprosulfamide - antidote) - 0.44 l ha^{-1}; 3. Gardoprim Plus Gold 550 SC (312.5 g/l s-metolachlor + 187.5 g/l terbuthylazine) - 4.0 l ha^{-1}; 4. Camix 560 SE (60 g/l mesotrione + 500 g/l s-metolachlor) - 2.5 l ha^{-1}; 5. Stomp Aqua (455 g/l pendimethalin) - 3.5 l ha^{-1}.

All treatments were performed after sowing before germination of maize (BBCH 00).

The herbicide spraying was accomplished via electrical backpack sprayer SOLO model 417 (Solo, Germany) with a volume of the working solution of 300 l ha^{-1}. The herbicide efficacy evaluations were performed 14, 28 and 56 days after herbicidal application. The 10-score scale of EWRS (European Weed Research Sociaty) for visual rating was used.

For herbicidal selectivity, the 9-score scale of EWRS was used.

Maize was grown as a mono-cropping system under non irrigation conditions.

The experiment was carried out on a meadow-drained soil type (former meadow-marsh), slightly saline, with a thickness of the A horizon of 25-28 cm. The humus content is about 2%, and the reaction is neutral (pH = 7.15). The content of physical clay in the upper horizons reaches 50%. It is dark-colored, with a well-defined crumbly-granular structure.

The soil is carbonate, alluvial-meadow, slightly saline with sandy-clay character (Yanchev and

Popova, 1999). The content of mobile forms of the main mineral elements, determined by standard methods in the Laboratory Complex of the Agricultural University - Plovdiv, is as follows: total nitrogen (N) - 26.65 mg/kg, total phosphorus (P_2O_5) - 11.21 mg/kg 100 g and potassium (K_2O) - 27.47 mg/100 g.

The soil preparation before sowing of the crop included deep autumn ploughing in 20-25 cm of depth. Also, two disking operations were performed. Pre-sowing fertilization with NPK 15:15:15 at the rate of 250 kg ha^{-1} was accomplished. Sowing was carried out in the optimal time for the crop at a spacing 20 x 70 cm. Spring dressing with NH_4NO_3 at the rate of 250 kg ha^{-1} was also done.

The agrometeorological data during the experiment is provided by the department of "Botany and Agrometeorology" at the Agricultural University of Plovdiv, Bulgaria. The amount of precipitation and the average air temperatures during the maize growing season (from April to September) during the experimental years are presented in Table 1.

Table 1. Monthly precipitation (mm) and average monthly air temperatures (C°)

Months	Years			
	2022	2023	2022	2023
	Precipitation (mm)		Temperatures (C°)	
April	52.00	64.75	392.5	373.3
May	33.50	63.25	588.4	512.2
June	106.80	83.75	685.2	685.3
July	11.00	26.50	805.9	808.5
August	46.8	33.50	816.8	817.1
September	30.8	19.75	586.6	654.7

The table thus presented makes an impression on the low amount of precipitation for July and September for the two experimental years.

The results of the conducted research with the software package of SPSS 17 program of one- and two-factorial analysis of variance were processed.

RESULTS AND DISCUSSIONS

Table 2 shows the dynamics in the efficacy of herbicides on *D. sanquinalis* on average for the two experimental years. Weeds were very successfully controlled by all herbicides tested, but only at the first reporting date (90-95%). Table 2 also shows that the products Gardoprim Plus Gold and Camix on the 28th day after treatment showed approximately the same herbicidal efficacy as on the 14th day. For the herbicides Adengo and Stomp Aqua, efficacy was 80% on the same reporting date. With the exception of the product Camix, in the other variants in the experiment, the herbicidal effect was unsatisfactory at the last reporting date (50-60%). Although on the 14th day after the treatment a high efficiency of 90 to 95% was reported in all variants of the experiment, on the 56th day it decreased and reached only 50-70%, due to high secondary infestation with *D. sanquinalis*.

Table 2. Efficacy of the studied herbicides against *D. sanquinalis*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	90	80	50
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	95	90	60
4. Camix - 2.5 l ha^{-1}	95	90	70
5. Stomp Aqua - 3.5 l ha^{-1}	90	80	50

Against *Ch. album* the results of the used herbicides are reflected on Table 3. Approximately excellent results against weed were reported from all variants of the experiment (on the 14th day after the application of the herbicides - from 95 to 100%). Despite the fact that at the first reporting date from the herbicides we have high results compared to the control of the weed, on the 28th day after treatment, the efficacy stared decrease gradually. On the 56th day after treatment, the efficacy reached 60% with Stomp Aqua. At the same reporting date, the herbicidal effect of the products Adengo, Gardoprim Plus Gold, and Camix was higher – from 70 to 80%.

Table 3. Efficacy of the studied herbicides against *Ch. album*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	100	90	70
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	95	90	75
4. Camix - 2.5 l ha^{-1}	100	95	80
5. Stomp Aqua - 3.5 l ha^{-1}	95	80	60

The results of the used herbicides against the weed *A. retroflexus* are presented on Table 4. Regardless of the tested herbicidal product, the weed control in all variants was 100% on the first reporting date. This is not the case for the next two evaluation dates. This maximum

efficacy against *A. retroflexus* lasted almost until the 28th day after treatment with the herbicides Adengo, Gardoprim Plus Gold, and Camix (90%). The variant with Stomp Aqua reported 85% herbicidal control on the same date. By the end of the maize growing season, secondary weeding with this weed species was observed, that is why, at the last reporting date, the efficiency decreased and reached from 65 to 80% in the different variants of the experiment.

Of all annual dicotyledonous weeds in trial, *Xa. strumarium* was the most difficult-to-control weed in the trial (Table 5). In none of the treatments the efficacy was satisfactory. The herbicides Gardoprim Plus Gold and Stomp Aqua had 0% efficacy at all reporting dates. Although with the other two herbicides the effect was from 90 to 95% only on the first reporting date, in subsequent observations the efficacy decreased progressively, reaching 70-75% on the 28th day. At day 56 after treatment, herbicide control was absent or very weak in all variants in the experiment. These low results are most likely due to the fact that the weed germinates over a long period of time and from different depths in the soil. This is also a reason for the presence of late secondary weed infestation.

Table 4. Efficacy of the studied herbicides against *A. retroflexus*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	100	90	80
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	100	90	75
4. Camix - 2.5 l ha^{-1}	100	90	80
5. Stomp Aqua - 3.5 l ha^{-1}	100	85	65

Table 5. Efficacy of the studied herbicides against *Xa. strumarium*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	95	75	25
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	0	0	0
4. Camix - 2.5 l ha^{-1}	90	70	20
5. Stomp Aqua - 3.5 l ha^{-1}	0	0	0

Approximately excellent efficacy results were obtained from the tested herbicides in the experiment against *A. theophrasti* - i.e. an efficacy of 90 to 100% was obtained on the 14th day after application (Table 6). This maximum efficacy against *A. theophrasti* did not persist in the 28th and 56th day after herbicidal treatments. Comparatively, the efficacy was lower in the variants treated with Gardoprim Plus Gold and Stomp Aqua (60-65%) at the second reporting date. On the last reporting date a very low efficacy at variants 2 and 4 was recorded (55-60%).

Table 6. Efficacy of the studied herbicides against *A. theophrasti*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	100	85	55
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	90	65	30
4. Camix - 2.5 l ha^{-1}	100	85	60
5. Stomp Aqua - 3.5 l ha^{-1}	95	60	25

Table 7 shows that only the herbicides Adengo and Camix showed 100 percent control of *D. stramonium* at the first reporting date. At the next date, the efficacy was good only from Camix (80%). At the 56th day from the date of treatment, the herbicidal effect against the weed was significantly reduced due to heavy secondary weed infestation with *D. stramonium.*

All herbicidal products completely controlled (100%) *S. nigrum*, only up to the 14th day after treatment (Table 8). At the second reporting date, it was reported that the weed was highly controlled by Camix (90%). The remaining products also showed relatively high efficacy rates of 80 to 85%. However, this was not the case at the last reporting date - on the 56th day after the application of the herbicides. The herbicidal effect then varies from 60 to 70%.

Table 7. Efficacy of the studied herbicides against *D. stramonium.*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	100	70	35
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	90	65	25
4. Camix - 2.5 l ha^{-1}	100	80	50
5. Stomp Aqua - 3.5 l ha^{-1}	90	60	20

Table 8. Efficacy of the studied herbicides against *S. nigrum*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	100	85	60
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	100	85	65
4. Camix - 2.5 l ha^{-1}	100	90	70
5. Stomp Aqua - 3.5 l ha^{-1}	100	80	60

Against the weed *P. oleracea*, the results of the herbicides used are presented on Table 9. Excellent results were obtained from all variants on the 14th day after treatment - 100%. At the next reporting date, the herbicidal effect decreased and reached 75-85% for variants from 2 to 4. The product Stomp Aqua had a slightly higher efficiency - 90%. This trend is also preserved for the third reporting date.

Table 9. Efficacy of the studied herbicides against *P. oleracea*, average for the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Adengo - 0.44 l ha^{-1}	100	85	65
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	100	75	60
4. Camix - 2.5 l ha^{-1}	100	85	70
5. Stomp Aqua - 3.5 l ha^{-1}	100	90	75

Visible signs of phytotoxicity were not observed in any of the variants.

Table 10 presents the results of the yields obtained from the individual replications on average for each variant of the experiment. Differences in yields are determined by the herbicidal efficacy of the products and by their ability to control the weeds present. The natural background with highly competitive weed species for 2022 and 2023, as well as the low amount of rainfall during the maize growing season in both experimental years resulted in a very low average yield of the untreated control (2.71 t ha^{-1}). According to the degree of mathematical proof, five separate groups are distinguished (a, b, c, d, f). It was found that treatment 4 (Camix -2.5 l ha^{-1}) is from the group (e) - the most distanced group from the untreated control (a), that is, with the highest yield followed by variant 3 (Adengo). Due to the fact that the herbicides Gardoprim Plus Gold and Stomp Aqua cannot control the main dicotyledonous weed in the experiment (*Xa. strumarium*), their yield is reduced compared to the yield of the above products. Although compared to the other herbicides, Stomp Aqua had the lowest yield, it also had a statistically proven difference compared to the untreated control.

Table 10. Maize grain seed yield, t ha^{-1}

Treatments	Yields
1. Untreated control	2.71a
2. Adengo - 0.44 l ha^{-1}	5.40*d
3. Gardoprim Plus Gold - 4.0 l ha^{-1}	4.90*c
4. Camix - 2.5 l ha^{-1}	5.78*e
5. Stomp Aqua - 3.5 l ha^{-1}	4.31*b

Legend: All values with a * sign have significant differences with the result of the untreated control. All values followed by different letters are with proved difference according to Duncan's test at $P < 0.05$

CONCLUSIONS

The herbicidal products Camix 250 SE and Adengo 465 SC outperformed all other herbicides in the experiment in their control against *Xa. strumarium*.

Against *Ch. album* the highest herbicidal effect from the products Adengo 465 SC, Gardoprim Plus Gold 550 SC and Camix 250 SE was obtained. The lowest herbicidal efficacy against weeds was observed with the product Stomp Aqua.

Of all the annual dicotyledonous weeds in the experiment *Xa. strumarium* was the most difficult-to-control by the evaluated herbicides.

Of all the weeds available in the trial, *A. retroflexus* was best controlled.

No visible signs of phytotoxicity were observed in either variant throughout the maize vegetation.

Compared to the untreated control, mathematically proven differences in corn grain yield were reported in favor of all variants treated with herbicides.

The highest maize grain seed yield after the application of Camix 250 SE - 2.5 l ha^{-1} was found (5.78 t ha^{-1}).

Of all the herbicide-treated variants, the lowest yields after the treatment with Stomp Aqua (4.31 t ha^{-1}) were obtained.

ACKNOWLEDGEMENTS

This experiment was carried out with the support of Project 17-12 at The Centre of Research, Technology Transfer and Protection of Intellectual Property Rights at the Agricultural University of Plovdiv, Bulgaria.

REFERENCES

Absy, R. (2019). Weed Control Efficiency of some Pre- and Post-Emergence Herbicides in Maize. J. Plant Prod., 10, 1037–1042 [CrossRef].

Andr, J., V. Hejnák, M. Jursík, V. Fendrychová. Effects of application terms of three soil active herbicides on herbicide efficacy and reproductive ability for weeds in maize. Plant Soil Environ, Vol. 60, 2014, No. 10: 452–458.

Böcker, T.; Brıtz, W.; Fınger, R. Modelling the effects of a glyphosate ban on weed management in silage maize production. Ecol. Econ. 2018, 145, 182–193 [CrossRef].

Delchev, G., 2021. Efficacy and Selectivity of Some Herbicides in Five Field Crops; Monograph, -LAP LAMBERT Academic Publishing: Saarbrücken, Germany,; p. 225.

Delchev, G. Productivity of duo system and conventional grain maize (*Zea mays* L.) By influence of some herbicides and herbicide tank mixtures. Agron. J. 2022, 1, 283–288.

Dimitrova, M., Minev, N., Yordanova, N., Valcheva, V., & Yanev, M. (2019). Effect of planting density of different maize hybrids on crop growth and yield. *Scientific Papers. Series A. Agronomy*, Vol. LXII, № 2, 73-76.

Foley, J.A.; Ramankutty, N.; Brauman, K.A.; Cassidy, E.S.; Gerber, J.S.; Johnston, M.; Mueller, N.D.; O0Connell, C.; Ray, D.K.; West, P.C.; et al., 2011. Solutions for a cultivated planet. Nature, 478, 337–342 [CrossRef].

Gąsiorowska, B., Makarewicz, A., 2008. The efficiency of selected herbicides in maize cultivation. Prog. Plant Protection/Post. Ochr. Roślin 48(2): 578–581 (in Polish).

Gołębiowska, H., Rola, H., 2008. Maize varieties reaction to herbicides in the light of studies conducted in the lower Silesia region during 1992–2007. Prog. Plant Protection/Post. Ochr. Roślin 48(2): 590–601 (in Polish).

Goranovska, S., Kalinova, S., & Yanev, M. (2022). Influence of herbicides and foliar fertilizers on the yield, the structural elements of yield and technological qualities of the maize grain. *Bulgarian Journal of Agricultural Science*, *28*(1), 137-144.

Goranovska, S., Yanev, M. (2016). Economic efficiency of the chemical control of the weeds in maize. *Proceedings of Science-Technical Conference with International Participation - Ecology and Health*, 82–85.

Green, T.R.; Kipka, H.; David, O.; McMaster, G.S., 2018. Where is the USA Corn Belt, and how is it changing? Sci. Total Environ., 618, 1613–1618. [CrossRef]

Hançerli, L.; Uygur, F.N. Çukurova bölgesi mısır ekim alanlarındaki yabancı ot türleri. Turk. J. Weed Sci. 2017, 20, 55–60. (In Turkish)

Hristeva, Ts, Yanev, M., Kalinova, Sht., & Bozukov, H. (2014). Comparative analysis of some herbicides from amide and dinitroaniline families on the soil microorganisms. *Turkish Journal of Agricultural and Natural Sciences*, Special Issue, 2, 1447–1454.

Hristeva, Ts., Yanev, M., Bozukov, Hr., & Kalinova, Sht. (2015). Condition of soil microbial communities when exposed to some chloroacetamide herbicides. *BJAS*, *21*(4), 730–735.

Hruszka, M. 2003. Effectiveness of environmental and chemical methods of weed control in fodder corn plantings. Zesz. Probl. Post. Nauk Rol. 490: 81–97 (in Polish).

Hurle, K. (1988): How to handle weeds? – Biological and economic aspects. Ecological Bulletins, 39: 63–68.

Idziak, R.; Waligóra, H.; Szuba, V., 2022. The influence of agronomical and chemical weed control on weeds of corn. J. Plant Prot. Res., 62, 215–222.

Imoloame, E.O., 2017. Evaluation of herbicide mixtures and manual weed control method in maize (*Zea mays* L.) production in the Southern Guinea agro-ecology of Nigeria. Cogent Food Agric., 3, 3–17 [CrossRef].

Jursík, M., Kočárek, M., Hamouzová, K., Soukup, J., Venclová, V. (2013): Effect of precipitation on the dissipation, efficacy and selectivity of three chloroacetamide herbicides in sunflower. Plant, Soil and Environment, 59: 175–182.

Kakade, S.U.; Deshmukh, J.P.; Thakare, S.S.; Solanke, M.S. Efficacy of pre-and post-emergence herbicides in maize. Indian J. Weed Sci. 2020, 52, 143–146. [CrossRef]

Kalinova, Sht., & Yanev, M. (2015). Influence of soil herbicides on technological parameters of oriental tobacco. *Scientific Works of the Agricultural University of Plovdiv, LIX*(3), 65–70.

Kostadinova, S., Kalinova, Sht., & Yanev, M. (2016). Sunflower productivity in response to herbicide diflufenican (Pelican 50SC) and foliar fertilizing. *Agriculture & Food*, 4, 122–128

Marinov-Serafimov, P., Golubinova, I., Kalinova, Sht., Yanev, M., & Ilieva, A. (2017). Allelopathic activity of some parasitic weeds. *BJAS*, 23 (№ 2), 219-226.

Mati´c, L.; Gajin, D.; Daki´c, P. Application of herbicide sulcotrione for weed control in maize. Biljn. Lek. 2011, 39, 528–534.

Meissle, M.; Mouron, P.; Musa, T.; Bigler, F.; Pons, X.; Vasileiadis, V.P.; Otto, D.; Antichi, J.; Kiss, Z.; Pálinkás, Z.; et al. Pests, pesticide use and alternative options in European maize production: Current status and future prospects. J. Appl. Entomol. 2010, 134, 357–375. [CrossRef]

Mennan, H.; I¸ Sık, D., 2003. Samsun ili mısır ekim alanlarında son 30 yılda yabancı ot florasında görülen de ˘gi¸siklikler ve bunların nedenlerinin ara¸stırılması. Türkiye Herboloji Derg., 6, 1–7. (In Turkish)

Mhlanga, B.; Chauhan, B.S.; Thierfelder, C., 2016. Weed management in maize using crop competition: A review. Crop Prot., 88, 28–36. [CrossRef]

Nenova, N, Valkova, D., & Penchev, E. (2019). Analaysis of importatant indices in new Bulgarian hybrids Linzi and Deveda. *International Journal of Innovative Approaches in Agricultural Research*, *3*(3), 505–509.

Oerke, E.C.; Dehne, H.W., 2004. Safeguarding production losses in major crops and the role of crop protection. Crop Prot., 23, 275–285 [CrossRef].

Schulte M., Ruegg, W.T., Sutton, P.B. (2002): Synergy of mesotrione, S-metolachlor and terbuthylazine in weed control strategies in maize. Journal of Plant Diseases and Protection, Special Issue 18: 785–793.

Schulte, M., Allen, J.R.F. (2000): GARDO((R)) GOLD – A significant advance in broad-spectrum weed-control in maize through isomer technology. Journal of Plant Diseases and Protection, Special Issue 17: 531–538.

Semerdjieva, I., Kalinova, S., Yanev, M., & Yankova-Tsvetkova, E. (2015). Anatomical changes in tobacco leaf after treatment with isoxaflutole. *IJCRBP*, *2*(7), 51–56.

Shopova, N. (2023). Planting time effect on the growth and yield of tomato (*Solanum lycopersicum* L.). *Scientific Papers. Series B. Horticulture*, *67*(2), 391-396.

Shopova, N., & Cholakov, D. (2014). Effect of the age and planting area of tomato (*Solanum licopersicum* L.) seedlings for late field production on the physiological behavior of plants. *Bulgarian Journal of Agricultural Science*, *20*(1), 173–177.

Shopova, N., & Cholakov, D. (2015). Economic efficiency of late tomato field production with seedlings grown in containers of different substrate composition. Agricultural University – Plovdiv, *Scientific Works*, *59*(4), 131–136.

Stephenson, D.O., Bond, J.A. (2012): Evaluation of thiencarbazonemethyl- and isoxaflutole-based herbicide programs in corn. Weed Technology, 26: 37–42.

Sulewska, H., Koziara, W., Ptaszyńska, G., Panasiewicz, K., 2008. Efficacy of new herbicides in weed control in maize. Prog. Plant Protection/Post. Ochr. Roślin 48(1): 313–316 (in Polish).

Tesfay, A.; Amin, M.; Mulugeta, N. (2014). Management of weeds in maize (*Zea mays* L.) through various pre and post emergency herbicides. Adv. Crop Sci. Tech., 2, 151–155.

Tursun, N.; Sakınmaz, M.S.; Kantarcı, Z. (2015). Mısır varyetelerinde yabancı ot kontrolü için kritik periyotların belirlenmesi. Tarla Bitk. Merk. Ara¸stırma Enstitüsü Derg., 25, 58–63. (In Turkish) [CrossRef].

Venkataraju, A.; Arumugam, D.; Stepan, C.; Kiran, R.; Peters, T. (2022). A review of machine learning techniques for ıdentifying weeds in corn. Smart Agric. Technol., 3, 100102 [CrossRef].

Yanchev, Iv., P. Popova, 1999. Comparative studying of some winter soft wheat cultivars depending on fertilization and irrigation. Symposium – Soil and Heir exploitation. Macedonia. Skopje. 22-23 October.

Yanev, M. & Kalinova, Sht. (2020). Influence of glyphosate on leaf gas exchange and photosynthetic pigments of broomrape-infested tobacco plants. *BJAS*, *26*(2), 435–440.

Yanev, M. (2020). Weed Control in Oilseed Rape (*Brassica napus* L.). *Scientific Papers. Series A. Agronomy*, *LXIII*(1), 622–631.

Yanev, M. (2021). Possibilities for herbicidal control of mixed weed infestation in maize (Zea mays L.). *Scientific Papers. Series A. Agronomy*, *LXIV*(1), 620–631.

Yanev, M. (2022). Herbicidal weed control in winter wheat (*Triticum aestivum* L.). *Scientific Papers. Series A. Agronomy*, *LXV* (1), 613–624.

Yanev, M. (2023). Application of herbicides for weed control before germination and in the early vegetation in maize. *Scientific Papers. Series A. Agronomy*, *66*(1), 631–642.

Yanev, M., Bozukov, H., & Kalinova, Sht. (2014a). Distribution of Orobanche ramosa L. and Orobanche mutelii Sch. in the Main Tobacco Producing Regions of Bulgaria. *Plant Science*, *LI*(1), 114–117.

Yanev, M., Kalinova, Sht., Bozukov, H., & Tahsin, N. (2014b). Technological Indexes of Oriental Tobacco Treated with Glyphosate for the Control of Broomrape. *Turkish Journal of Agricultural and Natural Sciences*, Special Issue, 1. 1025–1029.

Yanev, M. (2015). Study on weed infestation of tobacco fields in South Bulgaria. *Plant Science*, *LII*(3), 90–95.

Zhang, J.; Zheng, L.; Jäck, O.; Yan, D.; Zhang, Z.; Gerhards, R.; Ni, H (2013). Efficacy of four post-emergence herbicides applied at reduced doses on weeds in summer maize (*Zea mays* L.) fields in North China Plain. Crop Prot., 52, 26–32 [CrossRef].

Zimdahl, R.L. (2004). Weed-Crop Competition. 2nd Edition, Blackwell Publishing, Ames.