

Possibility of glyphosate-resistant goosegrass (*Eleusine indica*) in citrus fields in Rejang Lebong Districts, Bengkulu, Indonesia

MARULAK SIMARMATA^{1,*}, REKO APRIANTONEDI², NANIK SETYOWATI¹, HESTI PUJIWATI¹

¹Department of Crop Production, Faculty of Agriculture, Universitas Bengkulu. Jl. W.R. Supratman, Bengkulu 38371, Bengkulu, Indonesia. Tel./fax.: +62-736-21170, *email: marulak@unib.ac.id

²Department of Agrotechnology, Faculty of Agriculture, Universitas Pat Petulai. Jl. Basuki Rahmat, Rejang Lebong 39112, Bengkulu, Indonesia

Manuscript received: 30 April 2023. Revision accepted: 29 June 2023.

Abstract. Simarmata M, Apriantoned R, Setyowati N, Pujiwati H. 2023. Possibility of glyphosate-resistant goosegrass (*Eleusine indica*) in citrus fields in Rejang Lebong Districts, Bengkulu, Indonesia. *Biodiversitas* 24: 3624-3629. Weed abundances dominated by goosegrass (*Eleusine indica* L.) are a major constraint in the citrus fields of Rejang Lebong District, Province of Bengkulu, Indonesia. The objectives of this research were to investigate weed control methods applied by citrus farmers, analyze the dominant weed, and study the possibility of glyphosate resistance in goosegrass. A survey was conducted by interviewing three citrus farmers regarding weed control measures, followed by weed assessment in 10 sampling plots of each location. Then, field trials were conducted to evaluate glyphosate efficacy on weeds in the three locations of citrus fields. The survey found that glyphosate has been applied for weed control up to 4 L ha⁻¹ (1.92 kg a.i. ha⁻¹ of isopropyl amine salt) 2 to 3 times a year, and the farmers found that some weeds were resistant to glyphosate. Weed assessment showed that goosegrass is a dominant species with a summed dominance ratio (SDR) of 67.1, 70.8, and 79.0% at each location, respectively. The field trials observed that the levels of survival weeds in the experimental plots treated with glyphosate at 0.5, 1.0, 2.0, 4.0, and 8.0 L ha⁻¹ were 94-95%, 83-85.3%, 70-73.3%, 20-29%, and 10-12.3%, respectively. Goosegrass was identified as the survivor's weeds. The glyphosate doses (LD₅₀) required to eradicate 50% of the weed populations ranged between 2 and 4 L ha⁻¹ at the three sites. This study proved that goosegrass in the citrus groves of Rejang Lebong District, Bengkulu, is resistant to glyphosate.

Keywords: Gerga orange, glyphosate resistance, *rumpul belulang*, RGL variety

INTRODUCTION

The Gerga orange (*Citrus* sp.) variety of Rimau Gerga Lebong (RGL) is cultivated in Rejang Lebong Regency, Bengkulu Province, Indonesia. This orange is one of Bengkulu's leading commodities. It has a large fruit weight of 200-350 g, a fresh sweet-sour taste, and a high fruit juice content (Julianto 2015). One biological constraint of cultivation in citrus fields is weeds that emerge and grow rapidly among the plants (Suryani et al. 2015; Siagian et al. 2021). Weed species are very diverse and develop from the seeds carried with the organic manure fertilizers. From the initial observation, it is known that a dominant weed is a species of goosegrass (*Eleusine indica* L.) in Indonesia known as *Rumpul belulang*. If these weeds are not controlled properly, they will inhibit plant growth and decrease crop yields (Zimdahl 2018).

Weed control is important to limit weed infestations so plants can grow healthy and remain productive. Citrus farmers in Rejang Lebong Regency carry out chemical weed control using glyphosate and mechanical control using hoes (Suryani et al. 2015). The advantages of using herbicides are that weeds that grow between the rows, and in the circle of the citrus trunks can be completely controlled; however, sometimes, the herbicide is carried out unwisely, for example. In that case, the continuous use of one herbicide with increasing rates can decrease its efficacy, poison cultivated plants, and evolve herbicide-

resistant (HR) weeds (Heap 2014; Beckie et al. 2019; Martinelli et al. 2022).

Herbicide-resistant weeds can be part of the weed population to survive, grow normally, and regenerate after being exposed to herbicides at a normal rate (Heap 2014; Zimdahl 2018). In some areas, herbicides have become the only tool by which weeds are controlled, leading to evolving HR to increasingly powerful and complex resistance mechanisms (Peterson et al. 2018; Tampubolon et al. 2019). HR weeds evolved from the weed populations after being exposed intensively to the herbicide with the same action mode, so weeds became resistant (Chen et al. 2015). Another definition states that the evolution of HR is due to selection pressure created by the repeated use of similar herbicides over a long period (Sammons and Gaines 2014; Gaines et al. 2020). According to Ouyang et al. (2021), specific resistant putative weeds can develop and restore abundance without many environmental restrictions in rice fields. The glyphosate resistance site occurs in the shikimic acid pathway, which inhibits the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) enzyme (Simarmata et al. 2008). This enzyme is a precursor in the biosynthesis of three amino acids: phenylalanine, tyrosine, and tryptophan. Inhibition of these aromatic amino acids will eradicate plants (Chen et al. 2017; Zimdahl 2018). Because the resistant weeds can no longer be controlled with a similar herbicide, even at a higher rate, the HR weeds became a significant problem in weed management

tactics (Travlos et al. 2020).

The Herbicide Resistant Committee of WSSA routinely reports on herbicide-resistant weeds worldwide (Heap 2023). For example, glyphosate resistance first appeared in *Lolium rigidum* in an apple orchard in Australia in 1996. Next, the cases were also reported in some countries, such as Argentina, China, France, Mexico, South Africa, Spain, and the USA (Heap and Duke 2018). Glyphosate-resistant weeds have been reported worldwide, with 55 species distributed across 37 countries and in 34 crops (Heap 2023). HR weeds are generally predicted to occur due to selection pressure from excessive use of glyphosate (Gaines et al. 2020). Glyphosate-resistant (GR) goosegrass was first reported in Malaysia (Lee and Ngim 2000). Then the following reports are from Australia, Brazil, and China (Chen et al. 2015; Takano et al. 2017; Loddo et al. 2020). GR goosegrass has been reported in oil-palm plantations in North Sumatra, Indonesia (Tampubolon et al. 2019; Purba and Sipayung 2021). Most cases of GR goosegrass in citrus groves were reported in Mexico (Gherekhlou et al. 2017).

Glyphosate has been used to manage the out-of-control development of goosegrass in citrus orchards in the Rejang Lebong District, Bengkulu Province, and the application rates have risen over time. According to farmers, glyphosate at the recommended dose was no longer effective in weed control around citrus groves (Report of Citrus Farmers; Figure 1). Therefore, further study is required to assess the dominance of weed populations in citrus farms and the control measures the farmers apply. Also, glyphosate trials on the fields are needed to confirm if the goosegrass has developed to be resistance. The objectives of this research were to investigate weed control methods applied by the citrus farmers, analyze dominant weeds, and study the possibility of glyphosate resistance in goosegrass in citrus fields in Rejang Lebong District, Bengkulu Province, Indonesia.

MATERIALS AND METHODS

The research was conducted in citrus fields from Rejang Lebong District, Bengkulu Province, Indonesia, from October 2021 to January 2022. The research was done in two stages, the first was a survey of weed control management in the citrus fields, and the second was to identify the dominant weed species in the research areas following the field trials to evaluate the efficacy of glyphosate on weeds in the citrus fields.

Field survey

A survey was carried out among three citrus farmers who were selected by a purposive sampling method based on the ages of their citrus plants, which were between 5 to 10 years, and the areas were located within a radius of 10 km from the city of Curup in Rejang Lebong District. The coordinate locations of the research areas were 102.641820° E and 3.446941° S (location-1), 102.642071° E and 3.453092° S (location-2) and 102.654656° E and 3.454115° S (location-3). The information collected was about weed problems and control methods used in the

citrus fields. The data included the information of the farmer, data on the citrus plants, such as their age, type of citrus planted, planting area, fertilizer used, fertilizer dose, the pesticide used, weed control method, the herbicide used, including dose and frequency of application, and the effectiveness and efficacy of herbicide.

Plot design and weed assessment

Experimental plots were arranged on the citrus fields in the three selected locations. Sample plots were determined purposefully among the main crops by visually selecting the weedy areas. Ropes were used to delimit 18 plots (3 x 2 m²) in each location. The number of plots corresponded to 3 replications and 6 doses of glyphosate treatments. Then, 1.0 m² of space in the center of each experimental plot was specifically chosen for the weed assessment. The non-destructively observed variables included weed density and frequency (Simarmata et al. 2017). The number of individuals (weed density) and the frequency of occurrence of each weed species were counted and tabulated to evaluate the weed dominance by the SDR (Summed Dominance Ratio) as described in Equations 1, 2, and 3.

$$\begin{aligned} \text{SDR (Summed Dominance Ratio)} & \quad (1) \\ & = \frac{\text{RF} + \text{RD}}{2} \end{aligned}$$

$$\begin{aligned} \text{RF (Relative frequency)} & \quad (2) \\ & = \frac{\text{Total frequency of one species}}{\text{Total frequency of all species}} \times 100 \% \end{aligned}$$

Total frequency of one species is counted from 18 plots.

$$\begin{aligned} \text{RD (Relative density)} & \quad (3) \\ & = \frac{\text{Total density of one species}}{\text{Total density of all species}} \times 100 \% \end{aligned}$$

Total density of one species is counted from 18 plots.



Figure 1. Goosegrass infestation in the citrus field at Rejang Lebong District, Bengkulu Province of Bengkulu, Indonesia

Glyphosate application

The doses of glyphosate evaluated were: 0.5, 1.0, 2.0, 4.0, and 8.0 L ha⁻¹ or equal to isopropyl-amine salts of 0.24, 0.48, 0.96, 1.92, and 3.84 kg a.i. ha⁻¹, and without glyphosate as a control. The knapsack sprayer was calibrated before the herbicide application based on the spray volume of 400 L ha⁻¹. Calibration was carried out so that each experimental plot received the same volume of herbicide according to the treatment. The sprayer used is a knapsack sprayer with a capacity of 15 L using a flat-fan blue nozzle (1.5 m wide spray field and spray-flow at 75 mL minute⁻¹ at a pressure of 15 psi). Herbicide applications are carried out in good weather with no strong winds. The direction of the spray cross is adjusted to the width of the nozzle range.

Herbicide efficacy

Glyphosate efficacy due to the herbicide application was observed visually based on the symptoms of the weeds and the percentage of weeds that died after 5 weeks of herbicide application. The percentage of dead weed was used to calculate the weed resistance (Table 1) following Simarmata et al. (2015).

Data analysis

The information from the survey described the weed management applied by the farmers in the citrus fields in Rejang Lebong Regency and was analyzed descriptively. Weed assessment was analyzed to calculate the SDR values to determine the dominant weeds in the research areas. Data on glyphosate efficacy on goosegrass was described in a graph depicting the level of survivors' weed for each glyphosate dose. Meanwhile, the level of 50% of survivors in weed populations determines the lethal doses of LD₅₀ using the logistic model equation.

RESULTS AND DISCUSSION

Field survey

Table 2 displays the results of the initial survey on citrus plantations held by local farmers that were carried out at three locations. The citrus plants were, on average, 5 to 7 years old, with the land areas owned by the farmers ranging from 3 to 4 ha. The fertilizer used is an inorganic mixture of 16-16-16 NPK-mix at 2.5 kg per tree for two one-year applications. Fertilization was applied in a 30 cm hole at a 1.0 to 1.5 m distance from the citrus trunks. Farmers applied the cow's manure fertilizers twice a year at a dose of 30-50 kg per tree. Weed control was carried out using Roundup (glyphosate) because it is considered the most effective in killing weeds. Sometimes, if the farmers have spare time, they also do mechanical weed control using hoes. The dose of glyphosate applied is up to 4 L ha⁻¹ (1.92 kg a.i. ha⁻¹ of isopropyl amine salt) with a frequency of 2 to 3 times a year. Information from farmers indicates that some weed species are resistant to glyphosate, so glyphosate application is carried out at a higher dose. In

addition, farmers stated they would continue to control weeds chemically.

Weed assessment

Weed analyses at the three locations are tabulated in Table 3. There were 12 weed species, of which 3 were grasses and 9 broadleaves. But the numbers of weed species are different among the 3 locations, which are 11, 8, and 7 for the 1st, 2nd, and 3rd locations, respectively. Goosegrass dominated the areas with an SDR of 79.1, 91.7, and 89.0%, respectively. Goosegrass is an annual worst weed of a Poacea that is propagated from seeds (Chauhan et al. 2008). In citrus fields of the Rejang Lebong District, goosegrass propagated from the seeds, which are probably carried in cow manure and multiply rapidly to be dominant in the citrus sites. Because other weeds' populations can be easily controlled with glyphosate, the survival goosegrass propagated excessively and dominated the citrus fields. In addition, the same circumstances have been reported in citrus groves in Mexico after 15 years of being treated with glyphosate (Gherekhloo et al. 2017).

Goosegrass is difficult to control mechanically because it grows excessively, and its roots hold firmly to the soil. Goosegrass can produce seeds throughout the year, and each individual can produce 140,000 seeds each season (Saidi et al. 2017). The seeds are small and light, so they are easily spread by wind, water, endozoochory, or being carried away by agricultural tools (Chauhan et al. 2008). The citrus fields condition in Rejang Lebong is open to the sun with undulating terrain, so the spread and development of this weed's seeds are very fast. According to Saidi et al. (2017), goosegrass can grow well up to 1,600 m above sea level, which is suitable for the altitude of the Rejang Lebong area.

Glyphosate efficacy

The weeds survival ranges in the experimental plots applied with glyphosate at 0.5, 1.0, 2.0, 4.0, and 8.0 L ha⁻¹ were 94-95%, 83-85.3%, 70-73.3%, 20-29%, and 10-12.3%, respectively (Figure 2). The survivor's weeds from the dose of 1.0-8.0 L ha⁻¹ were identified as a goosegrass species, and Figure 3 showed the symptoms of the survivor's goosegrass at 8 L ha⁻¹ of glyphosate. Based on these data, the resistance levels of goosegrass at the 3 locations varied from 1.0 to 8.0 L ha⁻¹.

Table 1. The scoring system of glyphosate efficacy and glyphosate resistance

Herbicide efficacy	Dead weeds (%)	Survival weeds (%)
No or very light	<5%	>95%
Light	5-20	81-95%
Medium	21-50	51-80%
Heavy	51-80	21-50%
Very heavy	81-100	<20%

Resistance (survival weeds) = (100-Dead weeds) %

Table 2. Result of interviews with three respondents of citrus farmers in Rejang Lebong District, Bengkulu Province, Indonesia

Question	Answers		
	Farmer 1	Farmer 2	Farmer 3
How long have you been planting the citrus plants?	5 years	7 years	7 years
What is the variety of your citrus?	RGL	RGL	RGL
How many hectares are your citrus fields	3 hectares	4 hectares	2 hectares
What kind of fertilizer do you use?	Cow manure and mineral NPK	Cow manure and mineral NPK	Cow manure and mineral NPK
How do you apply the cow manure?	In a hole of 30 cm depth, circle 1.5-2 m away from citrus trees	In a hole of 30 cm depth, circle 1.5-2 m away from citrus trees	In a hole of 30 cm depth, circle 1.5-2 m away from citrus trees
How many times does the cow manure get applied in one year?	2 times	2 times	2 times
What is the dose of NPK fertilizers?	2.5 kg tree ⁻¹ for 2 applications in one year	2.5 kg tree ⁻¹ for 2 applications in one year	2.5 kg tree ⁻¹ for 2 applications in one year
What is the dose of cow manure in one application?	30 kg per tree	50 kg per tree	50 kg per tree
How do you manage the weeds?	Using herbicide	Using herbicide	Using herbicide
What is the brand or chemical name of your herbicide?	Roundup (glyphosate)	Roundup (glyphosate)	Roundup (glyphosate)
What is the dose of glyphosate applied?	4 L ha ⁻¹	4 L ha ⁻¹	4 L ha ⁻¹
How many times do you apply the herbicide in one year?	2 times	3 times	2 times
How do you apply the herbicide?	Spraying application using a knapsack sprayer	Spraying application using a knapsack sprayer	Spraying application using a knapsack sprayer
What happens to the weeds after herbicide application?	Some weeds have died, but some are still alive	Some weeds have died, but some are still alive.	Some weeds have died, but some are still alive.
In the future, what are you doing for weed control?	Using herbicide	Using herbicide	Using herbicide

Table 3. The summed dominance ratio (SDR) determines weed dominance in three locations

Weed species	Weed family	SDR (%)		
		Loc. 1	Loc. 2	Loc. 3
<i>Eleusine indica</i>	G	79.11	91.74	88.97
<i>Setaria palmifolia</i>	G	2.51	-	0.57
<i>Axonopus compressus</i>	G	1.96	1.12	-
<i>Asystasia coromandeliana</i>	B	2.45	-	1.33
<i>Ageratum conyzoides</i>	B	1.13	1.22	2.26
<i>Borreria alternans</i>	B	1.82	-	-
<i>Euphorbia serpens</i>	B	2.96	0.33	1.6
<i>Mikania micrantha</i>	B	1.77	3.19	2.75
<i>Marsilea crenata</i>	B	2.70	-	2.52
<i>Cardamine pensylvanica</i>	B	1.65	0.83	-
<i>Stellaria media</i>	B	1.94	0.55	-
<i>Conyza sumatrensis</i>	B	-	1.02	-
Total		100	100	100

Notes: G: grasses; B: broadleaf

Goosegrass was reported with glyphosate resistance for the first time in Malaysia, where the resistance level may reach 8 to 12 folds (Lee and Ngim 2000). The glyphosate doses that killed 50% of the weed population were observed between 2.0 and 4.0 L ha⁻¹. These indicated that the level of GR at the three locations was very close.

Furthermore, using glyphosate at normal rates in these areas was no longer effective in controlling goosegrass in these locations. The survey reported that glyphosate had been used repeatedly since the establishment of citrus plantations, causing an abundance of GR goosegrass. Previous reports have indicated the consequences of using the same herbicide repeatedly over a long period may cause problems in weed control, such as an abundance of HR species and their dominance in the area (Singh et al. 2020).

GR goosegrass was reported worldwide, including in Indonesia (Tampubolon et al. 2019; Ferdinans et al. 2023). The resistance level in goosegrass varies in different growth areas; therefore, a specific tactic must be considered to manage the GR goosegrass (Fernández-Moreno et al. 2017; Tampubolon et al. 2020). The information from these experiments is needed for researchers and practitioners of weed control to prevent the abundance of GR goosegrass in Indonesia. Chemical weed control is still the main choice in agricultural practices; however, it can be achieved by applying glyphosate at the early stage of the weed life cycle or by rotating to an herbicide with a different application mode (Travlos et al. 2020). The other choice is switching to other weed control measures, such as cultural practices, preventive measures, or mechanical control (Singh et al. 2020).

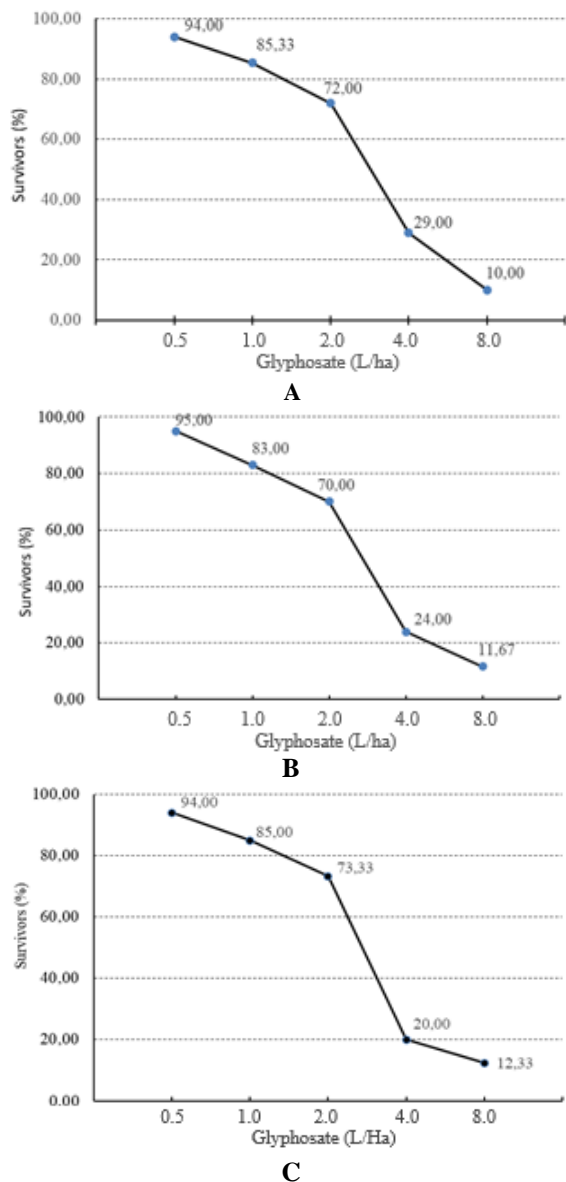


Figure 2. Goosegrass responses to glyphosate at 0.5 to 8.0 L ha⁻¹ (A, B, and C are Locations 1, 2, and 3, respectively)



Figure 3. The symptoms of GR goosegrass after 5 weeks treated with glyphosate at 8 L ha⁻¹

In conclusion, glyphosate was used as a main method of weed control in the citrus field in Rejang Lebong District, Bengkulu Province, Indonesia. Weed assessment indicated that a dominant weed in the three areas of the citrus farm was goosegrass, with the dose needed to inhibit 50% of goosegrass between 2.0 and 4.0 L ha⁻¹. This study provided important information for citrus farmers in Rejang Lebong District on managing weeds with other control strategies, including the early application of glyphosate, herbicide rotation to a different application mode, rotating with other weed control practices such as prevention of weed seed infestation from organic manures, or switching with other weed control practices to be integrated weed management.

ACKNOWLEDGEMENTS

The author would like to thank the Dean of the Agricultural Faculty and the Chairman of the Magister Program of the Department of Agrotechnology, the University of Bengkulu, Indonesia, for facilitating and supporting the research. Great appreciation to the Laboratory of Agronomy, University of Bengkulu staff for helping with the fieldwork.

REFERENCES

- Beckie HJ, Ashworth MB, Flower KC. 2019. Herbicide resistance management: Recent developments and trends. *Plants* 8: 161. DOI: 10.3390/plants8060161.
- Chauhan BS, Johnson DE. 2008. Germination ecology of goosegrass (*Eleusine indica*): An important grass weed of rainfed rice. *Weed Sci* 56: 699-706. DOI: 10.1614/WS-08-048.1.
- Chen J, Huang H, Wei S, Zhang C, Huang Z. 2015. Characterization of glyphosate-resistant goosegrass (*Eleusine indica*) populations in China. *J Integr Agric* 14: 919-925. DOI: 10.1016/S2095-3119(14)60910-2.
- Chen J, Huang H, Wei S, Huang Z, Wang H, Zhao D, Zhang C 2017. Characterization of *Eleusine indica* with gene mutation or amplification in EPSPS to glyphosate. *Pestic Biochem Physiol* 143: 201-206. DOI: 10.1016/j.pestbp.2017.09.012.
- Ferdinans, Guntoro D, Ardie SW. 2023. Mutation site identification confers glyphosate resistance in goosegrass (*Eleusine indica* L. Gaertn) from Jonggol, Bogor, Indonesia. *Indonesian J Agron* 51 (1): 1-8. DOI: 10.24831/ija.v51i1.45944.
- Fernández-Moreno PT, Travlos I, Brants I. 2017. Different levels of glyphosate-resistant *Lolium rigidum* L. among major crops in southern Spain and France. *Sci Rep* 7: 13116. DOI: 10.1038/s41598-017-13384-2.
- Gaines TA, Duke SO, Morran S, Rigon CAG, Tranel PJ, Küpper A, Dayan FE. 2020. Mechanisms of evolved herbicide resistance. *J Biol Chem* 295 (30): 10307-10330. DOI: 10.1074/jbc.REV120.013572.
- Gherekhloo J, Fernández-Moreno PT, Alcántara-de la Cruz R. 2017. Pro-106-Ser mutation and EPSPS overexpression acting together simultaneously in glyphosate resistant goosegrass (*Eleusine indica*). *Nat Sci Rep* 7: 6702. DOI: 10.1038/s41598-017-06772-1.
- Heap I. 2014. Global perspective of herbicide-resistant weeds. *Pest Manag Sci* 70 (9): 1306-1315. DOI: 10.1002/ps.3696.
- Heap I, Duke SO. 2018. Overview of glyphosate-resistant weeds worldwide. *Pest Manag Sci* 74: 1040-1049. DOI: 10.1002/ps.4760.
- Heap I. 2023. International Survey of Herbicide Resistant Weed. <http://www.science.org>.
- Julianto. 2015. Hunting Gerga Oranges to Bengkulu. <https://tabloidinsartani.com/detail/indeks/klinik-teknologi/2300-berburu-jeruk-gerga-hingga-ke-bengkulu-> [Indonesian]
- Lee LJ, Ngim J. 2000. A first report of glyphosate-resistant goosegrass (*Eleusine indica* L. (Gaertn) in Malaysia. *Pest Manag Sci* 56 (4): 336-

339. DOI: 1002/(SICI)1526-4998(200004)56:4<336:AID-PS123>3.0.CO;2-8.
- Loddo D, Imperatore G, Milani A Panozzo S, Farinati S, Sattin M, Zanin G. 2020. First report of glyphosate-resistant biotype of *Eleusine indica* (L.) Gaertn. in Europe. *Agronomy* 10: 1692. DOI: 10.3390/agronomy10111692.
- Martinelli R, Rufino Jr. RL, de Melo AC, Cruz RA, da Silva MFdGF, da Silva JR, Boaretto RM, Monquero PA, Mattos Jr D, de Azevedo FA. 2022. Glyphosate excessive use chronically disrupts the shikimate pathway and can affect photosynthesis and yield in citrus trees. *Chemosphere* 308: 136468. DOI: 10.1016/j.chemosphere.2022.136468.
- Peterson MA, Collavo A, Ovejero R, Shivrain V, Walsh MJ. 2018. The challenge of herbicide resistance around the world: A current summary. *Pest Manag Sci* 74: 2246-2259. DOI: 10.1002/ps.4821.
- Purba E, Sipayung R. 2021. Confirmation and control of glyphosate-resistant biotype of goosegrass (*Eleusine indica* L.) in Sumatran oil palm. *J Saudi Soc Agric Sci* 21: 318-323. DOI: 10.1016/j.jssas.2021.10.010.
- Ouyang C, Liu W, Chen S et al. 2021. The naturally evolved EPSPS from goosegrass confers high glyphosate resistance to rice. *Front Plant Sci* 12: 756116. DOI: 10.3389/fpls.2021.756116.
- Saidi N, Kadir J, Hong LW. 2017. Genetic diversity and morphological variations of goosegrass [*Eleusine indica* (L.) Gaertn] ecotypes in Malaysia. *Weed Turf Sci* 5: 144-154. DOI: 10.5660/WTS.2016.5.3.144.
- Sammons RD, Gaines TA. 2014. Glyphosate resistance: State of knowledge. *Pest Manag Sci* 70: 1367-1377. DOI: 10.1002/ps.3743.
- Siagian IC, Nurmegawati, Puspitasari M, Miswanti, Dinata K, Mikasari W, Hartono R, Yuliasari S, Sastro Y. 2021. Analysis of limiting factors of RGL citrus fruit productivity (study case in Pal VII Village, Bermani Ulu Raya Subdistrict, Rejang Lebong District). *IOP Conf Ser Earth Environ Sci* 648: 012008. DOI: 10.1088/1755-1315/648/1/012008.
- Simarmata M, Penner D. 2008. The basis for glyphosate resistance in rigid ryegrass (*Lolium rigidum*) from California. *Weed Sci* 56: 181-188. DOI: 10.1614/WS-07-057.1.
- Simarmata M, Sitanggang CD, Djamilah D. 2015. Shifting weed compositions and biomass production in sweet corn field treated with organic composts and chemical weed controls. *AGRIVITA J Agric Sci* 37: 226-236. DOI: 10.17503/agrivita.v37i3.582.
- Simarmata M, Taufik M, Peranginangin ZZA. 2017. Efficacy of paraquat and glyphosate applied in water solvents from different sources to control weeds in oil palm plantation. *ARPN J Agric Biol Sci* 12: 58-64.
- Singh UP, Kamboj A, Sharma M. 2020. Herbicide resistance in weed and its management-a review. *Intl J Edu Technol Sci Res* 8 (12): 123-223.
- Suryani S, Rambe M, Ivanti L. 2015. Pengaruh pemupukan dan pemangkasan terhadap kualitas buah jeruk gerga lebung. <https://adoc.pub/pengaruh-pemupukan-dan-pemangkasan-terhadap-kualitas-buah-je.html> [Indonesian]
- Takano HK, de Oliveira Júnior RS, Konstantin J, Braz GBP, Gheno EA. 2017. Goosegrass resistant to glyphosate in Brazil. *Planta Daninha* 35: 10. DOI: 10.1590/s0100-83582017350100013.
- Tampubolon K, Purba P, Basyuni M, Hanafiah DS. 2019. Glyphosate resistance of *Eleusine indica* populations from North Sumatra, Indonesia. *Biodiversitas* 20: 1910-1916. DOI: 10.13057/biodiv/d200717.
- Tampubolon K, Saragih WS, Purba Z, Hamzani I. 2020. Single and multiple resistance of *Eleusine indica* from Asahan Regency, Indonesia. *J Res Weed Sci* 3: 24-35. DOI: 10.26655/JRWEEDSCI.2020.1.3.
- Travlos I, de Prado R, Chachalis D, Bilalis DJ. 2020. Editorial: Herbicide resistance in weeds: Early detection, mechanisms, dispersal, new insights and management issues. *Front Ecol Evol* 8: 213. DOI: 10.3389/fevo.2020.00213.
- Zimdahl RL. 2018. Properties and Uses of Herbicides. In: *Fundamentals of Weed Science*, fifth ed., Elsevier Inc. DOI: 10.1016/B978-0-12-811143-7.00016-0.