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The effect of weed control using herbicide on soil bacteria, growth, and yield of sweet corn

Abstract. Weeds are managed by herbicides, but this can reduce the abundance of soil bacteria. This research aimed to determine the effect of active compounds of herbicides on weeds, the abundance of soil bacteria, growth and yield of sweet corn. The experiment was conducted from June to October 2023 in the fields and Laboratory of Agronomy and Horticulture, Universitas Jenderal Soedirman, Purwokerto. A randomized block design was used, consisting of eight treatments and four replications. The treatments included control (H0); weeding (H1); paraquat (H2); glyphosate (H3); paraquat, atrazine, mesotrione (H4); glyphosate, atrazine, mesotrione (H5); paraquat, atrazine, mesotrione, nicosulfuron (H6); and glyphosate, atrazine, mesotrione, nicosulfuron (H7). Results showed that glyphosate and paraquat, were applied before planting, could suppress weeds on sweet corn until 15 days after planting (DAP). Application of atrazine, mesotrione, and nicosulfuron at 21 DAP can increase the success of weed control observed up to 35 DAP of sweet corn. The application of glyphosate, atrazine, and mesotrione showed the highest values for growth variables (plant height, number, and leaf greenness index) and yield variables (fresh weight, diameter, and length of sweet corn cob). Herbicide decrease abundance of soil bacteria on sweet corn field, from 10.07×10^{-8} CFU/mL to 9.55×10^{-8} CFU/mL (total bacteria), 9.53×10^{-8} CFU/mL to 9.52×10^{-8} CFU/mL (phosphate solubilizing bacteria), 9.90×10^{-8} CFU/mL to 9.40×10^{-8} CFU/mL (Rhizobium) and 9.91×10^{-8} CFU/mL became 9.78×10^{-8} CFU/mL (nitrogen fixing bacteria). The total density of phosphate-solubilizing bacteria and nitrogen-fixing bacteria in the application of glyphosate, atrazine, and mesotrione (7.78 CFU/g and 9.52 CFU/g) was greater than control (8.77 CFU/g and 8.15 CFU/g).

Keywords: Herbicide · Soil bacteria · Sweet corn · Weeds

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Introduction

Corn is the second main food after rice, which is a source of carbohydrates and has high economic value. Sweet corn has a taste that is liked by people, which causes sweet corn's demand to increase (Sidahmed et al., 2024), but its productivity is still low (8.31 tons/ha) compared to the potential yield (14–18 tons/ha) (Sunari et al., 2022). Weeds are obstacles for sweet corn cultivation because they compete for resources like sunlight, water, and growing space (Asih et al., 2018). Weeds can decrease corn yields up to 10-15 percent, even up to 20-80 percent if not controlled (Radjabov et al., 2025). Herbicide application has been a standard agricultural practice to control weeds because it is effective and efficient in time, energy, and costs (Espig et al., 2022).

The effectiveness level of determined by the active ingredients contained. Farmers usually use herbicides containing the active ingredients glyphosate and paraquat. Glyphosate is a systemic and non-selective herbicide, so that not only the target weeds but also the main plants can die due to improper application (Martinez et al., 2018). Paraquat is a non-selective contact herbicide that can penetrate weed organs and react in them to produce hydrogen peroxide, which can damage cell membranes in all plant organs, showing the effect of burning plants (Chen et al., 2021).

Application of herbicides to corn fields is generally done before planting to make planting easier. Therefore, when corn enters the vegetative phase, weeds have started to grow and can disturb the corn. Kurniadie, et al., (2022) reported that up to the age of 28 DAP the ability of the herbicide paraquat decreased in its ability to control weeds. The usage of non-selective paraquat and glyphosate herbicides can be combined with selective post-emergence herbicides such as mesotrione, nicosulfuron, and atrazine to increase their effectiveness (Giraldeli et al., 2019).

Herbicide applications can also have negative impacts on the environment and living creatures (Bruggen et al., 2021). Herbicides affect the agroecosystem and the activity of non-target organisms such as soil microbes, which play a role in increasing the absorption of nitrogen, phosphorus, and potassium in situ, as well as the production of siderophores, which indirectly provide a source of nutrition for plants (Jeyaseelan et al., 2024). Herbicide residues can enter through plants to the root area or directly into the soil (Fuchs et al., 2023). The effect of herbicide application can be inhibiting, activating, or showing no effect on soil microorganisms (Bharathi et al., 2024). Glyphosate affects the number of microbes and the enzymatic activities in the rhizosphere (Lupwayi et al., 2022). Pose-Juan et al. (2017) reported that high-dose application of triasulfuron reduced the number of soil microbes. Tyagi et al. (2018) showed there were differences of soil bacteria population, fungi, and actinomycetes after 5 days of herbicide application compared to before herbicide application. Based on Xu et al. (2022), application of herbicides containing sterane could reduce the variety and density of soil bacteria in corn fields at 10 DAP, but they increase again by 60 DAP. Meanwhile, Fernandes et al. (2020) stated that atrazine could increase atzA and trzN genes in Brazilian Red Latosol soil, where these residues did not cause significant changes in the long-term structure of the bacterial community. Therefore, effect of herbicide on soil microbes still needs further research (Chen et al., 2021).

This research aims to determine the effect of active compounds herbicides, i.e., paraquat, glyphosate, atrazine, mesotrione, and nicosulfuron, in controlling weeds in corn plantations, and their effect on the growth and yield of sweet corn and the abundance of soil bacterial populations. It is hoped that this research will provide benefits for researchers, institutions, and the general public, especially farmers, to find out the types of herbicides that are safe for the abundance of soil bacteria but effective in controlling weeds in corn plantations.

Materials and Methods

Experimental Materials. This research used materials, including 'Exsotic' sweet corn seeds produced by PT. Agri Makmur Pertiwi, distilled water, acetone, urea fertilizer produced by PT. Petrokimia Gresik, KCl MerokeMOP® fertilizer, TSP-46 MerokeTSP® fertilizer, tissue, paraquat (Gramoxon), glyphosate (Roundup), atrazine-mesotrion (Gandewa), nicosulfuron (Neocron), nutrient Agar media, NFb media, yeast-monitol agar media, pikovskaya media, cotton, spirits, and pesticide Dangke 40WP. The tools used include laminar air flow, test tube (Pyrex),

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measuring cup (Pyrex), Erlenmeyer (Pyrex), beaker glass (Pyrex), SPAD (Konica Minolta), oven (Lab-Line Instruments), 16L sprayer, analytical balance (Paj1003), petri dishes, labels, envelope paper, and stationery.

Land Preparation. This research was conducted in the fields and Laboratory of Agronomy and Horticulture, Universitas Jenderal Soedirman Purwokerto at an altitude of approximately 74 masl with the Inceptisol soil classification. This research was conducted on Mei until October 2023. Land preparation using a no-tillage system. The land was plotted into 32 plots consisting of 8 treatments and 4 replications. Each plot measures 5 m x 5 m was marked with a treatment label and bounded with rope. After the land is prepared, sweet corn seeds are planted into holes 2-3 cm deep at a distance of 60 cm x 30 cm. The hole is covered with compost and watered to keep the soil moist.

Application of Herbicides. This research used randomized block design (RBD) consisting of one factor (weed control) with eight treatments replicated four times. The treatments are:
H0 = control (without weeding)
H1 = weeding
H2 = paraquat
H3 = gyphosate
H4 = paraquat, atrazine, mesotrione
H5 = glyphosate, atrazine, mesotrione
H6 = paraquat, atrazine, mesotrione, nicosulfuron
H7 = glyphosate, atrazine, mesotrione, nicosulfuron

Weeding was applied every 2 months. Paraquat and glyphosate were applied one week before planting. Atrazine, mesotrione, and nicosulfuron were applied at 21 DAP of corn. The herbicide application doses are 4 L/ha for glyphosate, 3 L/ha for paraquat, and 2 L/ha for atrazine+mesotrione and nicosulfuron.

Data Collection Procedures

The variables observed in this research included:

Weed Identification. Weed identification was carried out 3 times, i.e., before planting, 15 DAP, and 35 DAP of corn. Weed sampling before planting was carried out by taking weeds directly using a quadrat method measuring 0.5 x 0.5 m in experimental fields. Weed sampling points before planting were chosen randomly and carried out ten times. Weed sampling after planting was also carried out using the quadrat method in each experimental plot. The data analysis process was proposed to determine the type and dominance of weeds in the area. The dominant weed type is determined by looking for the Summed Dominance Ratio (SDR) value. The SDR value is obtained from calculating the relative density of a species, the relative dominance of a species, the relative frequency of a species, and the importance value index (Tsytsiura, 2020).

$$SDR = \frac{RD+RF+RD'}{3}$$

Growth and Yield of Sweet Corn. The growth and yield variables observed included sweet corn growth (number of leaves, leaves greenness index, and plant height) and sweet corn yield (length, weight, and diameter of corn cobs). Leaves greenness index measured by SPAD meter for the base, middle, and tip of the 3rd leaf from the topmost shoot. Cob weight was measured by weighing corn cobs with husks and without husks, the cobs length was measured from base to tip of the cobs both with husks and without husks, and the diameter of the corn was measured from the most bulging part of the cob using a caliper.

Population density of soil bacteria. To calculate the population density of soil bacteria, soil samples are first taken to isolate the bacteria, carried out before planting, and after harvest. Soil sampling before planting was chosen deliberately (purposive sampling) on the experimental land (figure 1), while soil sampling post-harvest was carried out on each treatment plot (figure 2). It was carried out using a diagonal system. The number of points was set 5 points with a distance of ± 32.5 m from the center point. Soil was taken at a depth of 0-20 cm, then the five samples were mixed (Liu et al., 2021).

10 grams of soil samples were put into Erlenmeyer flask containing 90 mL of distilled water, then shaken until homogeneous using a shaker. The 1 mL sample solution was placed in a test tube containing 9 mL of distilled water and diluted 10^{-8}. 1 mL of each dilution was taken and placed in a sterile petri dish, then the petri dish was poured with solid NFb media, YMA, Pikovskaya, and NA media using the pour plate method.

Calculation of the total bacteria, nitrogen fixing bacteria, phosphate solubilizing bacteria, and rhizobium uses the total plate count (TPC) method. The number of bacteria is expressed as colony farming units (CFU) (Martini et al., 2023). The following is the formula for calculating TPC:

$$\text{Bacteria Population} = n\frac{1}{\text{Dilution Factor}}\ \text{CFU/g}$$

Information:
n : The number of colonies contained in the 10x dilution series tube
CFU/g : Colony forming unit/g

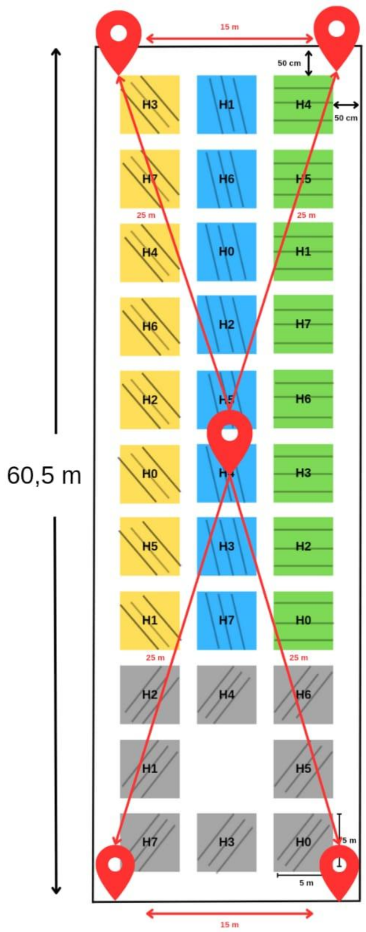

Figure 1. Soil sampling point before planting

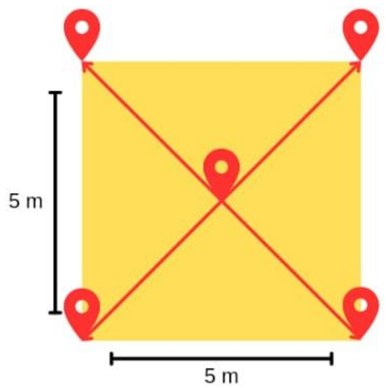

Figure 2. Soil sampling point at harvest time in each plot

Data Analysis. Data on growth and yields of sweet corn and bacteria density were processed using analysis of variance (ANOVA). The multiple comparison test, Duncan's multiple range test (DMRT), was employed once significant differences were detected at an α-value of 5%.

Results and Discussion

Weed identification. Weed identification aims to determine the dominant weed. This is the first step for successful weed control (Mishra & Gautam, 2021). Based on the results of weed identification before sweet corn planting, the number of weed species identified was 18 (Table 1).

Table 1. Summed dominance ratio (SDR) value of weeds before herbicide application

No.	Weed	SDR(%)
	Broadleaf weed	
1	*Ageratum conyzoides*	4.51
2	*Physalis angulata*	2.12
3	*Peperomia pellucida*	1.23
4	*Cleome rutidosperma*	6.49
5	*Alternanthera philoxeroides*	9.36
6	*Tridax procumbens*	2.24
7	*Ipomoea reptans*	5.57
8	*Borreria alata*	0.97
9	*Hedyotis corymbosa*	1.30
10	*Rorippa palustris*	1.12
11	*Eclipta prostrata*	1.61
	Grassy weed	
1	*Echinochloa colona*	16.27
2	*Eleusine indica*	19.38
3	*Bracharia mutica*	2.12
4	*Murdannia nudiflora*	5.40
5	*Cyperus rotundus*	9.32
6	*Digitaria ciliaris*	7.42
7	*Digitaria sanguinalis*	3.58
	Total	100

The land before planting sweet corn was dominated by grassy weeds. Dominant weeds are determined through vegetation analysis by calculating the SDR value (Firmansyah & Pusparani, 2019). The weeds that dominate are the grassy weeds *Eleusine indica* (SDR 19.38%), *Echinochloa colona* (SDR 16.27%), and *Cyperus rotundus* (SDR 9.36%). The dominant broadleaf weed is *Alternanthera philoxeroides* (SDR 9.36%). Weeds dominance on a land influenced by superior physiological characteristics of weeds, such as high germination, pollination capacity, and rapid adaptation to the environment (Anwar et al., 2021).

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Table 2. Summed dominance ratio (SDR) of weeds in sweet corn fields aged 15 and 35 DAP

No.	Weed	15 DAP								35 DAP							
		H0	H1	H2	H3	H4	H5	H6	H7	H0	H1	H2	H3	H4	H5	H6	H7
	Broadleaf weed																
1	*Ageratum conyzoides*	9.46	3.05	2.67	34.06	3	4.66	3.62	4.56	18.27	19.09	31.16	33.11	5.78		7.5	
2	*Peperomia pellucida*				8.04												
3	*Cleome rutidosperma*							1.81		1.34	8.33	6.69	6.18				
4	*Euphorbia hirta*	1.41		2.27		2.58	5.16	2.01		2.05							
5	*Scoparia dulcis*	1.54							5.46		5.9	1.37					
6	*Calyptocarpus vialis*	2.77							9.98		3.84						
7	*Pyllanthus urinaria*		2.19	2.03							1.13						
8	*Tridax procumbens*	3.11	4.97				4.47	1.74									
9	*Chenopodium album*	1.61				2.34											
10	*Physalis angulata*									3.29	1.27	3.50	9.39				
11	*Alternanthera philoxeroides*									10.76	7.49	10.53	3.06			4.79	5.68
12	*Eclipta prostrata*	6.96	12.77	14.87		16.09	4.8	15.66		3.89	1.44	1.70					15.50
13	*Parietaria judaica*	5.31	6.64	6.45		7.57		4.5						4.78			
14	*Ipomoea reptans*	2.7	2.4	4.45		8.08	8.95	3.36		1.47							
15	*Sisymbrium officinale*	2								3.99	4.17		1.78	22.04	10.77	12.98	20.09
16	*Cirsium arvense*			2.3								1.62					
17	*Hedyotis corymbosa*	2.29						3.42									
18	*Murdannia nudiflora*										1.36		2.71				
19	*Portulaca oleraceae*							1.82			10.28	7.86					
	Grassy weed																
1	*Echinochloa colona*	8.12	2.29	5.55	7.29	6.21		1.86		2.39	4.43	2.83	12.35	52.34	6.26	23.97	
2	*Eleusine indica*	18.47	34.96	17.37	36.9	15.2	39.57	21.29	48.18	19.22	20.80	22.92	15.82		31.99		19.38
3	*Bracharia mutica*	14.9	5.79	15.66				9.13		10.17						7.26	
4	*Commelina diffusa*	1.75	5.14	4.28				11.07	11.55					15.06		29.40	
5	*Kyllinga brevifolia*	10.07	10.38	22.1	13.72	28.16	32.39	12.45	20.27	5.46	7.83	7.37	15.59		50.97		15.78
6	*Cynodon dactylon*		2.66			3.69				2.82						14.1	
7	*Bracharia eruciformis*					7.08				3.82	2.63	2.46					
8	*Cyperus rotundus*	2.38								6.67							23.56
9	*Digitaria ciliaris*	5.15	6.77					6.26		4.38							
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: H0 (control), H1 (manual weeding), H2 (paraquat), H3 (glyphosate), H4 (paraquat, atrazine, and mesotrione), H5 (glyphosate, atrazine, and mesotrione), H6 (paraquat, atrazine, mesotrione and nicosulfuron), H7 (glyphosate, atrazine, mesotrion and nicosulfuron).

There were several new types of weeds that did not grow before sweet corn planting, but grew at 15 DAP (21 days after application of paraquat and glyphosate) and 35 DAP (20 days after application of atrazine, mesotrione, and nicosulfuron). These weeds include *Euphorbia hirta, Scoparia dulcis, Calyptocarpus vialis, Pyllanthus urinaria, Chenopodium album, Parietaria judaica, Commelina diffusa, Sisymbrium officinale, Kyllinga brevifolia, Cynodon dactylon, Cirsium arvense, Bracharia eruciformis, Portulaca oleraceae*. There are also types of weeds that appeared before planting, but did not reappear during observation, i.e., *Borreria alata* and *Rorippa palustris*.

The weeds that grew in control and manual weeding were more diverse than in herbicide treatment. At the 15 DAP observation (21 days after the application of paraquat and glyphosate), types of weeds grew in glyphosate treatment fewer than in paraquat treatment. The dominant weeds in sweet corn cultivation land in all treatments were *Eleusine indica* and *Kyllinga brevifolia*. This indicates that both types of weeds show preliminary indications of resistance to paraquat and glyphosate.

Glyphosate is non-selective herbicide that works by inhibiting the activity of enzyme 5-enol-pyruvyl-shikimate-3-phosphate synthase (EPSPS) which catalyzes the sixth step in the shikimic acid pathway (Tampubolon et al., 2019). Glyphosate inhibits this enzyme, which stops the shikimate pathway from producing aromatic amino acids like tryptophan, tyrosine, and phenylalanine (El-Mergawi et al., 2025). Glyphosate can translocate within plants, accumulate in roots, and be released into the rhizosphere by the root exudates. Inside the plant, glyphosate may be transported within the plant xylem in the apoplastic pathway or enter the phloem and get transported to metabolic sinks via the symplastic pathway. For both foliar and root uptake, glyphosate translocation may be basipetal or acropetal (upwards and downwards), moving toward various tissues, such as meristems, leaves flowers, and fruits. As glyphosate is stable and not immediately metabolized in many plant species, substantial amounts can be extensively translocated to regions of active growth and accumulate, particularly in young tissues. Glyphosate reaches any actively growing tissue or organ. The physicochemical properties and high solubility of glyphosate in water enable it to be translocated via the phloem to the same tissues that are metabolic sinks for sucrose (Zioga et al., 2022).

Eleusine indica is a weed that grows quickly, especially at high sunlight intensity and is classified as a C4 plant (Correia et al., 2022). This weed flowers all year round, can self-pollinate and can produce up to 140,000 seeds per plant (Tampubolon et al., 2019). The seeds can survive for up to 2 years in a soil depth of 20 cm and have a growth capacity of 79% (Umiyati et al., 2023).

Eleusine indica has resistance to various herbicides, including glyphosate, paraquat, ammonium glufosinate, and ACCase inhibitors (Kurniadie et al., 2023). Repeated applications of herbicides with the same mode of action can select for herbicide-resistant biotypes. *Eleusine Indica* was found to be resistant to glyphosate in research conducted on oil palm plantations in North Sumatera (Tampubolon et al., 2019). Weed genetic diversity, which arises from target-site or non-target-site modifications, is the cause of Eleusine indica's herbicide resistance (Deng et al., 2022).

Kyllinga brevifolia is a perennial weed that grows using rhizome when turf is maintained. Its populations form by germination of seeds, which peaks between 20 and 24 C. Hand pulling or digging is frequently useless when trying to manually eradicate Kyllinga brevifolia from turf grasses. By using rhizomatous growth to regenerate new plants, *Kyllinga brevifolia* are able to escape preemergence herbicides (Westbury et al., 2022).

Weeds grew with post-emergence herbicide treatment at 35 DAP (20 days after application of atrazine, mesotrione, and nicosulfuron) is lower than in the treatment without post-emergence herbicide. Application of atrazine, mesotrione, and nicosulfuron aims to prevent weed resistance after application of glyphosate and paraquat. Atrazine, mesotrione, and nicosulfuron have a different mechanism of action from glyphosate and paraquat, so they can increase the effectiveness of weed control (Arslan et al., 2016; Xu et al., 2022).

The dominant weeds in control treatment, manual weeding, and application of paraquat and glyphosate were *Eleusine indica* (grassy weed) and *Ageratum conyzoides* (broadleaf weed). The dominant weeds in the paraquat, atrazine, mesotrion (H4) and paraquat, atrazine, mesotrion, nicosulfuron (H6) treatments were *Echinocloa colona* and *Commelina diffusa*. In the glyphosate, atrazine, mesotrione treatments,

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Eleusine indica and *Kyllingia Brevifolia* were dominated, while the glyphosate, atrazine, mesotrione and nicosulfuron treatments were dominated by *Eleusine indica* and *Cyperus rotundus*. This indicates that the weed is resistant to post-emergence herbicide.

The synthetic triazine herbicide, i.e., atrazine (6-chloro-N-ethyl-N0-(1-methylethyl)-1,3,5-triazine-2,4-diamine) used to suppress broadleaf and grassy weeds in corn, beans, sorghum, wheat, and sugarcane (Kumar & Singh, 2016; Zhao et al., 2017). Atrazine enters through the roots and is absorbed by the xylem along with water, then inhibit electron transport in photosystem II. Atrazine herbicide poisoning in weeds is characterized by symptoms of chlorosis starting from the edges of the leaves (Cordon et al., 2022).

Mesotrione belongs to the triketone category of herbicides. Mesotrione inhibits ALS (acetolactate synthase) and is efficient against species that are resistant to triazine. This herbicide works by blocking the p-hydroxy-phenylpyruvate dehydrogenase (HPPD) enzyme, which prevents the formation of carotenoid pigments. This can disrupt photosynthesis and result in symptoms such as leaf bleaching and eventual death (Cordon et al., 2022).

Nicosulfuron is a common herbicide used in agriculture, especially corn cultivation, that is effective, safe, and selective at low dosages (Zhang et al., 2020). Nicosulfuron inhibits ALS activity and decreases the synthesis of branched-chain amino acids, including valine, leucine, and isoleucine (Délye et al., 2018). Nicosulfuron also causes chloroplast disintegration and changes plant leaves colour. Photosynthetic pigments and plant protein activities related to photosynthesis were significantly reduced (Xu et al., 2022). This causes inhibition of the plant's electron transport rate, which results in inhibition of ATP and NADPH synthesis (Wang et al., 2021).

According to Ofosu et al. (2023), weeds that may grow and endure following herbicide application are known as herbicide-resistant weeds. Herbicide resistance can be classified into three levels: (i) single resistance, which happens when a weed is resistant to only one group of herbicides and/or one mode of action (like resistance to glyphosate); (ii) cross resistance, which happens when a weed is resistant to one or more groups of herbicides with a similar mode of action (like resistance to imidazolinone and sulfonylurea herbicides, which are both part of the Acetolactate synthase (ALS) mode of action); and (iii) multiple resistance, which happens when a weed is resistant to more than two groups of herbicides and more than two modes of action herbicides (e.g. resistance to Pursuit (ALS) and glyphosate) (Tampubolon et al., 2019).

Growth and Yield of Sweet Corn. Application of glyphosate, atrazine and mesotrione (H5) showed the highest sweet corn plant height values, namely 26.40 cm (2 WAP), 73.17 cm (4 WAP) and 145.20 cm (6 WAP). Herbicide treatment had a significant effect on plant height compared to the control treatment. between the herbicide treatment paraquat, atrazine and mesotrione (H4) and the herbicide treatment glyphosate, atrazine and mesotrione (H5), the effect was not different at plant age of 4 WAP and 6 WAP. Treatments H4 and H5 were able to increase plant height by 23% and 22.5%, respectively, compared to the control. This is because the weed species are not diverse, so there is no tight competition for nutrients even though *E. indica* and *K. brevifolia* are the dominant weeds.

The treatments of glyphosate, atrazine, and mesotrione (H5) also showed the highest number of leaves, namely 4.95 pieces (2 WAP) and 10.85 pieces (6 WAP). The highest number of leaves at the age of 4 WAP was obtained from the paraquat, atrazine a,nd mesotrione (H4) treatments with 7.80 leaves. The herbicide treatment were analyzed using ANOVA followed by Duncan's Multiple Range Test (DMRT) at 5% significance level had a significant effect on leaf number compared to the control treatment, but between the glyphosate, atrazine and mesotrione (H5) and paraquat, atrazine, mesotrione, nicosulfuron (H6) treatments the effect was not different. Treatments H5 and H6 increased the number of leaves by 19.88% and 18.78% respectively compared to the control.

The treatments of paraquat, atrazine and mesotrione (H4) and glyphosate, atrazine and mesotrione (H5) showed the highest value of leaf greenness index at 6 WAP, namely 52.15 and 51.92 units. Treatments H4 and H5 increased leaf greenness index by 0.98% and 0.94% respectively compared to the control.

According to Singh et al. (2022), competition between main plants and weeds includes competition in obtaining water, competition in obtaining nutrients because weeds absorb more nutrients than main plants, competition in obtaining light in conditions of sufficient water and nutrients for plant growth, then the next limiting factor is sunlight. Competition between main plants and weeds inhibits plant growth. In general, glyphosate, atrazine and mesotrione (H5) treatment is the best treatment, because plants can compete with weeds for environmental resources, such as space, nutrients, sunlight and water (Lateef et al., 2021; Sawicka et al., 2020). Thus, treatment H5 optimizes the vegetative growth of sweet corn.

The treatment of glyphosate, atrazine and mesotrione (H5) showed the highest value in the variable weight of husked cobs (447.39 g), weight without husks (312.83 g), diameter of husked cobs (65.70 mm), cob diameter without husks (53.49 mm), and cob length (31.73 cm). The H4 treatment (paraquat, atrazine, and mesotrione) showed the highest value for the highest effective corn weight per plot variable (41.87 kg/plot) and corn weight per hectare (16.75 tons/ha), namely increasing the weight by 60.30% compared to the control treatment. Although H5 produced heavier individual cobs, the total yield per plot was greater in H4. This may be attributed to a better plant stand or higher plant survival rate in the H4 treatment, leading to a higher number of marketable cobs per plot.

The rate of weeds development and the physiological and morphological changes to their root systems guarantee that more nutrients are absorbed from the substrate. Weeds consequently become fierce competitor to plants (Sawicka et al., 2020). The growth and development of weeds depend on plant cultivation (Barbaś et al., 2020; Feledyn-Szewczyk et al., 2020; Pszczółkowski et al., 2020), environmental conditions (Ramesh et al., 2017; Varanasi et al., 2016; Vilà et al., 2021), and agricultural practices (Gaweda et al., 2018; Jabran et al., 2017; Nwosisi et al., 2019).

Table 3. Effect of herbicide on growth of sweet corn at 2, 4, and 6 week after planting (WAP)

Treatments	Plant height (cm)			Number of leaves			Leaf greenness index (units)		
	2	4	6	2	4	6	2	4	6
H0	22.95 bc	59.92 b	118.47 b	4.30 c	6.20 d	9.05 c	30.15 b	42.43 b	47.47 c
H1	21.01 ab	65.17 ab	124.75 b	4.30 c	6.70 cd	9.50 c	30.14 b	42.65 ab	48.13 bc
H2	23.40 abc	66.65 ab	120.42 b	4.40 bc	7.05 bc	9.65 bc	31.02 ab	44.35 ab	48.37 bc
H3	22.27 bc	69.65 ab	134.60 ab	4.65 abc	7.15 bc	9.95 abc	33.63 ab	44.93 ab	49.92 abc
H4	25.35 ab	71.55 a	145.72 a	4.75 ab	7.80 a	10.45 ab	32.75 ab	45.77 ab	52.15 a
H5	26.40 a	73.17 a	145.20 a	4.95 a	7.55 ab	10.85 a	33.51 ab	46.13 a	51.92 a
H6	24.42 ab	67.10 ab	136.45 ab	4.70 ab	7.45 ab	10.75 a	43.26 a	44.62 ab	51.03 ab
H7	22.65 bc	64.27 ab	132.65 ab	4.50 bc	7.50 ab	10.40 ab	31.72 ab	43.75 ab	51.07 ab

Note: Numbers followed by the same letter in the same column indicate that not significant based on Duncan's multiple range test at 5%; H0 (control), H1 (manual weeding), H2 (paraquat), H3 (glyphosate), H4 (paraquat, atrazine, and mesotrione), H5 (glyphosate, atrazine, and mesotrione), H6 (paraquat, atrazine, mesotrione and nicosulfuron), H7 (glyphosate, atrazine, mesotrion and nicosulfuron)

Table 4. Effect of herbicide on yields of sweet corn

Treatments	Fresh weight of cobs with husks (g)	Fresh weight of cobs without husks (g)	Cob diameter with husks (mm)	Cob diameter without husks (mm)	Length of cob (cm)	Weight per Effective Plot (kg/plot)	Weight per Hectare (ton/ha)
H0	303.93 c	217.04 c	56.80 d	47.65 c	28.24 c	26.12 b	10.45 b
H1	368.75 abc	255.00 abc	61.02 bcd	50.56 bc	29.91 abc	28.50 b	11.40 b
H2	351.57 bc	250.77 bc	59.44 cd	50.46 bc	28.84 bc	28.87 b	11.55 b
H3	390.90 ab	279.24 ab	63.06 abc	51.84 ab	28.99 bc	33.50 ab	14.15 ab
H4	418.48 ab	293.98 ab	64.12 ab	52.31 ab	31.11 a	41.87 a	16.75 a
H5	447.39 a	312.83 a	65.70 a	53.49 a	31.73 a	35,37 ab	14,15 ab
H6	409.95 ab	282.86 ab	21.23 ab	52.08 ab	31.13 a	40.37 a	11.40 b
H7	399.50 ab	276.09 abc	62.47 abc	51.35 ab	30.51 ab	39.75 a	15.90 a

Note: Numbers followed by the same letter in the same column indicate that not significant based on Duncan's multiple range test at 5%; H0 (control), H1 (manual weeding), H2 (paraquat), H3 (glyphosate), H4 (paraquat, atrazine, and mesotrione), H5 (glyphosate, atrazine, and mesotrione), H6 (paraquat, atrazine, mesotrione and nicosulfuron), H7 (glyphosate, atrazine, mesotrion and nicosulfuron)

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Herbicides can suppress growth of weed during the vegetative phase of sweet corn plants by inhibiting the photosynthesis process and damaging the weed chloroplast membrane so that it slowly kills the weeds (Kamdem et al., 2016). The formation of corn cobs is greatly influenced by the nutrients absorbed by plant roots in the soil through fertilization and weed control. Sweet corn plants will have less than ideal cob weight if fertilizers are unavailable (Sidahmed et al., 2024). Cob diameter is influenced by the availability of nutrients absorbed by plants, especially phosphorus and nitrogen (Budiastuti et al., 2023). These nutrients can be utilized optimally if the dominance of weeds can be suppressed, so that the size of the cobs formed is larger and the seed density is full. Both genetic and environmental variables affect corn cob length. Corn cob length is not optimal due to ecological factors dominated by weeds (Aisah et al., 2021).

Figure 3. Corn cobs with husks and without husks

Figure 3 shows the difference in ear size harvested from the control and herbicide application treatment. The glyphosate (H3) and paraquat (H2) treatments showed smaller ear sizes compared to the combination treatment with post-emergence herbicides atrazine, mesotrione and nicosulfuron (H4, H5, H6, and H7). A combination of pre-emergence and post-emergence herbicide treatment is an effort that can be applied currently, because there are weed species that are resistant to single herbicide treatment.

Population density of soil bacteria. Total density of soil bacteria pre-application and post-application of herbicides has different density values. The pre-application soil bacterial density was higher than the post-application herbicide bacterial density (Table 5).

Table 5. Number of bacterial densities pre-application and post-application of herbicides

Bacteria	pre-application (CFU/mL)	post-application (CFU/mL)
Total Bacteria	10.07x10^{-8}	9.55 x10^{-8}
Phosphate Solubilizing Bacteria	9.53 x10^{-8}	9.52 x10^{-8}
Rhizobium bacteria	9.90 x10^{-8}	9.40 x10^{-8}
Nitrogen Fixing Bacteria	9.91 x10^{-8}	9.78 x10^{-8}

The population and diversity of soil bacteria have decreased due to the toxic nature of exposure to active herbicide ingredients. According to S. Singh et al., (2020), glyphosate changes soil texture and microbial diversity by decreasing microbial populations and increasing populations of phytopathogenic fungi. Research by Adegaye et al. (2023) shows that paraquat can inhibit the population of microorganisms and the growth of bacteria, actinomyces and fungi in the soil. The research by S. Tyagi et al., (2018) show that there is an inhibitory effect on soil microbes due to herbicide application. The bacterial population in the paraquat and atrazine herbicide treatments was lower when compared to the control. The rate of inhibition of bacterial populations was 13.3%-100%, actinomyces populations 8.6%-100%, fungal populations 7.6%-100%. The inhibitory effect becomes weaker as time increases. The bacterial population in all treatments decreased in the 4th week after application, but increased progressively in the 6th and 8th weeks.

Based on the research results shown in table 6, the herbicide treatment glyphosate, atrazine and mesotrione (H5) showed the highest total density of P-solvent bacteria (9.78 CFU/mL), meaning it increased the total density of P-solvent bacteria by 24% compared to the control. The herbicide treatment glyphosate, atrazine and mesotrione (H5) also showed the highest total density of nitrogen-fixing bacteria (9.52 CFU/mL), meaning it increased the total density of nitrogen-fixing bacteria by 16.8% compared to the control.

Tabel 6. Effect of herbicide application on bacterial population density

Treatments	Density of phosphate solubilizing bacteria (CFU/g)	Density of nitrogen-fixing bacteria (CFU/g)
H0	8.77 b	8.15 b
H1	9.34 ab	8.82 ab
H2	8.67 b	8.93 a
H3	9.02 b	8.91 a
H4	8.88 b	9.02 a
H5	9.78 a	9.52 a
H6	8.78 b	9.19 a
H7	8.85 b	9.22 a

Note: Numbers followed by the same letter in the same column indicate that not significant based on Duncan's multiple range test at 5%; H0 (control), H1 (manual weeding), H2 (paraquat), H3 (glyphosate), H4 (paraquat, atrazine, and mesotrione), H5 (glyphosate, atrazine, and mesotrione), H6 (paraquat, atrazine, mesotrione and nicosulfuron), H7 (glyphosate, atrazine, mesotrion and nicosulfuron)

Glyphosate concentrations over a certain period of time have been shown to increase the abundance of several bacteria, such as Proteobacteria, Bulkholderia, Acidobacteria (Adomako & Akyeampong, 2016; Imparato et al., 2016; Newman et al., 2016). Glyphosate application has no effect or does not reduce microbial biomass over a wide concentration range (Nguyen et al., 2018). Glyphosate herbicide treatment has enhanced microbial activity as a result of certain microorganisms' ability to break down glyphosate and use it as a source of carbon for metabolism (Mesquita et al., 2023).The herbicide treatment glyphosate, atrazine, mesotrione (H5) which resulted in an increase in total bacterial density was thought to be because Atrazine had minimal impact on the relative abundance of different bacterial groupings but no discernible influence on bacterial populations (10–12 phyla, 29–34 genera). Atrazine residue levels over time of the year have a certain influence on the enzyme activity and microbial community population, function, in the cultivated soil layer in the corn area of the Chernozem (Yang et al., 2021).

Conclusion

Application of glyphosate and paraquat can reduce weed diversity in sweet corn plantings. The dominant weeds found at 15 DAP were *Eleusine indica* and *Kyllinga brevifolia*. The effectiveness of glyphosate and paraquat weed control individually decreased at 35 DAP of corn plants, causing the dominance of various types of weeds to increase. Application of post-emergent herbicides atrazine, mesotrione and nicosulfuron has proven to be effective and able to reduce weed diversity, especially *Ageratum conyzoides*. The dominant weed found at 35 DAP in the combination treatment of various active ingredients was *Eleusine indica*. The glyphosate, atrazine, and mesotrione treatments showed the best plant growth and yield. Soil bacterial densities after herbicide application were generally lower than before.

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References

Adegaye AC, Fabunmi BT, Ogunjo ST, Tokimi OR, Nwakaeme J O. 2023. Effects of two commonly used herbicides on soil microbial activity under conservation tillage. Environmental Advances, 13:1-11.

Adomako MO, Akyeampong S. 2016. Effect of some commonly used herbicides on soil microbial population. Journal of Environment and Earth Science, 6(1): 30–38.

Aisah AR, Fitrahtunnisa, Hipi A. 2021. Morphological characteristics and resistance to the pest of local corn variety of "jago Leke" genetic resources in West Nusa Tenggara. IOP Conference Series: Earth and Environmental Science, 911:1-10.

Anwar, M. P., Islam, A. K. M. M., Yeasmin, S., Rashid, M. H., Juraimi, A. S., Ahmed, S., Shrestha, A. 2021. Weeds and their responses to management efforts in a changing climate. Agronomy, 11(10): 1–20.

Arslan ZF, Williams MM, Becker R, Fritz VA, Peachey RE, Rabaey TL. 2016. Alternatives to Atrazine for Weed Management in Processing Sweet Corn. Weed Science, 64(3): 531–539.

ISSN: 1412-4718, eISSN: 2581-138x

Asih, D. N. S., Setiawan, A. N., Sarjiyah. 2018. Weeds Growth in Various Population of Sweet Corn-Peanut Intercropping. Planta Tropika: Journal of Agro Science, 6(1): 22–31.

Barbas P, Sawicka B, Marczak BK, Pszczółkowski P. 2020. Effect of mechanical and herbicide treatments on weed densities and biomass in two potato cultivars. Agriculture (Switzerland): 10(10): 1–17.

Bharathi MJ, Anbarasu M, Ragu R, Subramanian E. 2024. Assessment of soil microbial diversity and soil enzyme activities under inorganic input sources on maize and rice ecosystems. Saudi Journal of Biological Sciences, 31(5): 1-7.

Bruggen AHCV, Finckh MR, He M, Ritsema CJ, Harkes P, Knuth D, Geissen V. 2021. Indirect effects of the herbicide glyphosate on plant, animal and human health through its effects on microbial communities. Frontiers in Environmental Science, 9: 1–22.

Budiastuti MTS, Purnomo D, Pujiasmanto B, Setyaningrum D. 2023. Response of maize yield and nutrient uptake to indigenous organic fertilizer from corn cobs. Agriculture (Switzerland): 13(2): 1–11.

Chen J, Yang W, Li J, Anwar S, Wang K, Yang Z, Gao Z. 2021. Effects of herbicides on the microbial community and urease activity in the rhizosphere soil of maize at maturity stage. Journal of Sensors, 2021:1-11.

Cordon G, Lopez VI, Prieto A, Costa C, Marchi MC, Diz V. 2022. Effects of the nanoherbicide made up of atrazine-chitosan on the primary events of photosynthesis. Journal of Photochemistry and Photobiology, 12: 1–14.

Correia NM, Araújo LDS, Júnior RAB. 2022. First report of multiple resistance of goosegrass to herbicides in Brazil. Advances in Weed Science, 40: 1–9.

Délye C, Duhoux A, Gardin JAC, Gouzy J, Carrère S. 2018. High conservation of the transcriptional response to acetolactate-synthase-inhibiting herbicides across plant species. Weed Research, 58(1): 2–7.

Deng W, Duan Z, Li Y, Peng C, Yuan S. 2022. Multiple resistance mechanisms involved in glyphosate resistance in eleusine indica. Plants, 11(3199):1-11.

El-Mergawi R, El-Dabaa M, Elkhawaga F. 2025. Effect of splitting the sub-lethal dose of glyphosate on plant growth shikimate pathway-related metabolites and antioxidant status in faba beans. Scientific Reports, 15(1): 1–14.

Espig M, Dynes RA, Henwood RJT, James TK. 2022. The drivers of herbicide use among arable farmers in canterbury, new zealand: toward an integrated approach. Society and Natural Resources, 35(3): 281–300.

Feledyn-Szewczyk B, Nakielska M, Jónczyk K, Berbéc AK, Kopínski J. 2020. Assessment of the suitability of 10 winter triticale cultivars (x Triticosecale Wittm. ex A. Camus) for organic agriculture: Polish case study. Agronomy, 10(8): 13–17.

Fernandes AFT, Wang P, Staley C, Moretto JAS, Altarugio LM, Campanharo SC, Stehling EG, Sadowsky MJ. 2020. Impact of atrazine exposure on the microbial community structure in a Brazilian tropical latosol soil. Microbes and Environments, 35(2): 1–7.

Firmansyah E, Pusparani S. 2019. Weed vegetation analysis in Universitas Perjuangan of Tasikmalaya. Journal of Physics: Conference Series, 1179(1):1-6

Fuchs B, Saikkonen K, Damera, A, Yang B, Helander M. 2023. Herbicide residues in soil decrease microbe-mediated plant protection. Plant Biology, 25(4): 571–578.

Gaweda D, Wozniak A, Harasim E. 2018. Weed infestations of winter wheat depend on the forecrop and the tillage system. Acta Agrobotanica, 71(3):1-9.

Giraldeli AL, da Silva GS, Silva AFM, Ghirardello GA, de Marco LR, Filho RV. 2019. Efficacy and selectivity of alternative herbicides to glyphosate on maize. Revista Ceres, 66(4): 279–286.

Imparato V, Santos SS, Johansen A, Geisen S, Winding A. 2016. Stimulation of bacteria and protists in rhizosphere of glyphosate-treated barley. Applied Soil Ecology, 98: 47–55.

Jabran K, Mahmood K, Melander B, Bajwa AA, Kudsk P. 2017. Weed dynamics and management in wheat. In Advances in Agronomy (1st ed, Vol. 145). Elsevier Inc.

Jeyaseelan, A, Murugesan, K, Thayanithi, S, Palanisamy, S. B. 2024. A review of the impact of herbicides and insecticides on the microbial communities. Environmental Research, 245: 118020.

Kamdem MM, Yanou NN, Filser J. 2016. Effects of soil treated glyphosate on growth parameters and chlorophyll content of maize *Zea mays* L. and bean *Phaseolus vulgaris* L. plants. Brazilian Journal of Biological Sciences, 3(6): 351–365.

Kumar A, Singh N. 2016. Atrazine and its metabolites degradation in mineral salts medium and soil using an enrichment culture. Environmental Monitoring and Assessment, 188(3): 1–12.

Kurniadie D, Umiyati U, Widianto R, Kato-Noguchi H. 2022. Effect of chitosan molecules on paraquat herbicidal efficacy under simulated rainfall conditions. Agronomy, 12(7): 1666.

Kurniadie D, Widianto R, Umiyati U, Widayat D, Nasahi C, Budiawan A. 2023. Management of *Eleusine indica* (L.) Gaertn resistance to glyphosate herbicide in Indonesia. Agronomy, 13(6): 1–10.

Lateef EMA. El-Mekki BB, El-Salam MSA, El-Metwally IM. 2021. Effect of different single herbicide doses on sugar beet yield, quality and associated weeds. Bulletin of the National Research Centre, 45(21): 1–9.

Liu Y, Fan X, Zhang T, Sui X, Song F. 2021. Effects of atrazine application on soil aggregates, soil organic carbon and glomalin-related soil protein. Plant, Soil and Environment, 67(3): 173–181.

Lupwayi NZ, Blackshaw RE, Geddes CM, Dunn R, Petri R. M. 2022. Multi-year and multi-site effects of recurrent glyphosate applications on the wheat rhizosphere microbiome. Environmental Research, 215(3): 114363.

Martinez DA, Loening UE, Graham MC. 2018. Impacts of glyphosate-based herbicides on disease resistance and health of crops: a review. Environmental Sciences Europe, 30(2): 1–14.

Martini KM, Boddu SS, Nemenman I, Vega NM. 2023. Maximum likelihood estimators for colony-forming units. Microbiology Spectrum, 12(9): 1–15.

Mesquita CPB, de-Solon AJ, Barfield A, Mastrangelo CF, Tubman AJ, Vincent K, Porazinska DL, Hufft RA, Shackelford N, Suding KN, Schmidt SK. 2023. Adverse impacts of Roundup on soil bacteria, soil chemistry and mycorrhizal fungi during restoration of a Colorado grassland. Applied Soil Ecology, 185: 104778.

Mishra AM, Gautam V. 2021. Weed species identification in different crops using precision weed management: A review. CEUR Workshop Proceedings, 2786: 180–194.

Murata N, Takahashi S, Nishiyama Y, Allakhverdiev SI. (2007). Photoinhibition of photosystem II under environmental stress. Biochimica et Biophysica Acta - Bioenergetics, 1767(6): 414–421.

Newman MM, Hoilett N, Lorenz N, Dick RP, Liles MR, Ramsier C, Kloepper JW. 2016. Glyphosate effects on soil rhizosphere-associated bacterial communities. Science of the Total Environment, 5432016: 155–160.

Nguyen DB, Rose MT, Rose TJ, van Zwieten L. 2018. Effect of glyphosate and a commercial formulation on soil functionality assessed by substrate induced respiration and enzyme activity. European Journal of Soil Biology, 85: 64–72.

Nwosisi S, Nandwani D, Hui D. 2019. Mulch treatment effect on weed biomass and yields of organic sweetpotato cultivars. Agronomy, 9(4): 1–15.

Ofosu R, Agyemang ED, Márton A, Pásztor G, Taller J, Kazinczi G. 2023. Herbicide resistance: managing weeds in a changing world. Agronomy, 13(6): 1–16.

Pose-Juan E, Igual JM, Sánchez-Martín, M. J, Rodríguez-Cruz, M. S. 2017. Influence of herbicide triasulfuron on soil microbial community in an unamended soil and a soil amended with organic residues. Frontiers in Microbiology, 8(MAR): 1–12.

Pszczółkowski, P, Barbaś P, Sawicka B, Krochmal-Marczak B. 2020. Biological and agrotechnical aspects of weed control in the cultivation of early potato cultivars under cover. Agriculture (Switzerland), 10(9): 1–18.

Radjabov J, Troyanovskaya I, Dvoryashina T, Vanzha V, Akhtyamova L. 2025. Impact of weed control methods on corn yield and soil fertility conservation. E3S Web of Conferences, 613(02003):1-11.

Ramesh K, Matloob A, Aslam F, Florentine SK, Chauhan B. S. 2017. Weeds in a changing climate: Vulnerabilities, consequences, and implications for future weed management. Frontiers in Plant Science, 8(February): 1–12.

Sawicka B, Krochmal-Marczak B, Barbaś P, Pszczółkowski P, Ćwintal M. 2020. Biodiversity of weeds in fields of grain in south-eastern Poland. Agriculture (Switzerland): 10(12): 1–17.

ISSN: 1412-4718, eISSN: 2581-138x

Sidahmed HMI, Illes A, ALmahi A, Nagy J. 2024. Performance of agricultural factors on yield of sweet corn (*Zea mays* L. Saccharata) - A review. Acta Agraria Debreceniensis, 1: 143–156.

Singh M, Kukal MS, Irmak S, Jhala AJ. 2022. Water use characteristics of weeds: a global review, best practices, and future directions. Frontiers in Plant Science, 12(January): 1–15.

Singh S, Kumar V, Gill JPK, Datta S, Singh S, Dhaka V, Kapoor D, Wani AB, Dhanjal DS, Kumar M, Harikumar SL, Singh J. 2020. Herbicide glyphosate: toxicity and microbial degradation. International Journal of Environmental Research and Public Health, 17(20): 1–18.

Sunari AAAAS, Sumiartha IK, Supartha IW, Mahaputra IGF, Yudha IKW, Utama IWEK, Wiradana PA. 2022. Potential yield reduction of sweet and glutinous corn varieties damaged by the invasive pest *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae): field trial scale. Proceedings of the 2nd International Conference on Education and Technology 2021, 630: 14–19.

Tampubolon K, Purba E, Basyuni M, Hanafiah D. S. 2019. Glyphosate resistance of *Eleusine indica* populations from North Sumatra, Indonesia. Biodiversitas, 20(7): 1910–1916.

Tsytsiura Y. 2020. Assessment of peculiarities of weed formation in oilseed radish agrophytocoenosis using different technological models. Chilean Journal of Agricultural Research, 80(4): 661–674.

Tyagi S, Mandal SK, Kumar R, Kumar S. 2018. Effect of different herbicides on soil microbial population dynamics in Rabi Maize (*Zea mays* L.). International Journal of Current Microbiology and Applied Sciences, 7: 3751–3758.

Tyagi VC, Wasnik VK, Choudhary M, Halli HM, Chander S. 2018. Weed Management in Berseem (*Trifolium alexandrium* L.): A Review. International Journal of Current Microbiology and Applied Sciences, 7(05): 1929–1938.

Umiyati U, Kurniadie D, Widianto R, Widayat D, Nasahi C. 2023. Resistance of *Eleusine indica* to non-selective herbicides in Indonesian oil palm plantation. Biodiversitas, 24(8): 4661–4667.

Varanasi A, Prasad PVV, Jugulam M. 2016. Impact of climate change factors on weeds and herbicide efficacy. Advances in Agronomy (Vol. 135). Elsevier Inc.

Vilà M, Beaury EM, Blumenthal DM, Bradley BA, Early R, Laginhas BB, Trillo A, Dukes JS, Sorte CJB, Ibáñez I. 2021. Understanding the combined impacts of weeds and climate change on crops. Environmental Research Letters, 16(034043):1-12.

Wang J, Gao H, Guo Z, Meng Y, Yang M, Li X, Yang Q. 2021. Adaptation responses in C4 photosynthesis of sweet maize (*Zea mays* L.) exposed to nicosulfuron. Ecotoxicology and Environmental Safety, 214(112096):1-12.

Westbury DP, McCullough PE, McElroy SJ, Rutland CA, Patel J. 2022. First report of ALS inhibitor-resistant green kyllinga (*Kyllinga brevifolia*). Weed Science, 70(3): 287–291.

Xu N, Wu Z, Li X, Yang M, Han J, Lu B, Lu B, Wang J. 2022. Effects of nicosulfuron on plant growth and sugar metabolism in sweet maize (*Zea mays* L.). PLoS ONE, 17(10): 1–15.

Yang F, Gao M, Lu H, Wei Y, Chi H, Yang T, Yuan M, Fu H, Zeng W, Liu C. 2021. Effects of atrazine on chernozem microbial communities evaluated by traditional detection and modern sequencing technology. Microorganisms, 9(9):1-22.

Zhang C, Chen L, Si H, Gao W, Liu P, Zhang J. 2020. Study on the characteristics and mechanisms of nicosulfuron biodegradation by Bacillus velezensis CF57. Journal of Basic Microbiology, 60(7): 649–658.

Zhao X, Wang L, Ma F, Bai S, Yang J, Qi S. 2017. Pseudomonas sp. ZXY-1, a newly isolated and highly efficient atrazine-degrading bacterium, and optimization of biodegradation using response surface methodology. Journal of Environmental Sciences (China), 54: 152–159.

Zioga E, White B, Stout J. C. 2022. Glyphosate used as desiccant contaminates plant pollen and nectar of non-target plant species. Heliyon, 8(12): e12179.