Bulgarian Journal of Agricultural Science, 26 (No 5) 2020, 1003–1012

Application of monosodium methyl arsenate with diuron herbicide to control the characteristics of glyphosate-resistant *Eleusine indica* at oil palm plantations

Koko Tampubolon[1], Edison Purba[2*], Mohammad Basyuni[3] and Diana Sofia Hanafiah[2]

[1]*Universitas Sumatera Utara, Doctoral Program of Agricultural Science, Faculty of Agriculture, Padang Bulan, Medan 20155, Indonesia*
[2]*Universitas Sumatera Utara, Program Study of Agrotechnology, Faculty of Agriculture, Padang Bulan, Medan 20155, Indonesia*
[3]*Universitas Sumatera Utara, Department of Forestry, Faculty of Forestry, Padang Bulan, Medan 20155, Indonesia*
[*]*Corresponding author:* epurba@yahoo.com

Abstract

Tampubolon, K., Purba, E., Basyuni, M. & Hanafiah, D. S. (2020). Application of monosodium methyl arsenate with diuron herbicide to control the characteristics of glyphosate-resistant *Eleusine indica* at oil palm plantations. *Bulg. J. Agric. Sci., 26 (5)*, 1003–1012

The glyphosate-resistant *Eleusine indica* (GR-ESU) case has dominated at oil palm plantations in North Sumatra Province, Indonesia and will increase evolution into resistance. This research was aimed to determine the role of Monosodium Methyl Arsenate (MSMA)+diuron to control the agronomic characteristics of GR-ESU biotypes. This research was conducted in the Weed Research Center Land, Faculty of Agriculture, Universitas Sumatera Utara in November 2017 until August 2018. This research used Randomized Block Design non-factorial with factor GR-ESU biotypes that were sprayed with glyphosate at the dose of 3 $l.ha^{-1}$, and MSMA+diuron at the dose of 5 $l.ha^{-1}$ within four replications. The parameters were analyzed using one-way ANOVA and were continued by DMRT at $P < 0.05$ with IBM SPSS Statistics v.20 software. The results showed that a decrease in the survival of GR-ESU at the changes from glyphosate to MSMA+diuron. The GR-ESU on MSMA+diuron showed leaf color changes (leaf green loss/chlorosis) at 3 until 21 days after sprayed. The ability of MSMA+diuron had completely (100%) controlled within 18 of 29 GR-ESU biotypes and had effectively controlled the tillers, flowering, fresh- and dry weight in GR-ESU biotypes of 87.53%; 66.88%; 95.66%; and 95.92% respectively compared to glyphosate. The use of MSMA+diuron as a different mode of action herbicide is highly recommended to control GR-ESU biotypes at oil palm estate.

Keywords: Eleusine indica; glyphosate; MSMA; diuron; oil palm plantations; resistant
Abbreviations: GR-ESU (Glyphosate-Resistant *E. indica* from North Sumatra, Indonesia); ESU-0 (Glyphosate-susceptible *E. indica*); MSMA (Monosodium Methyl Arsenate); MoA (Mode of action)

Introduction

The resistance case of Goosegrass [*Eleusine indica* (L.) Gaertn] to glyphosate at oil palm plantations in North Sumatra Province, Indonesia had been reported, and the resistance index showed that it was difficult to control *E. indica.* The previous research reported that resistance index of *E. indica* in North Sumatra, Lubis et al. (2012) reported that 7-fold of *E. indica* was glyphosate-resistant at Adolina Estate in the Serdang Bedagai District. Dali-

munthe et al. (2015) reported that 7.5-fold of *E. indica* was glyphosate-resistant at Adolina Estate in the Serdang Bedagai District. In addition, Syahputra et al. (2016) reported that 98.28% of *E. indica* populations were glyphosate-resistant at the dose of 480 g a.i.ha^{-1} from the first to 9th afdeling blocks at Adolina Estate in the Serdang Bedagai District. Tampubolon et al. (2019a) reported that 65.56% of *E. indica* populations were glyphosate-resistant at the dose of two l.ha^{-1} from oil palm plantations in the North Sumatra Province, Indonesia.

The use of glyphosate is still dominant and used frequently to control *E. indica* at oil palm plantations in the North Sumatra Province, Indonesia. Controlling of *E. indica* with a similar mode of action herbicide will increase the evolution of herbicide-resistant *E. indica* and cause losses including increased input costs and labor. The management of herbicide-resistant weed was needed to prevent spread of resistant-seedbank. According to Monaco et al. (2002), the management of herbicide-resistant weed was conducted by rotation the mode of action (MoA) herbicide, rotation of the MoA herbicides during crop rotation, or mixing herbicides with different MoA.

The use of different MoA herbicides was conducted with mixture herbicides include Monosodium Methyl Arsenate (MSMA)+diuron, etc. The use of mixture herbicides had been reported to be more effectively controlled *E. indica* than a single herbicide. Rusli et al. (2014) stated that MSMA+diuron at the dose of 5 l.ha^{-1} effectively (100%) controlled *E. indica* at 5 weeks after application (WAA) compared to paraquat dichloride at the dose of 3.3 l.ha^{-1}; glufosinate ammonium at the dose of 6 l.ha^{-1}; isopropylammonium glyphosate at the dose of 3 l.ha^{-1} with an effectiveness rate of 70%, 50%, and 70%, respectively at oil palm plantations in the Sungai Jejawi, Perak, Malaysia. Sim et al. (2018) also reported that MSMA 3000 g a.i.ha^{-1} combined with diuron 600 g a.i.ha^{-1} effectively (100%) controlled *E. indica* at 2 WAA compared to glyphosate at the dose of 1440 g a.i.ha^{-1}; glufosinate ammonium at the dose of 500 g a.i.ha^{-1} and fluazifop-butyl at the dose of 710 g a.i.ha^{-1} with an effectiveness rate of 1.7%; 20%; and 13.3%, respectively in the Ara Kuda, Penang, Malaysia.

More efforts to use herbicide mixtures are needed in control glyphosate-resistant *E. indica* (GR-ESU) biotypes. The research was determined that role of MSMA+diuron as a different the MoA herbicide to control the agronomic characteristics of GR-ESU biotypes at oil palm plantations in North Sumatra, Indonesia.

Material and Methods

Glyphosate-resistant and –susceptible E. indica Biotypes Selection

E. indica populations were collected at oil palm plantations on 11 districts from North Sumatra (Table 2). *E. indica* seeds were soaked in 0.2% KNO_3 for 30 min (Ismail et al., 2002) which aimed to break dormancy of *E. indica* seeds. Topsoil and manure were mixed with the 1:1 ratio for germination media, then was treated at 100°C for 3 h (Tampubolon & Purba, 2018). The media was then filled into the germination trays of the size 33 cm x 24 cm. Seedling of *E. indica* that had 2-3 leaf stage were transplanted by ten.pot^{-1} with topsoil, sand, and manure mixed at the 1: 1: 1 ratio. Glyphosate herbicide was sprayed at the dose recommendation of two l.ha^{-1} when *E. indica* was at the 3-4 leaf stage (Hess et al., 1997). The resistance classification was conducted at 3 weeks after spraying (WAS). Mature seeds of the highest resistance of 2 biotypes GR-ESU in each district were collected until 6 WAS.

Seedling Process

The seedling process for single and mixture herbicides treatment were conducted by the related method with the selection section. The selection and seedling process were conducted in the Weed Research Center Land, Faculty of Agriculture, Universitas Sumatera Utara in November 2017 until August 2018.

Single and Mixture Herbicides Application

GR-ESU biotypes from each pot were prepared used the Randomized Block Design (RBD) non-factorial with four replications. GR-ESU biotypes were sprayed with glyphosate at the dose of 3 l.ha^{-1} (Round-up 486 SL, PT. Menagro Kimia) and MSMA 39.5% + diuron 7.8% at the dose of 5 l.ha^{-1} (Monex HC 486 SL, ANCOM Crop Care SDN. BHD). The spray volume was calibrated at 296 l.ha^{-1}, during sunlight at 37°C and 66% moisture.

Parameters Analysis

GR-ESU biotypes survival and resistance classification wasperformedat 3 WAS. Tillers, fresh weight (FW), dry weight (DW), flowering, and growth reduction in GR-ESU were observedat 6 WAS, then oven-dried at 65°C for 72 h (Jalaludin et al., 2015). The growth reduction percentage of GR-ESU biotypes was calculated using the dry weight and the category can be seen in Table 1 (Mohamad et al., 2010). The GR-ESU toxicity assessment was visually observed at 3, 7, and 21 days after sprayed (DAS) with scored based on the leaf color. 0 (green), 1 (yellowish-green), 2 (yellow in overall), 3 (brownish yellow) and 4 (brown and shrunken).

$$\text{GR-ESUsurvival} = \frac{\sum\text{GR-ESU tillers sprayed}}{\sum\text{GR-ESU were planted}} \times 100\% \quad (1)$$

$$\text{Controlling of GR-ESU tillers} = 100 - \frac{\sum\text{GR-ESU tillers sprayed}}{\sum\text{GR-ESU tillers unsprayed}} \times 100\% \quad (2)$$

$$\text{Controlling of GR-ESU FW} = 100 - \frac{\text{GR-ESU FW sprayed}}{\text{GR-ESU FW unsprayed}} \times 100\% \quad (3)$$

$$\text{Controlling of GR-ESU DW} = 100 - \frac{\text{GR-ESU DW sprayed}}{\text{GR-ESU DW unsprayed}} \times 100\% \quad (4)$$

$$\text{Controlling of GR-ESU flowering} = 100 - \frac{\text{GR-ESU flowering sprayed}}{\text{GR-ESU flowering unsprayed}} \times 100\% \quad (5)$$

Table 1. Description effectiveness controlling of GR-ESU

Score	Percentage	Effectiveness Controlling of Weeds
0	≤ 0.00	no weed control
1	0.01-10.00	Very poor weed control
2	10.01-20.00	Poor weed control
3	20.01-30.00	Poor to deficient weed control
4	30.01-40.00	Deficient weed control
5	40.01-50.00	Deficient to moderate weed control
6	50.01-60.00	Moderate weed control
7	60.01-70.00	Weed control somewhat less than satisfactory
8	70.01-80.00	Satisfactory to good weed control
9	80.01-90.00	Very good to excellent weed control
10	90.01-100	Complete weed destruction

Source: Mohamad et al. (2010)

The resistance classification of both herbicides application was informed by the survival of GR-ESU biotypes. Herbicide-susceptible (S) had the survival percentage ranged from 0-1.99%, herbicide-developing resistant (DR) ranged from ≥ 2.00–19.99%, and herbicide-resistant (R) ≥ 20% (Owen & Powles, 2009). The herbicide-resistant (R) was modified by the authors into 2 parts, such as the classification of herbicide-resistant (R) had the survival percentage ranged from ≤ 20–60% and herbicide-resistant extremely (ER) > 60%. The parameters were analyzed with one-way ANOVA and were continued by DMRT at $P < 0.05$ with IBM SPSS Statistics v.20 software.

Results and Discussion

Survival and Resistance Classification of GR-ESU

The GR-ESU biotypes survival on MSMA+diuron-sprayed was lower compared to glyphosate-sprayed and was significantly controlled within 22 of 29 GR-ESU (Figure 1). The MSMA+diuron was completely (100%) controlled within 18 of 29 GR-ESU biotypes compared to glyphosate, only one biotype.

There are 11 of 29 GR-ESU biotypes had the ability to survive ranged from 2.50 to 27.50% with the

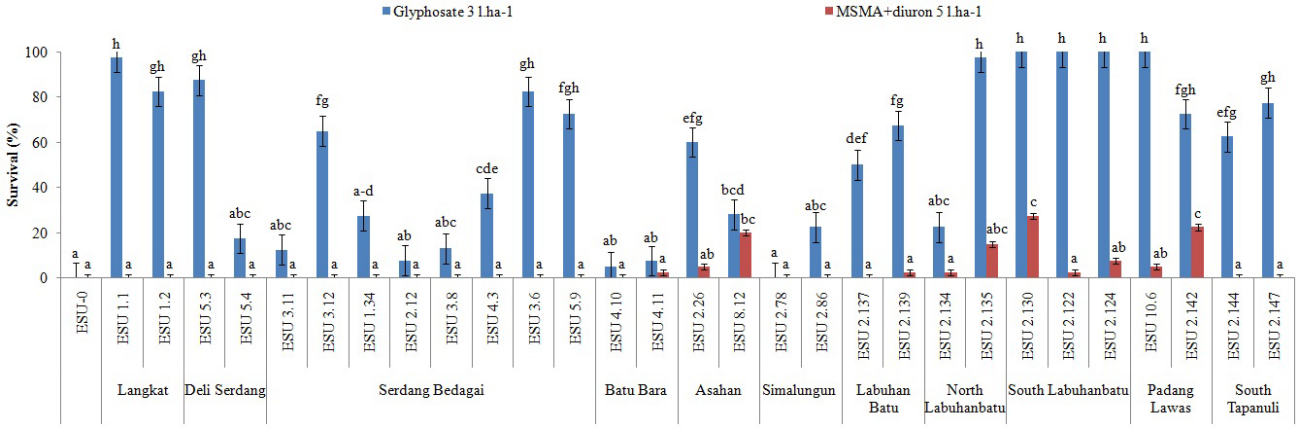

Fig. 1. GR-ESU biotypes survival on glyphosate- and MSMA+diuron-sprayed at oil palm plantations in North Sumatra at 3 WAS

Vertical bars indicate ± SE. Different lowercase letters mean significant difference by DMRT at P < 0.05

MSMA+diuron-sprayed. A decrease in the ability to survive GR-ESU biotypes by changing the MoA from glyphosate to MSMA+diuron. The resistance classification of GR-ESU biotypes can be seen in Table 2.

There are 15 of 29 GR-ESU biotypes were classified as glyphosate-resistant extremely and un-found classified as mixture-resistant extremely. Seven of 29 GR-ESU were classified as glyphosate-resistant and one of them found in $ESU_{8.12}$ biotype with mortality rate by 80.00% was classified as mixture-resistant. There are 6 of 29 GR-ESU were classified as glyphosate-developing resistant and one of them found in $ESU_{4.11}$ biotype with mortality rate of 97.50% was classified asmixture-developing resistant. It showed the use of mixture herbicide MSMA+diuron as more effective on rotation mode of action to control GR-ESU biotypes compared to glyphosate. According to Monaco et al. (2002), the resistant weed control could be controlled by rotation mode of action, rotation of the MoA herbicides during crop rotation, or mixing herbicides with different MoA. Rusli et al. (2014) stated that MSMA+diuron at the dose of 5 $l.ha^{-1}$ could control *E. indica* by 90%, 95%, and 99%, respectively at 1, 2, and 3 weeks after treatment (WAT) and was higher compared to isopropylammonium glyphosate at 3 $l.ha^{-1}$ by 40%, 50%, and 55% respectively from oil palm plantations in the Sun-

Table 2. The resistance classification and growth reduction score of GR-ESU biotypeson glyphosate and MSMA+diuron sprayed at oil palm plantations in North Sumatra

Districts	Biotypes	Resistance Classification								Growth Reduction Score	
		Glyphosate 3 l/ha				MSMA+diuron 5 l/ha				Glyphosate 3 $l.ha^{-1}$	MSMA+ diuron 5 $l.ha^{-1}$
		S	DR	R	ER	S	DR	R	ER		
Langkat	ESU 1.1	–	–	–	√	√	–	–	–	3	10
	ESU 1.2	–	–	–	√	√	–	–	–	5	10
Deli Serdang	ESU 5.3	–	–	–	√	√	–	–	–	1	10
	ESU 5.4	–	√	–	–	√	–	–	–	7	10
Serdang Bedagai	ESU 3.11	–	√	–	–	√	–	–	–	5	10
	ESU 3.12	–	–	–	√	√	–	–	–	4	10
	ESU 1.34	–	–	√	–	√	–	–	–	4	10
	ESU 2.12	–	√	–	–	√	–	–	–	8	10
	ESU 3.8	–	√	–	–	√	–	–	–	7	10
	ESU 4.3	–	–	√	–	√	–	–	–	7	10
	ESU 3.6	–	–	–	√	√	–	–	–	3	10
	ESU 5.9	–	–	–	√	√	–	–	–	4	10
Batu Bara	ESU 4.10	–	√	–	–	√	–	–	–	10	10
	ESU 4.11	–	√	–	–	–	√	–	–	9	10
Asahan	ESU 2.26	–	–	√	–	–	√	–	–	7	10
	ESU 8.12	–	–	√	–	–	–	√	–	9	8
Simalungun	ESU 2.78	√	–	–	–	√	–	–	–	10	10
	ESU 2.86	–	–	√	–	√	–	–	–	10	10
Labuhan Batu	ESU 2.137	–	–	√	–	√	–	–	–	1	10
	ESU 2.139	–	–	–	√	–	√	–	–	1	10
North Labuhanbatu	ESU 2.134	–	–	√	–	–	√	–	–	6	10
	ESU 2.135	–	–	–	√	–	√	–	–	1	8
South Labuhanbatu	ESU 2.130	–	–	–	√	–	–	√	–	1	5
	ESU 2.122	–	–	–	√	–	√	–	–	1	10
	ESU 2.124	–	–	–	√	–	√	–	–	2	10
Padang Lawas	ESU 10.6	–	–	–	√	–	√	–	–	1	10
	ESU 2.142	–	–	–	√	–	–	√	–	1	10
South Tapanuli	ESU 2.144	–	–	–	√	√	–	–	–	1	10
	ESU 2.147	–	–	–	√	√	–	–	–	6	10

Note. S = susceptible (*E. indica* survival 0 until 1.99%); DR = developing-resistant (*E. indica* survival >2 until 19.99%); R = resistant (*E. indica* survival ≥ 20%) (Owen & Powles., 2009) and was modified by authors, classification R = resistant (*E. indica* survival ≤ 20 until 60%) and ER = extremely-resistant (*E. indica* survival > 60%)

gai Jejawi, Perak, Malaysia. Sim et al.(2018) reported that the use of MSMA+diuron at the dose of 3000+600 g a.i.ha^{-1} could control of herbicide-resistant *E. indica* ranged from 80 to 95% in the greenhouse condition. Tampubolon et al. (2019b) stated that the glufosinate-ammonium and triclopyr at doses of 2 to 8-fold effectively (100%) suppressed the survival, tillers, fresh- and dry weight of glyphosate-resistant *E. indica* biotypes compared to glyphosate.

GR-ESU Tillers

The ability of MSMA+diuron had significantly suppressed the tillers within 25 of 29 GR-ESU biotypes compared to glyphosate, only one biotype controlled (Figure 3A) and was effectively controlled the tillers by 87.52% compared to glyphosate only 37.77% (Figure 3B). The GR-ESU tillers growth are relatively fast and depends on dry matter accumulation. It was linear with the dry weight of GR-ESU on MSMA+diuron that was lower compared to glyphosate (Figure 5A). The tillers can be used as a source of information in determining the seeds number that will be produce by GR-ESU in one life cycle. The seeds were produced by tillers and parents of GR-ESU on glyphosate- and MSMA+diuron-sprayed could be confirmed to carry resistance genes to their offspring. According to Zhang et al. (2015) the EPSPS enzyme on glyphosate-resistant *E. indica* biotype quickly responded and was detected at 12 h after glyphosate-treated from South China. The mRNA and protein expression of glyphosate-resistant *E. indica* biotype constantly increases with increasing levels of glyphosate. Takano et al. (2016) stated that *E. indica* could produce the tillers between 38 to 43 days after emergence (DAE) with an accumulation of the total dry matter and a substantial increase of the absolute growth rate.

Biomass and Growth Reduction of GR-ESU

Glyphosate at the dose 3 l.ha^{-1} was ineffectively controlled the fresh- and dry weight of GR-ESU by 41.24 and 41.67%, respectively at 6 WAS compared to MSMA+diuron by 95.66 and 95.92%, respectively (Figures 4B and 5B). The ability of MSMA+diuron significantly suppressed the fresh weight in 26 of 29 GR-ESU compared to glyphosate, only three biotypes controlled (Figure 4A) and significantly suppressed the

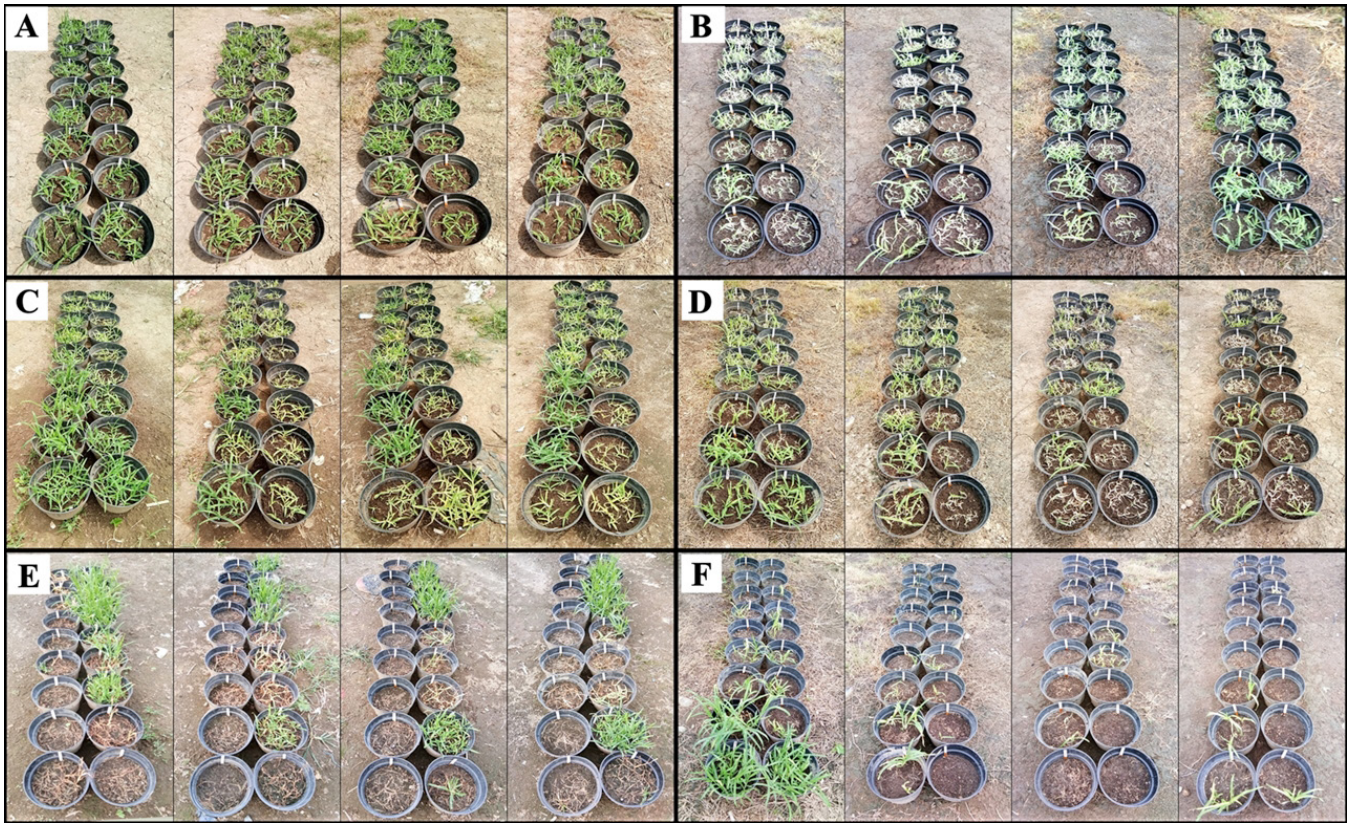

Fig. 2. The observation of GR-ESU biotypes at oil palm plantations in North Sumatra. Glyphosate-spayed at 3 days (A); 7 days (C); and 21 days (E). MSMA+diuron-sprayed at 3 days (B); 7 days (D); and 21 days (F)

dry weight 24 of 29 GR-ESU compared to glyphosate, only one biotype controlled (Figure 5A). The growth reduction of GR-ESU biotypes using MSMA+diuron was also dominated effectively as complete weed destruction and $ESU_{2.130}$ biotype was classified as deficient to reasonable weed control. The ability of MSMA+diuron had been effective at 3 DAS by visual observations (Figure 2), change occurs in color leaves of GR-ESU. The MSMA+diuron could improve the effectiveness of complete weed destruction to control the growth reduction on 26 of 29 GR-ESU at 6 WAS (Table 2).

According to Sim et al. (2018), the glyphosate-resistant *E. indica* biotypes could stimulate the growth of 125% on glyphosate at the dose of 1440 g a.i.ha^{-1}, meanwhile the MSMA+diuron at the dose of 3000+600 g a.i.ha^{-1} could suppress the dry weight only 9% compared to untreated at 4 WAT in the greenhouse. Rusli et al. (2014) also stated that the MSMA+diuron at the dose of 5 l.ha^{-1} could inhibit the *E. indica* growth of 48% and was greater compared to isopropylammonium glyphosate at the dose of 3 l.ha^{-1} (only 6%) at 5 WAT.

GR-ESU Flowering

Glyphosate at the dose 3 l.ha^{-1} could control the flowering of GR-ESU at 14.14% and was ineffective compared to MSMA+diuron at the dose 5 l.ha^{-1} of 66.88% at oil palm plantations in North Sumatra (Figure 6). The average flowering of 29 GR-ESU on glyphosate- and MSMA+diuron-sprayed were needed at 38.13 and 38.83 days, respectively. The flowering could be used as a reference presence and was needed as an initial stage to prevent the spread of herbicides-resistant seedbank. This seedbank spread resulted in a difficult to control GR-ESU biotypes at oil palm plantations in North Sumatra. GR-ESU biotypes flowering were prevented with

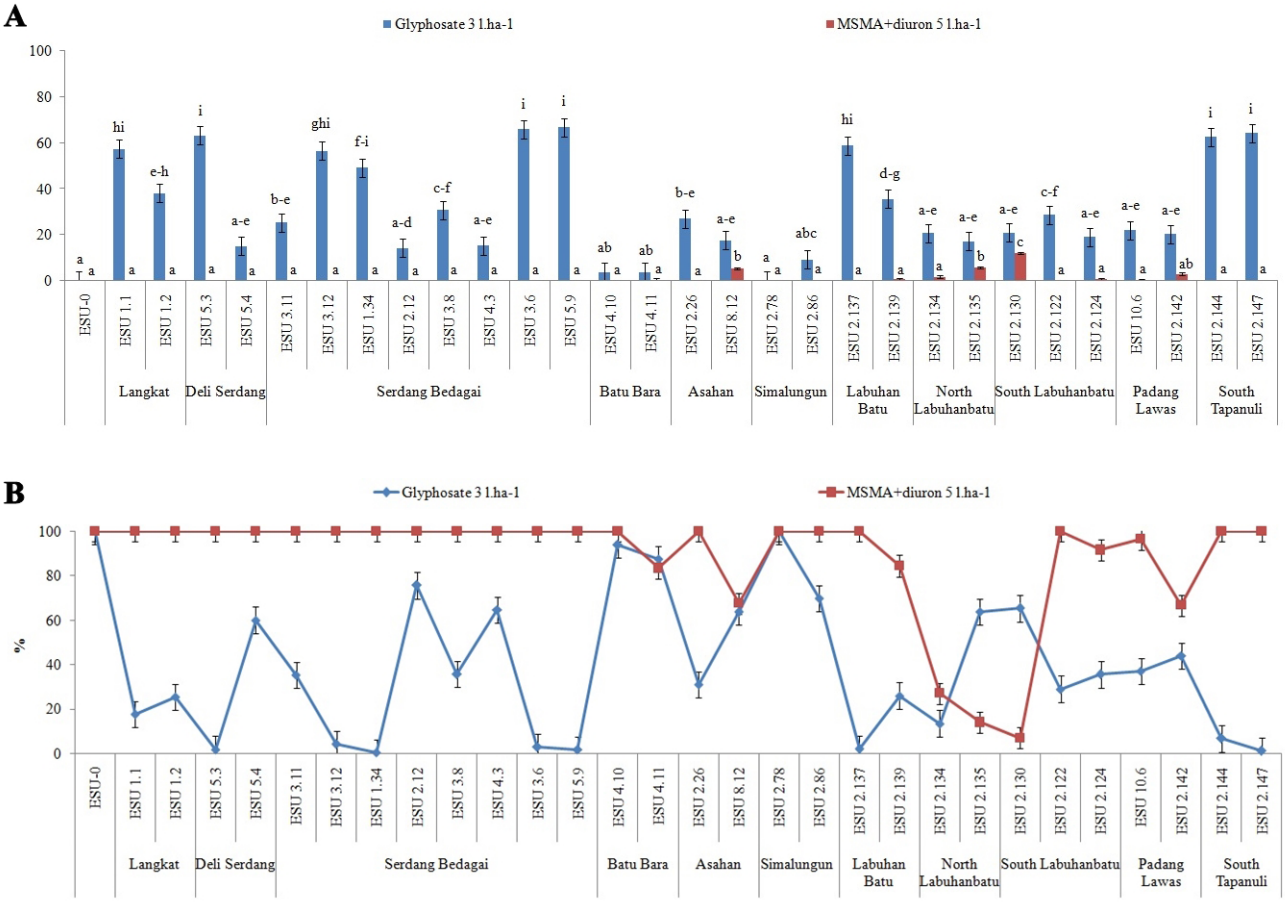

Fig. 3. GR-ESU biotypes tillers (A) and controlling tillers of non-spraying (B) on glyphosate- and MSMA+diuron-sprayed at oil palm plantations in North Sumatra at 6 WAS. Vertical bars indicate ± SE. Different lowercase letters mean significant difference byDMRT at *P*<0.05

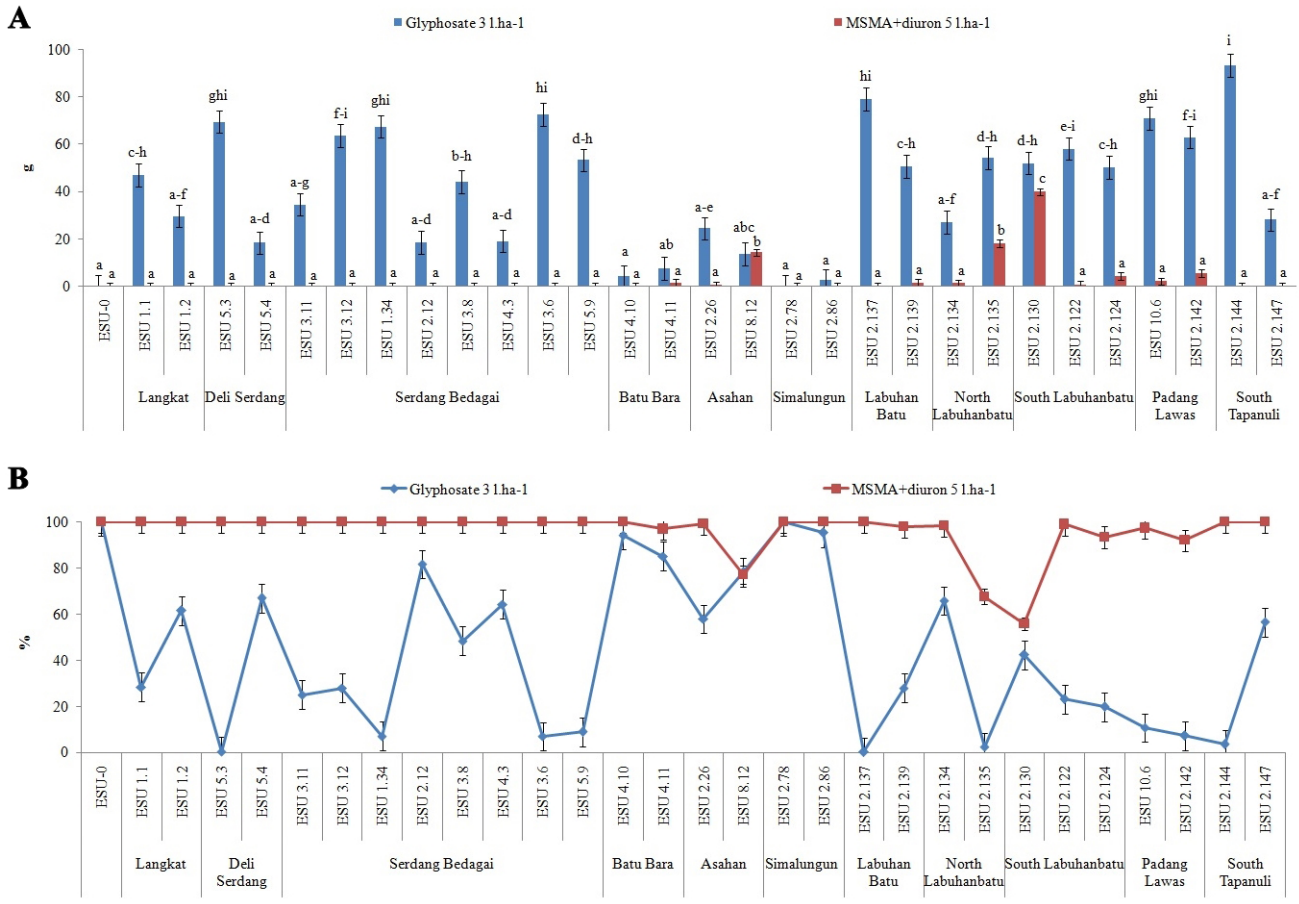

Fig. 4. The fresh weight of GR-ESU biotypes (A) and controlling of non-spraying (B) on glyphosate- and MSMA+diuron-sprayed at oil palm plantations in North Sumatra at 6 WAS. Vertical bars indicate ± SE. Different lowercase letters mean significant difference by DMRT at $P<0.05$

the MSMA+diuron up to 66.88%. According to Takano et al. (2016) *E. indica* could produce seeds at 38 DAE, and the number of seeds/plant continued to increase until the end of the life cycle, and each species produced a number of seeds that continued to increase through a period at least 70 days.

GR-ESU Toxicity Assessment

The MSMA+diuron at the dose 5 l.ha^{-1} significantly changed the leaf color such as leaf green loss/chlorosis of GR-ESU biotypes at 3 to 21 DAS (Table 3).

The MSMA+diuron herbicide showed significant toxicity in 5 of 29 GR-ESU at 3 DAS and the highest was 25 of 29 GR-ESU at 7 DAS, meanwhile 23 of 29 GR-ESU at 21 DAS. The glyphosate herbicide significantly changed the leaf color in ESU-0 (susceptible population) compared to other GR-ESU biotypes. It was linear with the visual observation, the use of glyphosate-sprayed did not show chlorosis symptoms (Figure 2). The GR-ESU biotypes leaf showed a yellowish-green until yellow in overall at glyphosate-sprayed, meanwhile MSMA+diuron presented a brownish-yellow, shrunken leaf and caused death at 7 DAS. Based on the visual observations at 21 DAS, GR-ESU biotypes that survived in glyphosate-sprayed showed that the leaf color returns to green and was marked by tillers from the stem, meanwhile MSMA+diuron showed that overall death. The survival of GR-ESU decreased at the change MoA herbicide from glyphosate to be MSMA+diuron. It was the circumstance that can be seen from biotypes that were first classified as glyphosate-resistant extremely to be mixture-resistant or glyphosate-resistant to be mixture-developing resistant. The finding suggests that the use of MSMA+diuron could be due to the delay and breakdown

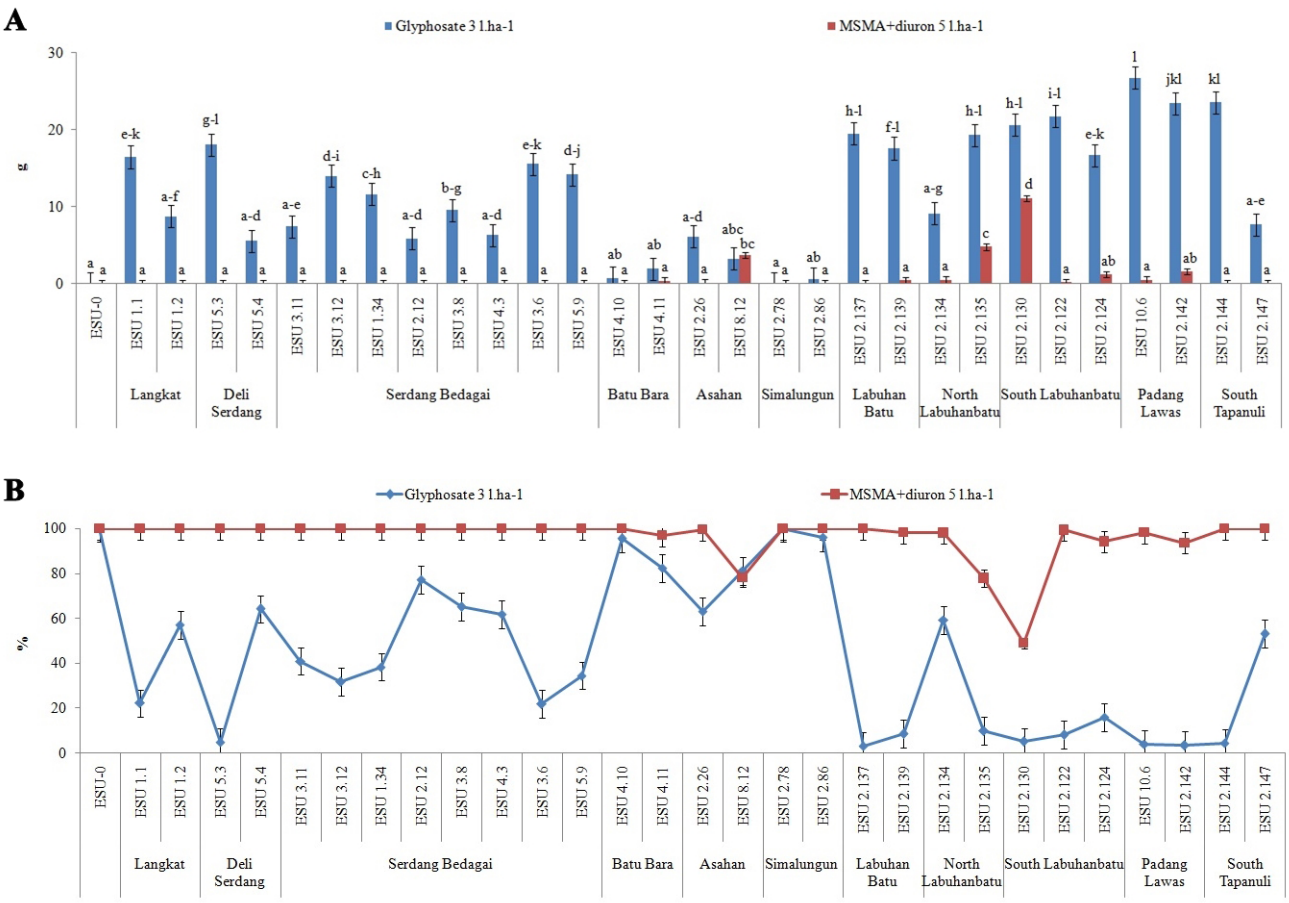

Fig. 5. The dryweight of GR-ESU biotypes (A) and controlling of non-spraying (B) on glyphosate- and MSMA+diuron-sprayed at oil palm plantations in North Sumatra at 6 WAS. Vertical bars indicate ± SE. Different lowercase letters mean significant difference by DMRT at *P*<0.05

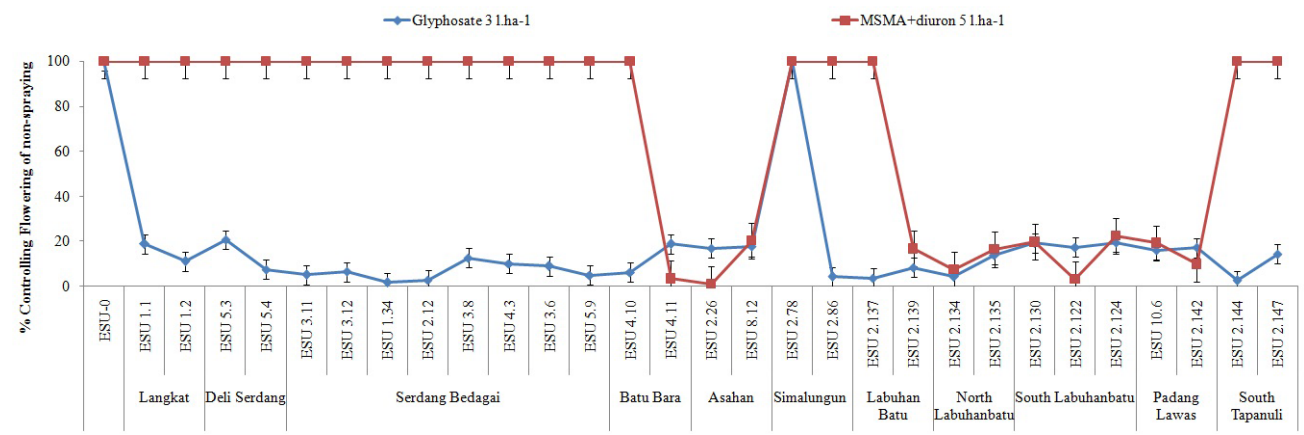

Fig. 6. Controlling flowering of GR-ESU biotypes on glyphosate- and MSMA+diuron-sprayed at oil palm plantations in North Sumatra. Vertical bars indicate ± SE

Table 3. The GR-ESU toxicity assessment on glyphosate and MSMA+diuron sprayed at 3, 7, and 21 DAS at oil palm plantations in North Sumatra

Districts	Biotypes	3 DAS		7 DAS		21 DAS	
		Glyphosate 3 l.ha^{-1}	MSMA+diuron 5 l.ha^{-1}	Glyphosate 3 l.ha^{-1}	MSMA+diuron 5 l.ha^{-1}	Glyphosate 3 l.ha^{-1}	MSMA+diuron 5 l.ha^{-1}
Medan City	ESU-0	0.00 ns	3.00 a	3.25 a	4.00 a	4.00 a	4.00 a
Langkat	ESU 1.1	0.00 ns	2.50 abc	0.25 i	3.75 a	0.00 g	4.00 a
	ESU 1.2	0.00 ns	2.25 abcd	0.50 hi	4.00 a	0.75 g	4.00 a
Deli Serdang	ESU 5.3	0.00 ns	2.75 ab	0.25 i	4.00 a	0.50 g	4.00 a
	ESU 5.4	0.00 ns	2.25 abcd	1.75 cdef	4.00 a	2.50 cd	4.00 a
Serdang Bedagai	ESU 3.11	0.00 ns	2.25 abcd	1.75 cdef	4.00 a	2.75 bcd	4.00 a
	ESU 3.12	0.00 ns	2.75 ab	0.75 ghi	4.00 a	1.25 efg	4.00 a
	ESU 1.34	0.00 ns	2.50 abc	1.50 defg	4.00 a	2.25 cde	4.00 a
	ESU 2.12	0.00 ns	2.75 ab	2.25 bcd	4.00 a	2.75 bcd	4.00 a
	ESU 3.8	0.00 ns	3.00 a	2.00 bcde	4.00 a	2.75 bcd	4.00 a
	ESU 4.3	0.00 ns	2.75 ab	1.75 cdef	4.00 a	2.00 def	4.00 a
	ESU 3.6	0.00 ns	2.50 abc	0.75 ghi	4.00 a	0.50 g	4.00 a
	ESU 5.9	0.00 ns	3.00 a	0.50 hi	4.00 a	0.75 g	4.00 a
Batu Bara	ESU 4.10	0.00 ns	2.50 abc	2.50 abc	4.00 a	3.75 ab	4.00 a
	ESU 4.11	0.00 ns	2.75 ab	2.25 bcd	3.75 a	3.25 abc	3.75 a
Asahan	ESU 2.26	0.00 ns	2.50 abc	1.25 efgh	3.50 a	1.00 fg	3.50 ab
	ESU 8.12	0.00 ns	2.00 bcd	2.00 bcde	2.75 b	2.50 cd	2.75 bc
Simalungun	ESU 2.78	0.00 ns	3.00 a	2.75 ab	4.00 a	4.00 a	4.00 a
	ESU 2.86	0.00 ns	2.50 abc	2.50 abc	4.00 a	3.25 abc	4.00 a
Labuhan Batu	ESU 2.137	0.00 ns	2.75 ab	1.50 defg	4.00 a	1.25 efg	4.00 a
	ESU 2.139	0.00 ns	2.50 abc	0.75 ghi	3.75 a	1.00 fg	3.75 a
North Labuhanbatu	ESU 2.134	0.00 ns	2.75 ab	1.75 cdef	3.75 a	2.50 cd	3.75 a
	ESU 2.135	0.00 ns	2.25 abcd	0.25 i	2.25 bc	0.00 g	2.75 bc
South Labuhanbatu	ESU 2.130	0.00 ns	1.50 d	0.00 i	1.75 c	0.00 g	2.25 c
	ESU 2.122	0.00 ns	2.75 ab	0.00 i	3.75 a	0.00 g	3.75 a
	ESU 2.124	0.00 ns	2.50 abc	0.00 i	3.50 a	0.00 g	3.50 ab
Padang Lawas	ESU 10.6	0.00 ns	2.75 ab	0.00 i	3.75 a	0.00 g	3.75 a
	ESU 2.142	0.00 ns	1.75 cd	1.00 fghi	2.50 b	0.75 g	2.50 c
South Tapanuli	ESU 2.144	0.00 ns	3.00 a	1.25 efgh	4.00 a	0.50 g	4.00 a
	ESU 2.147	0.00 ns	3.00 a	0.50 hi	4.00 a	0.25 g	4.00 a

Note: Different lowercase letters mean significant difference by DMRT at $P < 0.05$.ns= not significant

of GR-ESU biotypes at oil palm plantations in North Sumatra Province. Refer to three GR-ESU biotypes that were classified as mixture-resistant herbicides or 10.34%, eight GR-ESU biotypes were classified as mixture-developing resistant or 27.59% and the residual were classified as mixture-susceptible of 62.07% (Table 2). MSMA+diuron caused inhibition cell division and photosystem II of GR-ESU biotypes with lower survival compared to glyphosate (Figure 1). The continuous use of glyphosate at oil palm plantations will result in evolution resistance of *E. indica* biotypes. According to Monaco et al., (2002) MSMA could induce foliar chlorosis followed by gradual tissue browning, and finally necrosis.Tampubolon et al. (2019b) reported that the rotation mode of action herbicide using glufosinate-ammonium and triclopyr had significantly decreased SPAD value in biotype 12 (glyphosate-resistant *E. indica* biotypes) at 1 until 14 DAS compared to glyphosate was unable to decrease SPAD value.

Conclusion

Survival of GR-ESU biotypes decreased at the changes mode of action herbicide from glyphosate to MSMA+diuron at oil palm plantations in North Sumatra. The MSMA+diuron

significantly changed the leaf color in GR-ESU such as leaf green loss/chlorosis at 3 until 21 DAS. The ability of MSMA+diuron at the dose 5 $l.ha^{-1}$ was completely (100%) controlled within 18 of 29 GR-ESU biotypes and effectively controlled the tillers, flowering, fresh- and dry weight of 87.53%; 66.88%; 95.66%; and 95.92%, respectively compared to glyphosate at the dose 3 $l.ha^{-1}$. The management of GR-ESU biotypes with MSMA+diuron as an alternative action herbicide was greatly recommended for oil palm estate in North Sumatra.

Acknowledgments

The authors would like to thank PMDSU in 2015 from Ministry of Research, Technology & Higher Education, Republic of Indonesia for funding this research and Faculty of Agriculture, Universitas Sumatera Utara, and also oil palm plantations in North Sumatra Province for supporting this research activity.

References

Dalimunthe, S. P., Purba, E. & Meiriani. (2015). Dose response of glyphosate-resistant goosegrass (*Eleusine indica* L. Gaertn) biotype to glyphosate, paraquat, and indaziflam. *Jurnal Online Agroekoteknologi*, *3(2),* 625–633.

Hess, M., Barraljs, G., Bleiholder, H., Buhr, L., Eggers, T., Hack, H. & Stauss, R. (1997). Use of the extended BBCH scale-general for the descriptions of the growth stages of mono and dicotyledonous weed species. *Weed Research*, *37(6),* 433–441. https://doi.org/10.1046/j.1365-3180.1997.d01-70.x.

Ismail, B. S., Chuah, T. S., Salmijah, S., Teng, Y. T. & Schumacher, R. W. (2002). Germination and seedling emergence of glyphosate-resistant and susceptible biotypes of goosegrass (*Eleusine indica* [L.] Gaertn.). *Weed Biology and Management, 2(4),* 177–185. https://doi.org/10.1046/j.1445-6664.2002.00066.x

Jalaludin, A., Yu, Q. & Powles, S. B. (2015). Multiple resistance across glufosinate, glyphosate,paraquat and ACCase-inhibiting herbicides in an*Eleusine indica*population. *Weed Research*, *55(1)*, 82–89. https://doi.org/10.1111/wre.12118.

Lubis, L. A., Purba, E. & Sipayung, R. (2012). Dose response of glyphosate-resistant *Eleusine indica* biotype to glyphosate, paraquat, and glufosinate. *Jurnal Online Agroekoteknologi*, *1(1)*, 109-123.

Mohamad, R.B., Wibawa, W., Mohayidin, M.G., Puteh, A.B., Juraimi, A.S., Awang, Y.& Lassim, M.B.M.(2010).Management of mixed weeds in young oil-palm plantation with selected broad-spectrum herbicides. *Pertanika Journal of Tropical Agricultural Science*, *33(2),*193-203.

Monaco, J. T., Weller, C. S. & Ashton, M. F. (2002). Weed science principles and practices, 4th Edition. John Wiley & Sons. Inc., New York.

Owen, M. J. & Powles, S. B. (2009). Distribution and frequency of herbicide-resistant wild oat (*Avena* spp.) across the Western Australian grain belt. *Crop and Pasture Science*, *60(1),* 25–31. https://doi.org/10.1071/CP08178.

Rusli, M. H., Seman, I. A., Kamarudin, N. & Chuan, S. K. (2014). The combination effect of MSMA and Diuron (MON-EX HC) in controlling glyphosate resistant *Eleusine indica* in oil palm plantation. *The Planter*, *90(1064),* 801-815.

Sim, K. C., Tan, S. H. A., Wong, K. J. & Chuah, T. S. (2018). Efficacy of MSMA based premix herbicides on control of goosegrass (*Eleusine indica*) that evolved resistance across glyphosate, glufosinate and fluazifop. *The Planter*, *94(1102),* 13-20.

Syahputra, A. B., Purba, E. & Hasanah, Y. (2016). Distribution of herbicide multiple resistant *Eleusine indica* L. Gaertn. an oil palm estate in North Sumatera. *Jurnal Online Agroekoteknologi*, *4(4),* 2407-2419.

Takano, H. K., Oliveira, J. R. S., Constantin, J., Braz, G. B. P. & Padovese, J. C. (2016). Growth, development and seed production of goosegrass. *Planta Daninha*, *34(2),* 249–258. https://doi.org/10.1590/s0100-83582016340200006

Tampubolon, K. & Purba, E. (2018). Screening single resistance of *Eleusine indica* on oil palm plantation in Padang Lawas and Tapanuli Selatan Regency Indonesia. *Jurnal Natural*, *18(2)*, 101–106. https://doi.org/10.24815/jn.v18i2.11223

Tampubolon, K., Purba, E., Basyuni, M. & Hanafiah, D. S. (2019a). Glyphosate resistance of *Eleusine indica* populations from North Sumatra, Indonesia. *Biodiversitas Journal of Biological Diversity*, *20(7),* 1910–1916. https://doi.org/10.13057/biodiv/d200717

Tampubolon, K., Purba, E., Basyuni, M. & Hanafiah, D. S. (2019b). Histological, physiological and agronomic characters of glyphosate-resistant *Eleusine indica* biotypes. *International Journal of Agriculture and Biology, 22(6),* 1636–1644. https://doi.org/10.17957/IJAB/15.1245

Zhang, C., Feng, L., He, T. T., Yang, C. H., Chen, G. Q. & Tian, X. S. (2015). Investigating the mechanisms of glyphosate resistance in goosegrass (*Eleusine indica*) population from South China. *Journal of Integrative Agriculture*, *14(5),* 909-918. https://doi.org/10.1016/S2095-3119(14)60890-X.

Received: July, 24, 2019; *Accepted:* August, 22, 2019; *Published:* October, 31, 2020