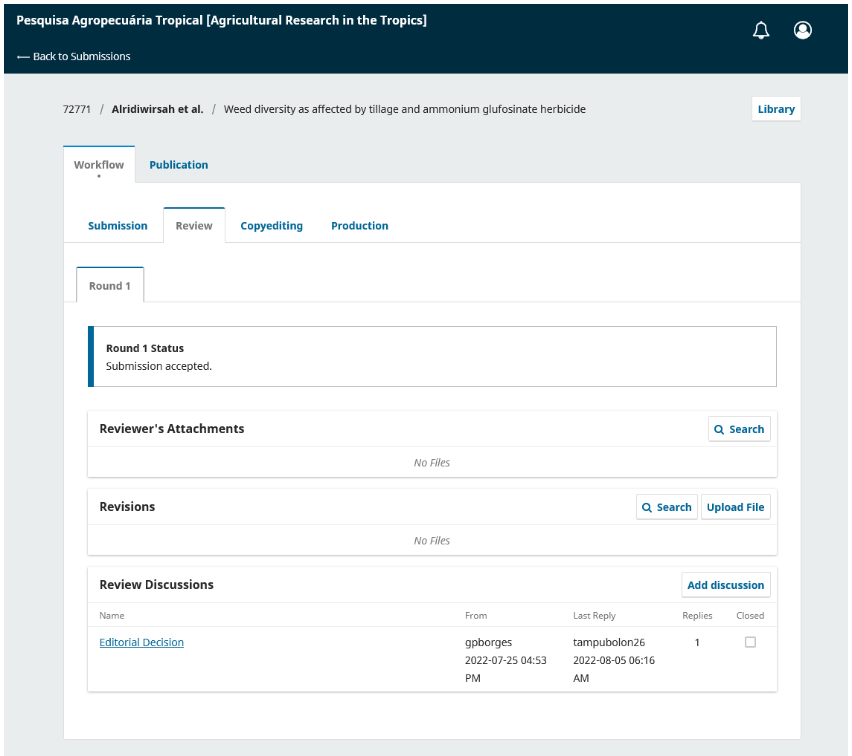
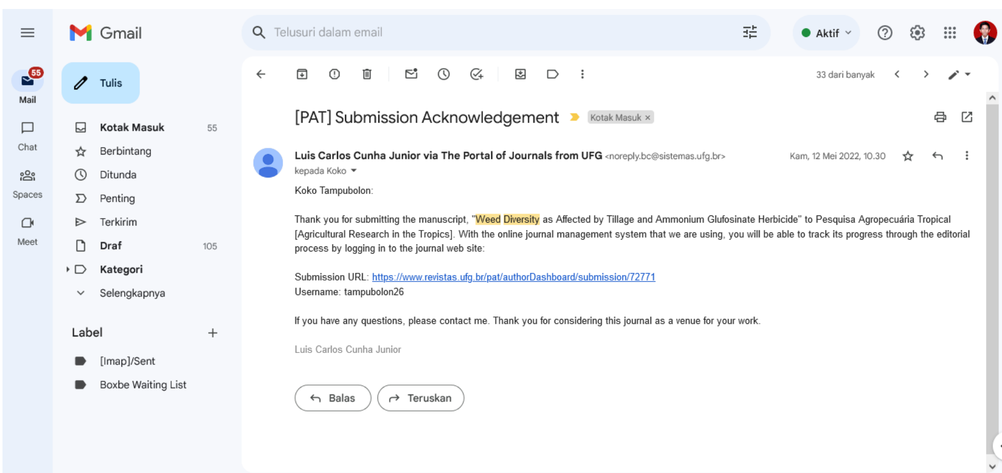
Weed diversity as affected by tillage and ammonium glufosinate herbicide.





Weed Diversity as Affected by Tillage and Ammonium Glufosinate Herbicide Kotak Masuk

GILSON PEDRO BORGES <gpborges@ufg.br> Sel, 26 Jul 2022, 02.53
kepada koko.tampubolon, alridiwirsah

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Best wishes,

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Thank you for collaborating with the PAT journal!

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Gilson P. Borges
Assistant Editor
Pesquisa Agropecuaria Tropical

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Research Article

Weed Diversity as Affected by Tillage and Ammonium Glufosinate Herbicide

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ABSTRACT

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage. It was conducted on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan City, Indonesia, from March to July 2021. Furthermore, a non-factorial Randomized Block Design was used consisting of the no-tillage (NT), 1-time tillage (T1), and 2-times tillage (T2) with three replications. The procedures include identifying weed vegetation, sampling analysis of several soil chemical properties, and spraying the ammonium glufosinate herbicide at a dose of 150 g ai.ha^{-1}. Based on the result, the weed species of *Cyperus rotundus* and *Ageratum conyzoides* were dominant in different tillage with a moderate diversity index. The T2 showed increased *A. conyzoides, Cynodon dactylon,* and *Euphorbia heterophylla* compared to NT, while a decrease was observed in the grasses weed during one and 2-times tillage. Moreover, there was a positive and significant correlation between *E. heterophylla* weed on the soil cation exchange capacity (0.727). In contrast, four new weed species, namely *Glyceria maxima*, *Leersia oryzoides*, *Scoparia dulcis*, and *Anthoxanthum oculatum* were found due to ammonium glufosinate herbicide in different tillage.

Keywords: correlation; diversity index; dominance; tillage; weed abundance

Diversidad de malezas afectadas por labranza y por el herbicida glufosinato de amonio

RESUMO

Los agricultores de Indonesia suelen rociar herbicidas para controlar las malas hierbas y utilizar la labranza durante las primeras etapas del cultivo; en consecuencia, estas actividades afectan a la composición y diversidad de las malas hierbas. Por lo tanto, los objetivos de este estudio fueron: (1) informar el índice de dominancia y diversidad de malezas debido a la labranza, (2) obtener correlaciones de la abundancia de malezas en varias características químicas del suelo debido a la labranza, (3) obtener el efecto del herbicida glufosinato de amonio en la abundancia de malezas en diferentes labranzas. Se llevó a cabo en tierras de cultivo en Padang Bulan, subdistrito de Medan Selayang, Medan, Indonesia, de marzo a julio de 2021. Además, se utilizó un diseño de bloques aleatorios no factorial que consistía en la no labranza (NT), la labranza de 1 vez (T1) y la labranza de 2 veces (T2) con tres repeticiones. Los procedimientos incluyen la identificación de la vegetación de malas hierbas, el análisis de muestras de varias propiedades químicas del suelo y la pulverización del herbicida glufosinato de amonio a una dosis de 150 g ai.ha-1. Según los resultados, las especies de malas hierbas

Cyperus rotundus y *Ageratum conyzoides* fueron dominantes en las diferentes labranzas con un índice de diversidad moderado. El T2 mostró un aumento de *A. conyzoides*, *Cynodon dactylon* y *Euphorbia heterophylla* en comparación con el NT, mientras que se observó una disminución de las malas hierbas durante el laboreo uno y dos veces. Además, hubo una correlación positiva y significativa entre la maleza *E. heterophylla* en la capacidad de intercambio catiónico del suelo (0.727). Por el contrario, se encontraron cuatro nuevas especies de malas hierbas, a saber, *Glyceria maxima, Leersia oryzoides, Scoparia dulcis* y *Anthoxanthum oculatum*, debido al herbicida glufosinato de amonio en diferentes labranzas.

Palabras clave: correlación; índice de diversidad; dominancia; labranza; abundancia de malas hierbas

INTRODUCTION

Uncontrolled weeds on farmlands reduce production up to 80% (Cousens & Mortimer, 1995). Therefore, sustainable agricultural practices affect its abundance and density. The weed abundance in the farmland is influenced by several factors such as seed bank buried in the soil (Norris 2007), environmental factors (Fried et al. 2008; Pinke et al. 2012), availability of nutrients and fertilization (Murphy & Lemerle 2006; Chemona et al. 2016), tillage and crop rotation (Ulber et al. 2009; Nichols et al. 2015), and weed control through herbicides (Derksen et al. 1995).

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Menalled et al. (2001) showed that different agricultural management systems significantly affect weed abundance, diversity, and consistency in the short and long term. Meanwhile, Derksen et al. (1995) reported that the germination of *Synapsis avensis* and *Brassica napus* weeds after spraying with herbicides was higher in the no-tillage, but there was a reduction in total weeds. Thomas et al. (2004) also reported perennial weed species such as *Cirsium arvense* and *Sonchus arvensis* was reduced tillage and no-tillage, while annual weeds were found in various tillage treatments. In addition, Trichard et al. (2013) stated that tillage favors weed seed bank germination and cause the extinction of other seeds.

On the other hand, different soil fertility in the planted area also affects the weed diversity (Yin et al. 2006). Fonge et al. (2013) reported that weed diversity is affected by organic-C content, nitrogen, calcium, and cation exchange capacity of the soil. Tang et al. (2014a) added that phosphorus+potassium (PK) fertilization increases the density of *Galium aparine, Vicia sativa, Veronica persica*, and *Geranium carolinianum* weeds compared to nitrogen+phosphorus (NP). Furthermore, Forcella et al. (2000) stated that the soil N concentration plays an important role in ending dormancy by removing germination constraints and stimulating seedling emergence. Tang et al. (2014b) reported that soil available-P is the primary nutrient, regulating the composition of weed species and diversity, followed by N and K nutrients.

The knowledge of farmers on the relationship between tillage and soil fertility status with weed diversity is relatively poor. The interviews conducted in this study showed that the farmers only carry out land clearing and manual tillage before planting, had never used herbicides, and unknowingly the soil fertility status. However, a new problem was found: weed growth was very rapid in a short time (2 days). Therefore, intensive control during one main crop cycle is highly needed. This problem persisted during crop rotation. Unnoticed by farmers, these activities impact the storage of the weed seed bank, and the tillage carried out, resulting in the weed seed bank at a certain depth of soil emerging to the soil surface. Studies on weed identification are needed to provide information on the relationship between soil fertility on the dominant weeds and the use of one herbicide with a recommended dose to suppress the presence of weeds. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage.

MATERIAL AND METHODS

Area and plot of the tillage

This study was carried out on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan (Indonesia) with the condition of continuous land use and a history of crop rotation for the last two years for corn, cucumber, and cowpea as well as manual tillage using a hoe, without the use of herbicides based on interviews with farmers. This study was conducted from March to July 2021. The land was cleared and then plotted with the square method of 1 m × 1 m and an interval of 2 m. Each plot was demarcated with plastic ropes at a distance of 0.2 m (Fig. 1).

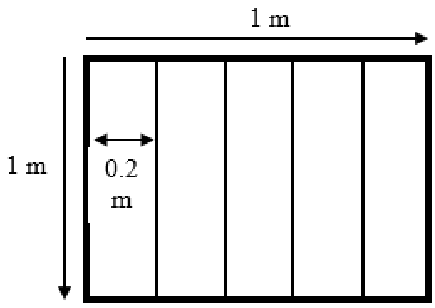

Figure 1. The size of plots with the square method.

Weed analysis

This study used a non-factorial Randomized Block Design with three replications: no-tillage, 1-time and 2-times tillage systems. Tillage was carried out by hoeing as deep as 20 cm. Meanwhile, the land was incubated for a month and then identified for weed vegetation using the flora book and applying formulas according to Kent (2012) such as absolute density (defined as the number of individual weed species in the sample plot), relative density, absolute frequency (defined as the number of sample plots containing certain species), relative frequency, importance value, and the summed dominance ratio (SDR) as shown in equation 1-4.

$$\text{Relative Density (RD)} = \frac{\text{The absolute density of a certain species}}{\text{Total absolute density of all species}} \times 100\% \quad (1)$$

$$\text{Relative Frequency (RF)} = \frac{\text{The absolute frequency of a certain species}}{\text{Total absolute frequencies of all species}} \times 100\% \quad (2)$$

$$\text{Importance Value (IV)} = \text{Relative Density (RD)} + \text{Relative Frequency (RF)} \quad (3)$$

$$\text{Summed Dominance Ratio} = \frac{\text{Relative Density (RD)} + \text{Relative Frequency (RF)}}{2} \quad (4)$$

Weed populations based on morphology (broadleaf, grasses, sedges) and total weeds were calculated. The species diversity index was calculated using the Shannon-Wiener index formula (Shannon & Weaver 1949):

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right) \left(\ln \frac{ni}{N}\right)$$

Note:

H'= Species diversity index

ni = The proportion of species *i*

N = The total number of species

ln = natural logarithm

The classification of the diversity index value for each tillage was conducted based on Magurran (1988) stated that if H'<1 (low), 1<H'<3 (moderate) and H'>3 (high).

Correlation of organic-C and cation exchange capacity on dominant weeds

Soil samples at a depth of 0-20 cm were taken using a drill with a diagonal method on each plot. Then it performed analysis on organic-C (Walkley & Black method) and cation exchange capacity/CEC (ammonium acetate pH 7) using a spectrophotometer at Socfin Indonesia Inc., Medan (Indonesia). At first, a natural logarithm was carried out on the organic-C, CEC data, and the total of dominant weeds as well as analyzed using the Pearson correlation.

Application of the ammonium glufosinate herbicide and data processing

The ammonium glufosinate herbicide was applied on 27 April 2021 at 10.00 to all plots at a dose of 150 g a.i.ha^{-1} after a spray calibration was carried out. Climatic data were recorded during spraying, such as temperature 28°C, humidity 83%, and air pressure 1002 hPa. Weed survival data were measured at six weeks after spraying (WAS).

$$\text{The spray volume calibration} = \frac{\text{Land area per ha}}{\text{Length} \times \text{width of spray}} \times \text{water used} = 202.90 \text{ L ha}^{-1}$$

$$\text{Ammonium glufosinate} = \frac{\text{Ammonium glufosinate dose per ha}}{\text{The spray volume calibration}} = 4.93 \text{ ml L}^{-1}$$

The data of weeds (broadleaf, grasses, sedges, total) and soil (organic-C, CEC) were processed using ANOVA and followed by DMRT level 5% using IBM SPSS v.20 software.

RESULTS AND DISCUSSION

Weed diversity due to tillage

The field observations obtained 16 species (*Ageratum conyzoides, Asystasia gangetica, Axonopus compressus, Borreria alata, Brachiaria mutica, Cleome rutidosperma, Cynodon dactylon, Cyperus rotundus, Eleusine indica, Euphorbia heterophylla, Galinsoga parviflora, Mimosa pudica, Oxalis corniculata, Pennisetum purpureum, Polanisia icosandra,* and *Stylochaeton lancifolius*) with 6639 populations from three tillage systems (NT, T1, T2) as presented in Fig. 2. The result showed that three dynamic patterns due to tillage, such as (1) an increase in the weed diversity due to 2-time tillage for *A. conyzoides, C. dactylon,* and *E. heterophylla,* (2) a decrease in weed diversity due to 2-time tillage for *A. gangetica, A. compressus, B. alata, C. rutidosperma,* and *E. indica,* (3) a fluctuating pattern, indicating a decrease in weed species in 1-time tillage and then an increase in 2-time tillage or vice versa for *B. mutica, G. parviflora, M. pudica, O. corniculata, P. purpureum, P. icosandra,* and *S. lancifolius.*

Weed population due to tillage based on morphology and total weed

The tillage had an insignificant effect on the number of broadleaf, grasses, sedges, and total weeds (Fig. 3). However, increasing the tillage by 2-times (T2) increased the broadleaf population and total weeds by 41.73% and 25.19%, respectively, compared to no-tillage (NT).

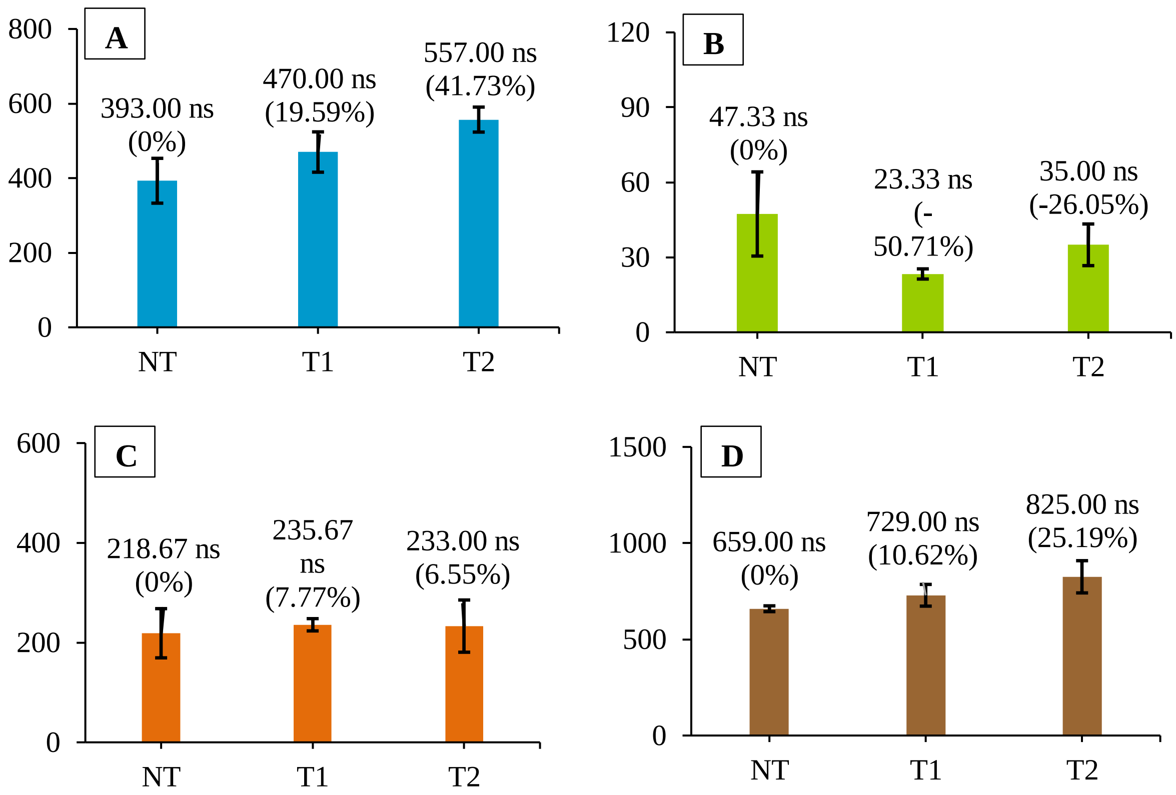

Figure 3. Weed populations based on morphology (A= broadleaf; B= grasses; C= sedges) and total weeds (D) due to tillage (NT=no tillage, T1= 1-time tillage, T2= 2-times tillage). The values followed by the ns (not-significant) in the graph are not significantly different at the 5% level based on the DMRT. The vertical line shows the standard error.

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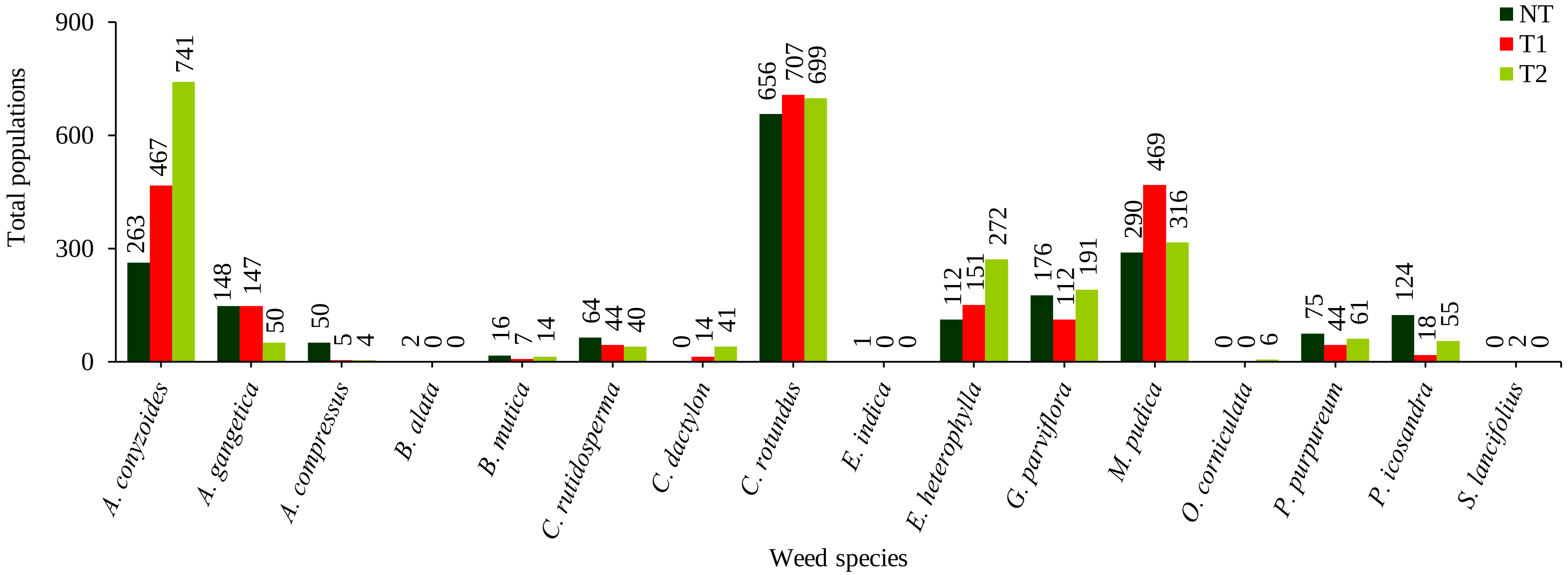


207 Figure 2. Total populations of weeds due to tillage. NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage.

Furthermore, the population of sedges weeds increased at 1-time tillage (T1) by 7.77% compared to NT and decreased to 6.55% at 2-times tillage (T2). The population of grasses weeds experienced the highest decrease in 1-time tillage (T1) of 50.71% compared to NT.

SDR and weed diversity index due to tillage

The dominant weeds (SDR) and diversity index due to tillage are presented in Tab. 1-2. In the no-tillage (NT) treatment found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *C. rutidosperma*, and *P. icosandra* of 22.78%; 13.37%; 12.50%; 10.90%; and 10.49%, respectively. In the 1-time tillage (T1) found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *A. gangetica*, and *E. heterophylla* of 22.61%; 16.42%; 16.41%; 10.87%; and 9.63%, respectively. Moreover, in the 2-times tillage (T2) also found in five species with the highest SDR sequentially were *A. conyzoides*, *C. rotundus*, *M. pudica*, *E. heterophylla*, and *G. parviflora* by 22.20%; 18.76%; 12.67%; 11.36%; and 9.90%, respectively. The diversity index (H') due to tillage (NT, T1, T2) were 2.261; 2.196 and 2.234 respectively, therefore it was moderate.

Correlation of organic-C and cation exchange capacity on dominant weeds

The tillage significantly increased cation exchange capacity (CEC) but it had insignificant effect on soil organic-C (Fig. 4). There was an increase in the CEC due to T1 and T2 by 16.56% and 13.14%, respectively. The correlation analysis of soil organic-C and CEC on the dominant weed population due to tillage is presented in Tab. 3. The results showed that only CEC had a significant and positive correlation in increasing the *E. heterophylla* by 0.727, but it was insignificant for *C. rotundus* and *C. rutidosperma*. Similarly, soil organic-C had an insignificant effect but was positively correlated to the population of *C. rotundus*, *A. conyzoides*, *M. pudica*, and *E. heterophylla*.

Table 1. SDR of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage).

Weeds Species	Replicate 1						Replicate 2						Replicate 3					
	AD	RD	AF	RF	IV	SDR	AD	RD	AF	RF	IV	SDR	AD	RD	AF	RF	IV	SDR
NT= no-tillage																		
A. conyzoides	19	2.94	5	11.90	14.84	7.42	148	20.87	5	12.20	33.07	16.53	96	15.46	5	11.63	27.09	13.54
A. gangetica	58	8.96	5	11.90	20.87	10.43	48	6.77	5	12.20	18.97	9.48	42	6.76	5	11.63	18.39	9.20
A. compressus	-	-	-	-	-	-	-	-	-	-	-	-	50	8.05	4	9.30	17.35	8.68
B. alata	-	-	-	-	-	-	2	0.28	1	2.44	2.72	1.36	-	-	-	-	-	-
B. mutica	4	0.62	3	7.14	7.76	3.88	-	-	-	-	-	-	12	1.93	4	9.30	11.23	5.62
C. rutidosperma	64	9.89	5	11.90	21.80	10.90	-	-	-	-	-	-	-	-	-	-	-	-
C. rotundus	387	59.81	5	11.90	71.72	35.86	109	15.37	5	12.20	27.57	13.78	160	25.76	5	11.63	37.39	18.70
E. indica	-	-	-	-	-	-	1	0.14	1	2.44	2.58	1.29	-	-	-	-	-	-
E. heterophylla	20	3.09	4	9.52	12.61	6.31	92	12.98	5	12.20	25.17	12.59	-	-	-	-	-	-
G. parviflora	24	3.71	5	11.90	15.61	7.81	112	15.80	5	12.20	27.99	14.00	40	6.44	5	11.63	18.07	9.03
M. pudica	49	7.57	5	11.90	19.48	9.74	96	13.54	5	12.20	25.74	12.87	145	23.35	5	11.63	34.98	17.49
P. purpureum	22	3.40	5	11.90	15.31	7.65	10	1.41	4	9.76	11.17	5.58	43	6.92	5	11.63	18.55	9.28
P. icosandra	-	-	-	-	-	-	91	12.83	5	12.20	25.03	12.52	33	5.31	5	11.63	16.94	8.47

Total	647		42			100	709		41			100	621		43			100
T1= 1-time tillage																		
A. conyzoides	181	27.18	5	11.63	38.81	19.40	73	12.17	5	11.90	24.07	12.04	213	23.13	5	12.50	35.63	17.81
A. gangetica	82	12.31	5	11.63	23.94	11.97	-	-	-	-	-	-	65	7.06	5	12.50	19.56	9.78
A. compressus	-	-	-	-	-	-	5	0.83	2	4.76	5.60	2.80	-	-	-	-	-	-
B. mutica	-	-	-	-	-	-	4	0.67	2	4.76	5.43	2.71	3	0.33	1	2.50	2.83	1.41
C. rutidosperma	-	-	-	-	-	-	21	3.50	5	11.90	15.40	7.70	23	2.50	5	12.50	15.00	7.50
C. dactylon	5	0.75	3	6.98	7.73	3.86	9	1.50	4	9.52	11.02	5.51	-	-	-	-	-	-
C. rotundus	193	28.98	5	11.63	40.61	20.30	255	42.50	5	11.90	54.40	27.20	259	28.12	5	12.50	40.62	20.31
E. heterophylla	53	7.96	5	11.63	19.59	9.79	54	9.00	5	11.90	20.90	10.45	44	4.78	5	12.50	17.28	8.64
G. parviflora	22	3.30	5	11.63	14.93	7.47	36	6.00	5	11.90	17.90	8.95	54	5.86	5	12.50	18.36	9.18
M. pudica	87	13.06	5	11.63	24.69	12.35	137	22.83	5	11.90	34.74	17.37	245	26.60	5	12.50	39.10	19.55
P. purpureum	25	3.75	5	11.63	15.38	7.69	4	0.67	3	7.14	7.81	3.90	15	1.63	4	10.00	11.63	5.81
P. icosandra	18	2.70	5	11.63	14.33	7.17	-	-	-	-	-	-	-	-	-	-	-	-
S. lancifolius	-	-	-	-	-	-	2	0.33	1	2.38	2.71	1.36	-	-	-	-	-	-
Total	666		43			100	600		42			100	921		40			100
T2= 2-times tillage																		

A. conyzoides	146	15.57	5	11.36	26.93	13.46	256	47.67	5	11.90	59.58	29.79	339	33.90	5	12.82	46.72	23.36
A. gangetica	-	-	-	-	-	-	-	-	-	-	-	-	50	5.00	5	12.82	17.82	8.91
A. compressus	2	0.21	2	4.55	4.76	2.38	2	0.37	2	4.76	5.13	2.57	-	-	-	-	-	-
B. mutica	3	0.32	3	6.82	7.14	3.57	1	0.19	1	2.38	2.57	1.28	10	1.00	4	10.26	11.26	5.63
C. rutidosperma	24	2.56	5	11.36	13.92	6.96	16	2.98	5	11.90	14.88	7.44	-	-	-	-	-	-
C. dactylon	26	2.77	4	9.09	11.86	5.93	-	-	-	-	-	-	-	-	-	-	-	-
C. rotundus	304	32.41	5	11.36	43.77	21.89	53	9.87	5	11.90	21.77	10.89	342	34.20	5	12.82	47.02	23.51
E. heterophylla	178	18.98	5	11.36	30.34	15.17	43	8.01	5	11.90	19.91	9.96	51	5.10	5	12.82	17.92	8.96
G. parviflora	76	8.10	5	11.36	19.47	9.73	43	8.01	5	11.90	19.91	9.96	72	7.20	5	12.82	20.02	10.01
M. pudica	150	15.99	5	11.36	27.36	13.68	85	15.83	5	11.90	27.73	13.87	81	8.10	5	12.82	20.92	10.46
O.corniculata	-	-	-	-	-	-	6	1.12	4	9.52	10.64	5.32	-	-	-	-	-	-
P. purpureum	29	3.09	5	11.36	14.46	7.23	32	5.96	5	11.90	17.86	8.93	-	-	-	-	-	-
P. icosandra	-	-	-	-	-	-	-	-	-	-	-	-	55	5.50	5	12.82	18.32	9.16
Total	938		44			100	537		42			100	1000		39			100

Table 2. Diversity index of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage).

Family	Weeds Species	NT				T1				T2			
		ni	ni/N	ln ni/N	H’	ni	ni/N	ln ni/N	H’	ni	ni/N	ln ni/N	H
Asteraceae	*A. conyzoides*	25.00	0.125	-2.079	0.260	32.83	0.164	-1.807	0.297	44.41	0.222	-1.505	0.334
	G. parviflora	20.56	0.103	-2.275	0.234	17.07	0.085	-2.461	0.210	19.80	0.099	-2.313	0.229
Acanthaceae	*A. gangetica*	19.41	0.097	-2.333	0.226	14.50	0.072	-2.624	0.190	5.94	0.030	-3.517	0.104
Araceae	*S. lancifolius*	-	-	-	-	0.90	0.005	-5.398	0.024	-	-	-	-
Capparaceae	*C. rutidosperma*	7.27	0.036	-3.315	0.120	10.13	0.051	-2.982	0.151	9.60	0.048	-3.036	0.146
Capparidaceae	*P. icosandra*	13.99	0.070	-2.660	0.186	4.78	0.024	-3.735	0.089	6.11	0.031	-3.489	0.107
Cyperaceae	*C. rotundus*	45.56	0.228	-1.479	0.337	45.21	0.226	-1.487	0.336	37.52	0.188	-1.673	0.314
Euphorbiaceae	*E. heterophylla*	12.60	0.063	-2.765	0.174	19.26	0.096	-2.340	0.225	22.72	0.114	-2.175	0.247
Fabaceae	*M. pudica*	26.73	0.134	-2.013	0.269	32.84	0.164	-1.807	0.297	25.34	0.127	-2.066	0.262
Oxalidaceae	*O. corniculata*	-	-	-	-	-	-	-	-	3.55	0.018	-4.032	0.072
Poaceae	*A. compressus*	5.78	0.029	-3.543	0.102	1.87	0.009	-4.675	0.044	3.30	0.016	-4.105	0.068
	B. mutica	6.33	0.032	-3.453	0.109	2.75	0.014	-4.286	0.059	6.99	0.035	-3.354	0.117
	C. dactylon	-	-	-	-	6.25	0.031	-3.466	0.108	3.95	0.020	-3.924	0.078
	E. indica	0.86	0.004	-5.449	0.023	-	-	-	-	-	-	-	-

	P. purpureum	15.01	0.075	-2.590	0.194	11.61	0.058	-2.847	0.165	10.77	0.054	-2.921	0.157
Rubiaceae	*B. alata*	0.91	0.005	-5.396	0.024	-	-	-	-	-	-	-	-
	Total			-39.350	2.261			-39.915	2.196			-38.110	2.234

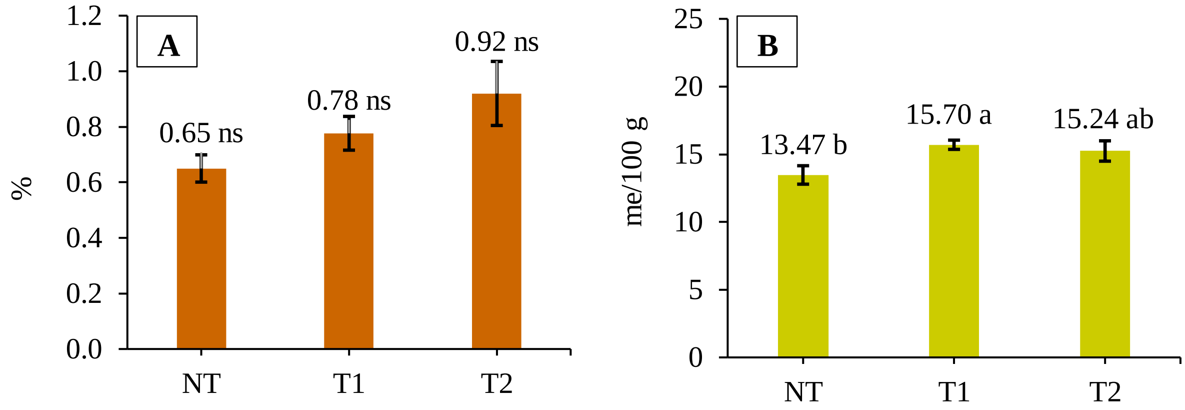


Figure 4. The soil organic-C (A) and cation exchange capacity (B) properties due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage). The values followed by the different letter in the graph are significantly at the 5% level based on the DMRT. The vertical line shows the standard error. ns= not-significant.

Table 3. Correlation analysis of organic-C and CEC of the soil on the dominant weed populations due to tillage.

Dominant weed species	Correlation coefficient	
	Organic-C	CEC
C. rotundus	0.449ns	0.262ns
A. conyzoides	0.132ns	-0.154ns
M. pudica	0.147ns	-0.054ns
E. heterophylla	0.127ns	0.727*
G. parviflora	-0.063ns	-0.240ns
A.gangetica	-0.298ns	-0.482ns
P. icosandra	-0.021ns	-0.646ns
C. rutidosperma	-0.095ns	0.591ns

Note: Correlation is significant at the 0.05 level (2-tailed). ns= not-significant.

Changes in weed vegetation due to the ammonium glufosinate

Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g ai.ha^{-1} on different tillage (NT, T1, T2) by species are presented in Fig. 5. The results showed an increase in *B. alata* and *B. mutica* due to the ammonium glufosinate in NT and 2-times tillage (T2). Meanwhile, others decreased, and two new weed species were found in NT, such as *Glyceria maxima* and *Leersia oryzoides*, and one new weed species were found in T2 (*G. maxima*). Similarly, the 1-time tillage (T1) increased *B. alata, B. mutica,* and *E. indica*. At the same time, other populations decreased, and four new weed species were found, namely *G. maxima, L. oryzoides, Scoparia dulcis,* and *Anthoxanthum oculatum*.

Based on morphology, the effectiveness of ammonium glufosinate on the weed-type abundance at different tillage (NT, T1, T2) is presented in Fig. 6. The herbicide application can decrease the abundance of broadleaf weeds by 82.13-84.98% and sedges by 8.15-19.05%. However, there was an increase in the grasses weed abundance in T1 and T2 tillage by 167.74% and 26.67%, respectively.

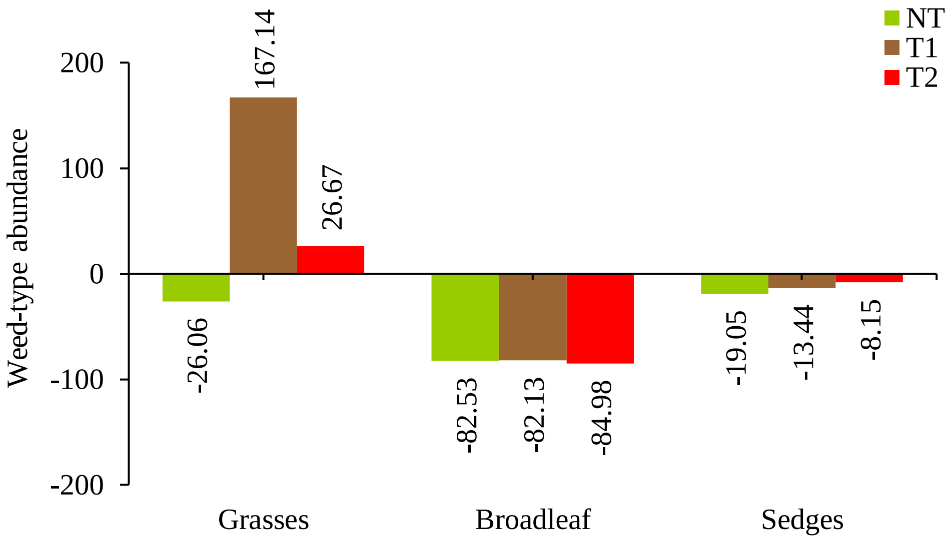
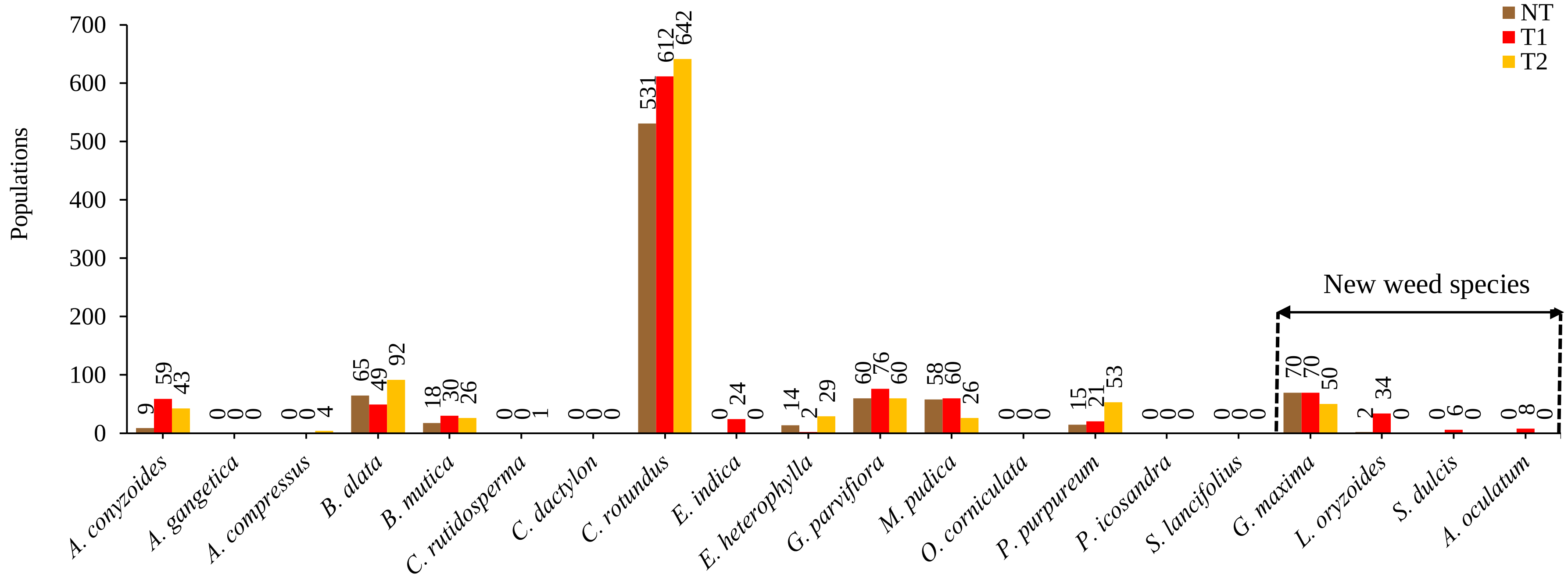


Figure 6. The effectiveness of ammonium glufosinate on the weed-type abundance at different tillage.



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262 Figure 5. Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g a.i.ha^{-1} on different tillage.

Effect of tillage on weed diversity

Based on the results, there were three dynamic patterns of weed diversity due to tillage, namely increasing, decreasing, and fluctuating patterns. The increasing weed species due to 2-times tillage (T2) include *A. conyzoides* (2.81-folds), *C. dactylon* (41 populations), and *E. heterophylla* (2.43-folds) compared to no-tillage (NT). It was caused by the seed banks of *A. conyzoides*, *C. dactylon*, and *E. heterophylla* during T2 tillage were triggered the emergence to the soil surface. Furthermore, soil fertility also supported its growth more rapidly. This was supported by the organic-C, which was positively correlated with the presence of *A. conyzoides* (0.132) and *E. heterophylla* (0.127). Besides, soil CEC was also significantly and positively correlated with the presence of *E. heterophylla* (0.727) (Tab. 3). These results are similar to Oziegbe et al. (2010); active weed seedbanks at deeper soil depths lead to lower oxygen availability and reduce the access to light required to support germination. In addition, Hossain et al. (2021) that the seed bank of *A. conyzoides* was not found at a depth of 0-10 cm, but 10-15 cm, and experienced an additional seed bank of 43.82% during conventional tillage. Horowitz (1972) reported that 88% of *C. dactylon* rhizomes were found at a depth of 30 cm. Ekeleme et al. (2019) added that *E. heterophylla* had the second-highest abundance of 19.53% after *Tridax procumbens* in Benue State, Nigeria.

SDR, diversity index, weed population due to tillage

The results showed that *C. rotundus* had the highest SDR in NT and T1 tillage, while *A. conyzoides* was dominant in T2 tillage. This was due to the presence of higher seed bank of *C. rotundus* and *A. conyzoides* at certain depths. Therefore, when the soil is tilled, the seedbanks trigger emergence on the soil surface. These results are similar to Hossain et al. (2021) which reported that up to 24% of the *C. rotundus* seed bank were found at a depth of 5-10 cm, while 21% of the *A. conyzoides* were found between 10-15 cm. Furthermore, Santín-Montanyá et al. (2013) reported that the weed abundance, diversity, and evenness were greatly increased in the no-tillage treatment. In this study, the results showed that the diversity index due to tillage (NT, T1, T2) was 2.261; 2.196; and 2.234 (moderate) (Tab. 2). The decrease in diversity index due to T1 and T2 compared to NT indicates that tillage decrease weed diversity. Mas & Verdú (2003) reported that the highest value of the Shannon-Wiener diversity index was found in the no-tillage treatment, while Amuri et al. (2010) suggested that no-tillage treatment contributes to the suppression of several weed species. Sepat et al. (2017) also reported that the lowest weed population was found in untilled beds.

The results showed that T2 tillage increased the broadleaf and total weeds. The population of sedges weeds increased at T1, but decreased during T2 tillage. In general, only grasses weeds decreased during T1 and T2 compared to NT, and the highest decrease was found at T1 tillage. This is linear with the Shannon-Wiener diversity index at T1, lower than other tillage (Tab. 2). These results are supported by Murphy et al. (2006) which reported that the weed density is only affected by tillage. Similarly, Hossain et al. (2021) said a decrease in the seed bank of grasses weed during conventional tillage by 76.31% at a depth of 0-5 cm compared to the no-tillage.

Correlation of organic-C and CEC to dominant weeds at different tillage

Cation Exchange Capacity (CEC) was significantly and positively correlated (0.727) with an increase in the population of *E. heterophylla*. The content of CEC and organic-C was also positively correlated but had an insignificant effect on the populations of *C. rotundus*, *C. rutidosperma*, *A. conyzoides*, and *M. pudica*. This was due to the higher content of CEC and organic-C in T1 and T2 compared to the NT (Fig. 4). When the weed seed bank at T1 and T2 emerged to the surface and received light and soil fertility than NT, it tends to support the growth of more weeds as indicated in the total weed population, which grows higher with increasing tillage (Fig. 3). These results are similar to Pätzold et al. (2020) which reported that soil organic-C affects weed species variability by 8.4%, while Gaston et al. (2001); Nordmeyer

& Häusler (2004); Korres et al. (2017) reported that organic carbon, texture, and nutrients of soil affect the emergence of weeds. Furthermore, Dorneles et al. (2015) reported that reduced tillage had a higher CEC than the no-tillage at 0-5 cm and 5-10 cm depths.

Changes in weed due to the ammonium glufosinate herbicide at different tillage

There was an increase in populations of *B. alata* (49), *B. mutica* (30), and *E. indica* (24) after spraying the ammonium glufosinate herbicide at a dose of 150 g ai.ha^{-1} with different tillage (NT, T1, T2), although *C. rotundus* (612) was more numerous than the other weeds. In general, four new weeds species, namely *G. maxima, L. oryzoides, S. dulcis,* and *A. oculatum* were found in NT, T1, and T2 due to the ammonium glufosinate herbicide. *Glyceria maxima* is a new weed species with the highest population in the NT, T1, and T2 tillage. Furthermore, the increase in population and new weed species was higher in the grasses weeds (*B. mutica, E. indica, G. maxima, L. oryzoides,* and *A. oculatum*) and two new species from the broadleaf weeds (*B. alata* and *S. dulcis*). Therefore, the ammonium glufosinate herbicide at different tillage decreased the abundance of broadleaf (Fig. 6) compared to the grasses weeds.

Using herbicides on tillage (T1 and T2) exposed the seed bank of grasses weeds to the soil surface to adequately obtain oxygen and light needed for growth. This is supported by Wibawa et al. (2009), which reported that the herbicide of dose 200 g.ha^{-1} significantly suppressed broadleaf of 94.68% compared to the grasses weeds by 59.65% at two weeks after spraying. Tampubolon et al. (2019) also found that the herbicide at a dose of 300 g ai.ha^{-1} significantly removed 100% of the glyphosate-susceptible *E. indica*, while Alridiwirsah et al. (2020) reported that the grasses was higher by 52.76% compared to the broadleaf and sedges weeds in guava plants. In addition, Głowacka (2011) stated that the number of *Echinochloa crus-galli* (grasses weed) was more dominant with mechanical control (18.0 populations) and herbicides (10.3 populations) in maize plants compared to other weeds including *G. parviflora, Chenopodium album, Cirsium arvense,* and *Polygonum lapathifolium*. Uddin et al. (2018) also added the abundance of grasses weeds was higher by 130.1% than broadleaf (108.5%) and sedges (61.4%) weeds in the rice and potato cropping pattern.

CONCLUSIONS

The 2-time tillage (T2) increased the *A. conyzoides* (2.81-folds), *C. dactylon* (41 population), and *E. heterophylla* (2.43-folds) compared to the no-tillage (NT). *C. rotundus* had the highest SDR at NT and T1, while *A. conyzoides* was found in T2 tillage with a moderate diversity index. Based on the classification, only grasses weeds decreased in T1 and T2 tillage. Furthermore, there was a significant and positive correlation between *E. heterophylla* weed with cation exchange capacity (0.727). A total of four new species of weeds, namely *G. maxima, L. oryzoides, S. dulcis*, and *A. oculatum* were found on NT, T1, and T2 tillage due to the application of ammonium glufosinate herbicide.

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Research Article

Weed Diversity as Affected by Tillage and Ammonium Glufosinate Herbicide

ABSTRACT

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage. It was conducted on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan City, Indonesia, from March to July 2021. Furthermore, a non-factorial Randomized Block Design was used consisting of the no-tillage (NT), 1-time tillage (T1), and 2-times tillage (T2) with three replications. The procedures include identifying weed vegetation, sampling analysis of several soil chemical properties, and spraying the ammonium glufosinate herbicide at a dose of 150 g ha^{-1}. Based on the result, the weed species of *Cyperus rotundus* and *Ageratum conyzoides* were dominant in different tillage with a moderate diversity index. The T2 showed increased *A. conyzoides*, *Cynodon dactylon*, and *Euphorbia heterophylla* compared to NT, while a decrease was observed in the grasses weed during one and 2-times tillage. Moreover, there was a positive and significant correlation between *E. heterophylla* weed on the soil cation exchange capacity (0.727). In contrast, four new weed species, namely *Glyceria maxima, Leersia oryzoides, Scoparia dulcis,* and *Anthoxanthum oculatum* were found due to ammonium glufosinate herbicide in different tillage.

Keywords: correlation; diversity index; dominance; tillage; weed abundance. [please, use more meaningful words]

Formatado: Fonte: Não Negrito

Comentado [A1]: present the history of cultivation in the studied area

Excluído: ai.

Comentado [A2]: what does moderate diversity index mean? the authors should indicate the obtained value to better exemplify

Comentado [A3]: increased by how much percent? indicate the value obtained

Comentado [A4]: decreased by how much percent? indicate the value obtained

Comentado [A5]: Could the new weed species found in the areas where the herbicide was applied be due to the selection of plants resistant or tolerant to the mechanism of action of GS?

How long has the area been managed with the same herbicide?

Formatado: Fonte: Não Negrito

INTRODUCTION

Uncontrolled weeds on farmlands reduce production up to 80% (Cousens & Mortimer, 1995). Therefore, sustainable agricultural practices affect its abundance and density. The weed abundance in the farmland is influenced by several factors such as seed bank buried in the soil (Norris 2007), environmental factors (Fried et al. 2008, [adjust all] Pinke et al. 2012), availability of nutrients and fertilization (Murphy & Lemerle 2006; Chemona et al. 2016), tillage and crop rotation (Ulber et al. 2009; Nichols et al. 2015), and weed control through herbicides (Derksen et al. 1995).

Excluído: ;

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Menalled et al. (2001) showed that different agricultural management systems significantly affect weed abundance, diversity, and consistency in the short and long term. Meanwhile, Derksen et al. (1995) reported that the germination of *Synapsis avensis* and *Brassica napus* weeds after spraying with herbicides was higher in the no-tillage, but there was a reduction in total weeds. Thomas et al. (2004) also reported perennial weed species such as *Cirsium arvense* and *Sonchus arvensis* was reduced tillage and no-tillage, while annual weeds were found in various tillage treatments. In addition, Trichard et al. (2013) stated that tillage favors weed seed bank germination and cause the extinction of other seeds.

Comentado [A6]: how long? 10years?

Comentado [A7]: reduced how much?

On the other hand, different soil fertility in the planted area also affects the weed diversity (Yin et al. 2006). Fonge et al. (2013) reported that weed diversity is affected by organic-C content, nitrogen, calcium, and cation exchange capacity of the soil. Tang et al. (2014a) added that phosphorus+potassium (PK) fertilization increases the density of *Galium aparine*, *Vicia sativa*, *Veronica persica*, and *Geranium carolinianum* weeds compared to nitrogen+phosphorus (NP). Furthermore, Forcella et al. (2000) stated that the soil N concentration plays an important role in ending dormancy by removing germination constraints and stimulating seedling emergence. Tang et al. (2014b) reported that soil available-P is the primary nutrient, regulating the composition of weed species and diversity, followed by N and K nutrients.

The knowledge of farmers on the relationship between tillage and soil fertility status with weed diversity is relatively poor. The interviews conducted in this study showed that the farmers only carry out land clearing and manual tillage before planting, had never used herbicides, and unknowingly the soil fertility status. However, a new problem was found: weed growth was very rapid in a short time (2 days). Therefore, intensive control during one main crop cycle is highly needed. This problem persisted during crop rotation. Unnoticed by farmers, these activities impact the storage of the weed seed bank, and the tillage carried out, resulting in the weed seed bank at a certain depth of soil emerging to the soil surface. Studies on weed identification are needed to provide information on the relationship between soil fertility on the dominant weeds and the use of one herbicide with a recommended dose to suppress the presence of weeds. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage.

MATERIAL AND METHODS

Area and plot of the tillage

This study was carried out on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan (Indonesia) with the condition of continuous land use and a history of crop rotation for the last two years for corn, cucumber, and cowpea as well as manual tillage using a hoe, without

Comentado [A8]: Is this information the result of the research? if so, it should be presented in the results and discussion section.

Better present the problem under study and the hypotheses

Formatado: Normal, Justificado, Recuo: Primeira linha: 1 cm the use of herbicides based on interviews with farmers. This study was conducted from March to July 2021.

Comentado [A9]: Describe clearly the management used in each system... where was the herbicide used?

Movido para baixo [1]: The land was cleared and then plotted with the square method of 1 m × 1 m and an interval of 2 m. Each plot was demarcated with plastic ropes at a distance of 0.2 m (Fig. 1).
¶
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Figure 1. The size of plots with the square method.

Weed analysis

This study used a non-factorial Randomized Block Design with three replications: no-tillage, 1-time and 2-times tillage systems. The land was cleared and then plotted with the square method of 1 m × 1 m and an interval of 2 m. Each plot was demarcated with plastic ropes at a distance of 0.2 m (Fig. 1).

Comentado [A10]: Describe clearly the management used in each system... where was the herbicide used?

Movido (inserção) [1]

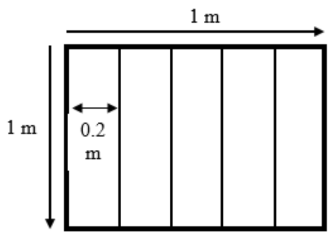

Figure 1. The size of plots with the square method.

Comentado [A11]: It is not clear whether this is the area of the plots in each treatment (NT, T1 and T2) or the area used to sample the weed community.

Tillage was carried out by hoeing as deep as 20 cm. Meanwhile, the land was incubated for a month and then identified for weed vegetation using the flora book and applying formulas according to Kent (2012) such as absolute density (defined as the number of individual weed species in the sample plot), relative density, absolute frequency (defined as the number of sample plots containing certain species), relative frequency, importance value, and the summed dominance ratio (SDR) as shown in equation 1-4.

$$\text{Relative Density (RD)} = \frac{\text{The absolute density of a certain species}}{\text{Total absolute density of all species}} \times 100\% \quad (1)$$

Comentado [A12]: Species dominance could be determined based on species biomass.

$$\text{Relative Frequency (RF)} = \frac{\text{The absolute frequency of a certain species}}{\text{Total absolute frequencies of all species}} \times 100\% \quad (2)$$

$$\text{Importance Value (IV)} = \text{Relative Density (RD)} + \text{Relative Frequency (RF)} \quad (3)$$

$$\text{Summed Dominance Ratio} = \frac{\text{Relative Density (RD)} + \text{Relative Frequency (RF)}}{2} \quad (4)$$

Weed populations based on morphology (broadleaf, grasses, sedges) and total weeds were calculated. The species diversity index was calculated using the Shannon-Wiener index formula (Shannon & Weaver 1949):

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right) \left(\ln \frac{ni}{N}\right)$$

Note:

H'= Species diversity index

ni = The proportion of species *i*

N = The total number of species

ln = natural logarithm

The classification of the diversity index value for each tillage was conducted based on Magurran (1988) stated that if $H'<1$ (low), $1<H'<3$ (moderate) and $H'>3$ (high).

Correlation of organic-C and cation exchange capacity on dominant weeds

Soil samples at a depth of 0-20 cm were taken using a drill with a diagonal method on each plot. Then it performed analysis on organic-C (Walkley & Black method) and cation exchange capacity/CEC (ammonium acetate pH 7) using a spectrophotometer at Socfin Indonesia Inc., Medan (Indonesia). At first, a natural logarithm was carried out on the organic-C, CEC data, and the total of dominant weeds as well as analyzed using the Pearson correlation.

Application of the ammonium glufosinate herbicide and data processing

The ammonium glufosinate herbicide was applied on 27 April 2021 at 10.00 to all plots at a dose of 150 g ha^{-1} after a spray calibration was carried out. Climatic data were recorded during spraying, such as temperature 28°C, humidity 83%, and air pressure 1002 hPa. Weed survival data were measured at six weeks after spraying (WAS).

The data of weeds (broadleaf, grasses, sedges, total) and soil (organic-C, CEC) were processed using ANOVA and followed by DMRT level 5% using IBM SPSS v.20 software.

Comentado [A13]: Abstract and figure

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Comentado [A14]: no-tillage? Or T1 and T2 too? got confused

Comentado [A15]: what was the equipment used for spraying? CO2 pressurized equipment, with a 6-tip bar (model?), with xxbar pressure and 202.9l/ha application volume....

What was the size of the weeds at the time of application?

Excluído: a.i.

Excluído: ¶

The spray volume calibration= $\frac{\text{Land area per ha}}{\text{Length} \times \text{width of spray}}$ × water used = 202.90 L ha^{-1}¶

Ammonium glufosinate = $\frac{\text{Ammonium glufosinate dose per ha}}{\text{The spray volume calibration}}$ = 4.93 ml L^{-1}

RESULTS AND DISCUSSION

Weed diversity due to tillage

The field observations obtained 16 species (*Ageratum conyzoides, Asystasia gangetica, Axonopus compressus, Borreria alata, Brachiaria mutica, Cleome rutidosperma, Cynodon dactylon, Cyperus rotundus, Eleusine indica, Euphorbia heterophylla, Galinsoga parviflora, Mimosa pudica, Oxalis corniculata, Pennisetum purpureum, Polanisia icosandra,* and *Stylochaeton lancifolius*) with 6639 populations from three tillage systems (NT, T1, T2) as presented in Fig. 2. The result showed that three dynamic patterns due to tillage, such as (1) an increase in the weed diversity due to 2-time tillage for *A. conyzoides, C. dactylon*, and *E. heterophylla*, (2) a decrease in weed diversity due to 2-time tillage for *A. gangetica, A. compressus, B. alata, C. rutidosperma*, and *E. indica*, (3) a fluctuating pattern, indicating a decrease in weed species in 1-time tillage and then an increase in 2-time tillage or vice versa for *B. mutica, G. parviflora, M. pudica, O. corniculata, P. purpureum, P. icosandra*, and *S. lancifolius*.

Comentado [A16]: the Figure should be presented right after it has been cited in the text

Comentado [A17]: We suggest presenting separately the weed community that occurred in each system evaluated (NT, T1 and T2), and then comparing the community diversity of each area graphically.

Excluído: **Weed population due to tillage based on morphology and total weed¶**
The tillage had an insignificant effect on the number of broadleaf, grasses, sedges, and total weeds (Fig. 3). However, increasing the tillage by 2-times (T2) increased the broadleaf population and total weeds by 41.73% and 25.19%, respectively, compared to no-tillage (NT). ¶
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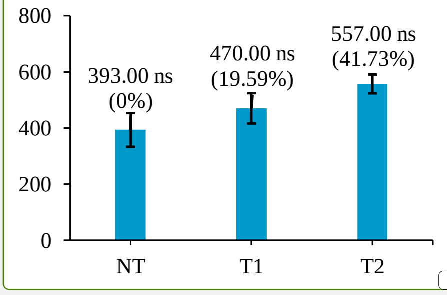

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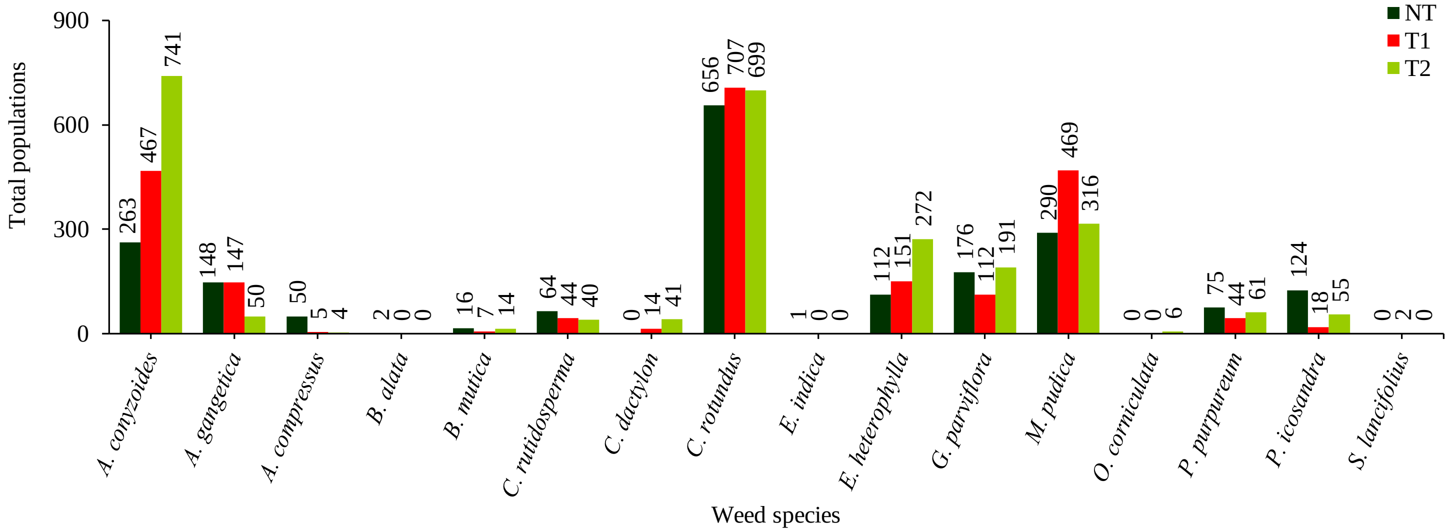

Total populations
900
600
300
0
NT
T1
T2
A. conyzoides
A. gangetica
A. compressus
B. alata
B. mutica
C. rutidosperma
C. dactylon
C. rotundus
E. indica
E. heterophylla
G. parviflora
M. pudica
O. corniculata
P. purpureum
P. icosandra
S. lancifolius
Weed species

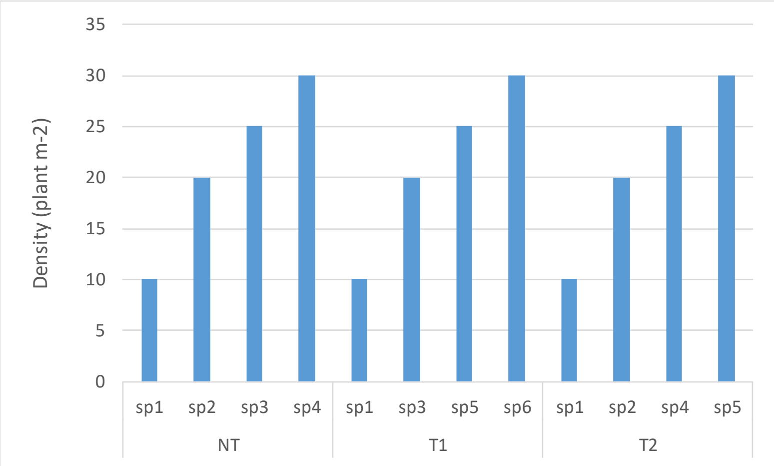

Figure 2. Total populations of weeds due to tillage. NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage.

Comentado [A19]: What is the unit of scale for the data on the Y axis of the graph? Density (plant/m2)?...
We suggest presenting separately the weed community that occurred in each system evaluated (NT, T1 and T2), and then comparing the community diversity of each area graphically.

Weed population due to tillage based on morphology and total weed

The tillage had an insignificant effect on the number of broadleaf, grasses, sedges, and total weeds (Fig. 3). However, increasing the tillage by 2-times (T2) increased the broadleaf population and total weeds by 41.73% and 25.19%, respectively, compared to no-tillage (NT).

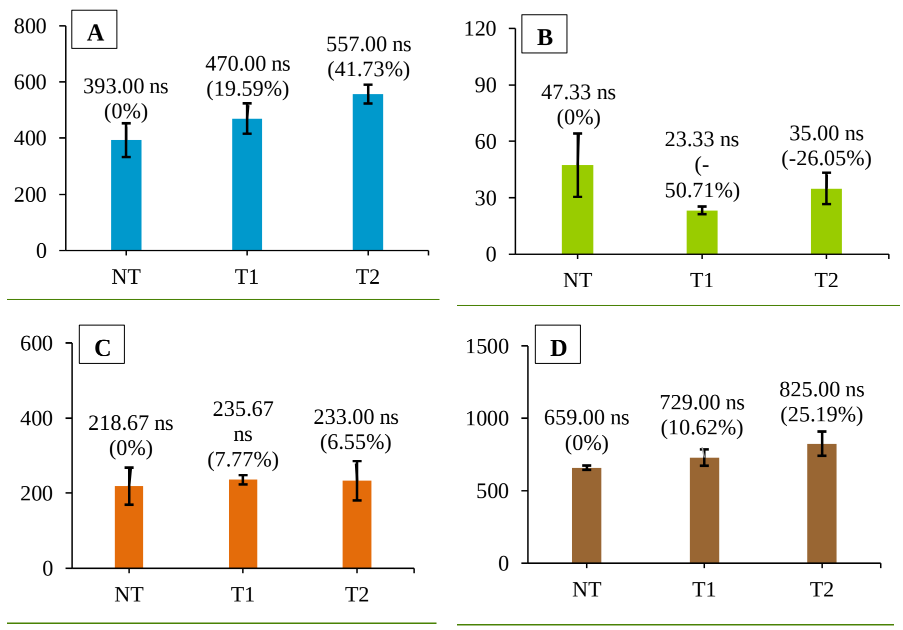

Figure 3. Weed populations based on morphology (A= broadleaf; B= grasses; C= sedges) and total weeds (D) due to tillage (NT=no tillage, T1= 1-time tillage, T2= 2-times tillage). The values followed by the ns (not-significant) in the graph are not significantly different at the 5% level based on the DMRT. The vertical line shows the standard error.

Comentado [A20]: What is the unit of scale for the data on the Y axis of the graph? Density (plant/m2)?... keep the same scale of the graphs to improve comparison between them

See Fig 2

Furthermore, the population of sedges weeds increased at 1-time tillage (T1) by 7.77% compared to NT and decreased to 6.55% at 2-times tillage (T2). The population of grasses weeds experienced the highest decrease in 1-time tillage (T1) of 50.71% compared to NT.

SDR and weed diversity index due to tillage

The dominant weeds (SDR) and diversity index due to tillage are presented in Tab. 1-2. In the no-tillage (NT) treatment found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica, A. conyzoides*, *C. rutidosperma,* and *P. icosandra* of 22.78%; 13.37%; 12.50%; 10.90%; and 10.49%, respectively. In the 1-time tillage (T1) found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *A. gangetica*, and *E. heterophylla* of 22.61%; 16.42%; 16.41%; 10.87%; and 9.63%, respectively. Moreover, in the 2-times tillage (T2) also found in five species with the highest SDR sequentially were *A. conyzoides*, *C. rotundus*, *M. pudica*, *E. heterophylla*, and *G. parviflora* by 22.20%; 18.76%; 12.67%; 11.36%; and 9.90%, respectively. The diversity index (H') due to tillage (NT, T1, T2) were 2.261; 2.196 and 2.234 respectively, therefore it was moderate.

Correlation of organic-C and cation exchange capacity on dominant weeds

The tillage significantly increased cation exchange capacity (CEC) but it had insignificant effect on soil organic-C (Fig. 4). There was an increase in the CEC due to T1 and T2 by 16.56% and 13.14%, respectively. The correlation analysis of soil organic-C and CEC on the dominant weed population due to tillage is presented in Tab. 3. The results showed that only CEC had a significant and positive correlation in increasing the *E. heterophylla* by 0.727, but it was insignificant for *C. rotundus* and *C. rutidosperma*. Similarly, soil organic-C had an insignificant effect but was positively correlated to the population of *C. rotundus, A. conyzoides, M. pudica*, and *E. heterophylla*.

Table 1. SDR of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage). [Please, explain the meaning of all acronyms in the table]

Weeds Species	Replicate 1						Replicate 2						Replicate 3					
	AD	RD	AF	RF	IV	SDR	AD	RD	AF	RF	IV	SDR	AD	RD	AF	RF	IV	SDR
NT= no-tillage																		
A. conyzoides	19	2.94	5	11.90	14.84	7.42	148	20.87	5	12.20	33.07	16.53	96	15.46	5	11.63	27.09	13.54
A. gangetica	58	8.96	5	11.90	20.87	10.43	48	6.77	5	12.20	18.97	9.48	42	6.76	5	11.63	18.39	9.20
A. compressus	-	-	-	-	-	-	-	-	-	-	-	-	50	8.05	4	9.30	17.35	8.68
B. alata	-	-	-	-	-	-	2	0.28	1	2.44	2.72	1.36	-	-	-	-	-	-
B. mutica	4	0.62	3	7.14	7.76	3.88	-	-	-	-	-	-	12	1.93	4	9.30	11.23	5.62
C. rutidosperma	64	9.89	5	11.90	21.80	10.90	-	-	-	-	-	-	-	-	-	-	-	-
C. rotundus	387	59.81	5	11.90	71.72	35.86	109	15.37	5	12.20	27.57	13.78	160	25.76	5	11.63	37.39	18.70
E. indica	-	-	-	-	-	-	1	0.14	1	2.44	2.58	1.29	-	-	-	-	-	-
E. heterophylla	20	3.09	4	9.52	12.61	6.31	92	12.98	5	12.20	25.17	12.59	-	-	-	-	-	-
G. parviflora	24	3.71	5	11.90	15.61	7.81	112	15.80	5	12.20	27.99	14.00	40	6.44	5	11.63	18.07	9.03
M. pudica	49	7.57	5	11.90	19.48	9.74	96	13.54	5	12.20	25.74	12.87	145	23.35	5	11.63	34.98	17.49
P. purpureum	22	3.40	5	11.90	15.31	7.65	10	1.41	4	9.76	11.17	5.58	43	6.92	5	11.63	18.55	9.28

Comentado [A21]: The table presents complex data that does not allow for understanding the results. The IV and SDR indices already cover the DR and FR and could be presented as suggested for the data in Figure 2.

Comentado [A22]: The formulas AD and AF were not described in the methodology

Very large tables that exceed one page should not be used

Formatado: Fonte: Não Negrito

P. icosandra	-	-	-	-	-	-	91	12.83	5	12.20	25.03	12.52	33	5.31	5	11.63	16.94	8.47
Total	647		42			100	709		41			100	621		43			100
T1= 1-time tillage																		
A. conyzoides	181	27.18	5	11.63	38.81	19.40	73	12.17	5	11.90	24.07	12.04	213	23.13	5	12.50	35.63	17.81
A. gangetica	82	12.31	5	11.63	23.94	11.97	-	-	-	-	-	-	65	7.06	5	12.50	19.56	9.78
A. compressus	-	-	-	-	-	-	5	0.83	2	4.76	5.60	2.80	-	-	-	-	-	-
B. mutica	-	-	-	-	-	-	4	0.67	2	4.76	5.43	2.71	3	0.33	1	2.50	2.83	1.41
C. rutidosperma	-	-	-	-	-	-	21	3.50	5	11.90	15.40	7.70	23	2.50	5	12.50	15.00	7.50
C. dactylon	5	0.75	3	6.98	7.73	3.86	9	1.50	4	9.52	11.02	5.51	-	-	-	-	-	-
C. rotundus	193	28.98	5	11.63	40.61	20.30	255	42.50	5	11.90	54.40	27.20	259	28.12	5	12.50	40.62	20.31
E. heterophylla	53	7.96	5	11.63	19.59	9.79	54	9.00	5	11.90	20.90	10.45	44	4.78	5	12.50	17.28	8.64
G. parviflora	22	3.30	5	11.63	14.93	7.47	36	6.00	5	11.90	17.90	8.95	54	5.86	5	12.50	18.36	9.18
M. pudica	87	13.06	5	11.63	24.69	12.35	137	22.83	5	11.90	34.74	17.37	245	26.60	5	12.50	39.10	19.55
P. purpureum	25	3.75	5	11.63	15.38	7.69	4	0.67	3	7.14	7.81	3.90	15	1.63	4	10.00	11.63	5.81
P. icosandra	18	2.70	5	11.63	14.33	7.17	-	-	-	-	-	-	-	-	-	-	-	-
S. lancifolius	-	-	-	-	-	-	2	0.33	1	2.38	2.71	1.36	-	-	-	-	-	-
Total	666		43			100	600		42			100	921		40			100

Formatado: Fonte: Não Negrito

T2= 2-times tillage																		
A. conyzoides	146	15.57	5	11.36	26.93	13.46	256	47.67	5	11.90	59.58	29.79	339	33.90	5	12.82	46.72	23.36
A. gangetica	-	-	-	-	-	-	-	-	-	-	-	-	50	5.00	5	12.82	17.82	8.91
A. compressus	2	0.21	2	4.55	4.76	2.38	2	0.37	2	4.76	5.13	2.57	-	-	-	-	-	-
B. mutica	3	0.32	3	6.82	7.14	3.57	1	0.19	1	2.38	2.57	1.28	10	1.00	4	10.26	11.26	5.63
C. rutidosperma	24	2.56	5	11.36	13.92	6.96	16	2.98	5	11.90	14.88	7.44	-	-	-	-	-	-
C. dactylon	26	2.77	4	9.09	11.86	5.93	-	-	-	-	-	-	-	-	-	-	-	-
C. rotundus	304	32.41	5	11.36	43.77	21.89	53	9.87	5	11.90	21.77	10.89	342	34.20	5	12.82	47.02	23.51
E. heterophylla	178	18.98	5	11.36	30.34	15.17	43	8.01	5	11.90	19.91	9.96	51	5.10	5	12.82	17.92	8.96
G. parviflora	76	8.10	5	11.36	19.47	9.73	43	8.01	5	11.90	19.91	9.96	72	7.20	5	12.82	20.02	10.01
M. pudica	150	15.99	5	11.36	27.36	13.68	85	15.83	5	11.90	27.73	13.87	81	8.10	5	12.82	20.92	10.46
O.corniculata	-	-	-	-	-	-	6	1.12	4	9.52	10.64	5.32	-	-	-	-	-	-
P. purpureum	29	3.09	5	11.36	14.46	7.23	32	5.96	5	11.90	17.86	8.93	-	-	-	-	-	-
P. icosandra	-	-	-	-	-	-	-	-	-	-	-	-	55	5.50	5	12.82	18.32	9.16
Total	938		44			100	537		42			100	1000		39			100

Formatado: Fonte: Não Negrito

Table 2. Diversity index of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage). [Please, explain the meaning of all acronyms in the table]

Family	Weeds Species	NT				T1				T2			
		ni	ni/N	ln ni/N	H’	ni	ni/N	ln ni/N	H’	ni	ni/N	ln ni/N	H’
Asteraceae	*A. conyzoides*	25.00	0.125	-2.079	0.260	32.83	0.164	-1.807	0.297	44.41	0.222	-1.505	0.334
	G. parviflora	20.56	0.103	-2.275	0.234	17.07	0.085	-2.461	0.210	19.80	0.099	-2.313	0.229
Acanthaceae	*A. gangetica*	19.41	0.097	-2.333	0.226	14.50	0.072	-2.624	0.190	5.94	0.030	-3.517	0.104
Araceae	*S. lancifolius*	-	-	-	-	0.90	0.005	-5.398	0.024	-	-	-	-
Capparaceae	*C. rutidosperma*	7.27	0.036	-3.315	0.120	10.13	0.051	-2.982	0.151	9.60	0.048	-3.036	0.146
Capparidaceae	*P. icosandra*	13.99	0.070	-2.660	0.186	4.78	0.024	-3.735	0.089	6.11	0.031	-3.489	0.107
Cyperaceae	*C. rotundus*	45.56	0.228	-1.479	0.337	45.21	0.226	-1.487	0.336	37.52	0.188	-1.673	0.314
Euphorbiaceae	*E. heterophylla*	12.60	0.063	-2.765	0.174	19.26	0.096	-2.340	0.225	22.72	0.114	-2.175	0.247
Fabaceae	*M. pudica*	26.73	0.134	-2.013	0.269	32.84	0.164	-1.807	0.297	25.34	0.127	-2.066	0.262
Oxalidaceae	*O. corniculata*	-	-	-	-	-	-	-	-	3.55	0.018	-4.032	0.072
Poaceae	*A. compressus*	5.78	0.029	-3.543	0.102	1.87	0.009	-4.675	0.044	3.30	0.016	-4.105	0.068
	B. mutica	6.33	0.032	-3.453	0.109	2.75	0.014	-4.286	0.059	6.99	0.035	-3.354	0.117

Comentado [A23]: Very large tables that exceed one page should not be used.

Comentado [A24]: Use only the data for H' for the discussion.

See Fig 2

	C. dactylon	-	-	-	-	6.25	0.031	-3.466	0.108	3.95	0.020	-3.924	0.078
	E. indica	0.86	0.004	-5.449	0.023	-	-	-	-	-	-	-	-
	P. purpureum	15.01	0.075	-2.590	0.194	11.61	0.058	-2.847	0.165	10.77	0.054	-2.921	0.157
Rubiaceae	*B. alata*	0.91	0.005	-5.396	0.024	-	-	-	-	-	-	-	-
	Total			-39.350	2.261			-39.915	2.196			-38.110	2.234

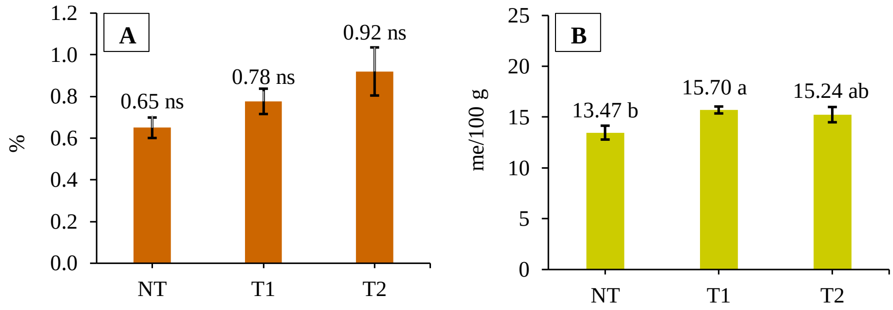

Figure 4. The soil organic-C (A) and cation exchange capacity (B) properties due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage). The values followed by the different letter in the graph are significantly at the 5% level based on the DMRT. The vertical line shows the standard error. ns= not-significant.

Table 3. Correlation analysis of organic-C and CEC of the soil on the dominant weed populations due to tillage.

Dominant weed species	Correlation coefficient	
	Organic-C	CEC
C. rotundus	0.449^{ns} [adjust all]	0.262ns
A. conyzoides	0.132ns	-0.154ns
M. pudica	0.147ns	-0.054ns
E. heterophylla	0.127ns	0.727^{*}
G. parviflora	-0.063ns	-0.240ns
A.gangetica	-0.298ns	-0.482ns
P. icosandra	-0.021ns	-0.646ns
C. rutidosperma	-0.095ns	0.591ns

Note: Correlation is significant at the 0.05 level (2-tailed). ns= not-significant.

Changes in weed vegetation due to the ammonium glufosinate

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Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g ai.ha^{-1} on different tillage (NT, T1, T2) by species are presented in Fig. 5. The results showed an increase in *B. alata* and *B. mutica* due to the ammonium glufosinate in NT and 2-times tillage (T2). Meanwhile, others decreased, and two new weed species were found in NT, such as *Glyceria maxima* and *Leersia oryzoides,* and one new weed species were found in T2 (*G. maxima*). Similarly, the 1-time tillage (T1) increased *B. alata, B. mutica,* and *E. indica*. At the same time, other populations decreased, and four new weed species were found, namely *G. maxima, L. oryzoides, Scoparia dulcis*, and *Anthoxanthum oculatum*.

Based on morphology, the effectiveness of ammonium glufosinate on the weed-type abundance at different tillage (NT, T1, T2) is presented in Fig. 6. The herbicide application can decrease the abundance of broadleaf weeds by 82.13-84.98% and sedges by 8.15-19.05%. However, there was an increase in the grasses weed abundance in T1 and T2 tillage by 167.74% and 26.67%, respectively.

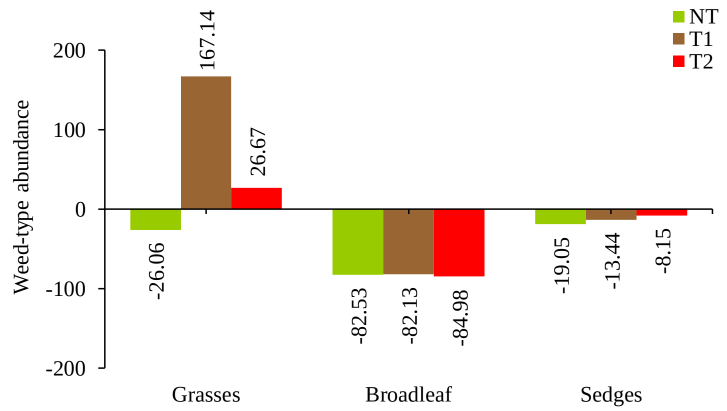

Figure 6. The effectiveness of ammonium glufosinate on the weed-type abundance at different tillage.

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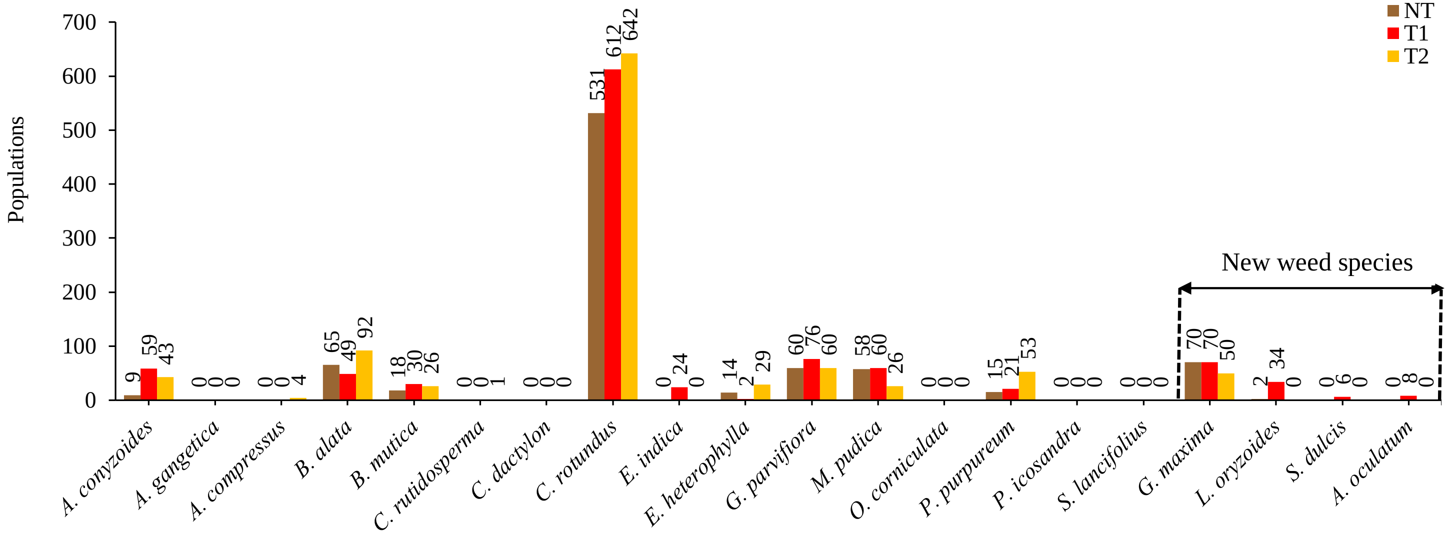

Figure 5. Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 gha^{-1} on different tillage.

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Effect of tillage on weed diversity

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Based on the results, there were three dynamic patterns of weed diversity due to tillage, namely increasing, decreasing, and fluctuating patterns. The increasing weed species due to 2-times tillage (T2) include *A. conyzoides* (2.81-folds), *C. dactylon* (41 populations), and *E. heterophylla* (2.43-folds) compared to no-tillage (NT). It was caused by the seed banks of *A. conyzoides*, *C. dactylon*, and *E. heterophylla* during T2 tillage were triggered the emergence to the soil surface. Furthermore, soil fertility also supported its growth more rapidly. This was supported by the organic-C, which was positively correlated with the presence of *A. conyzoides* (0.132) and *E. heterophylla* (0.127). Besides, soil CEC was also significantly and positively correlated with the presence of *E. heterophylla* (0.727) (Tab. 3). These results are similar to Oziegbe et al. (2010); active weed seedbanks at deeper soil depths lead to lower oxygen availability and reduce the access to light required to support germination. In addition, Hossain et al. (2021) that the seed bank of *A. conyzoides* was not found at a depth of 0-10 cm, but 10-15 cm, and experienced an additional seed bank of 43.82% during conventional tillage. Horowitz (1972) reported that 88% of *C. dactylon* rhizomes were found at a depth of 30 cm. Ekeleme et al. (2019) added that *E. heterophylla* had the second-highest abundance of 19.53% after *Tridax procumbens* in Benue State, Nigeria.

SDR, diversity index, weed population due to tillage

The results showed that *C. rotundus* had the highest SDR in NT and T1 tillage, while *A. conyzoides* was dominant in T2 tillage. This was due to the presence of higher seed bank of *C. rotundus* and *A. conyzoides* at certain depths. Therefore, when the soil is tilled, the seedbanks trigger emergence on the soil surface. These results are similar to Hossain et al. (2021) which reported that up to 24% of the *C. rotundus* seed bank were found at a depth of 5-10 cm, while 21% of the *A. conyzoides* were found between 10-15 cm. Furthermore, Santín-Montanyá et al. (2013) reported that the weed abundance, diversity, and evenness were greatly increased in the no-tillage treatment. In this study, the results showed that the diversity index due to tillage (NT, T1, T2) was 2.261; 2.196; and 2.234 (moderate) (Tab. 2). The decrease in diversity index due to T1 and T2 compared to NT indicates that tillage decrease weed diversity. Mas & Verdú (2003) reported that the highest value of the Shannon-Wiener diversity index was found in the no-tillage treatment, while Amuri et al. (2010) suggested that no-tillage treatment contributes to the suppression of several weed species. Sepat et al. (2017) also reported that the lowest weed population was found in untilled beds.

The results showed that T2 tillage increased the broadleaf and total weeds. The population of sedges weeds increased at T1, but decreased during T2 tillage. In general, only grasses weeds decreased during T1 and T2 compared to NT, and the highest decrease was found at T1 tillage. This is linear with the Shannon-Wiener diversity index at T1, lower than other tillage (Tab. 2). These results are supported by Murphy et al. (2006) which reported that the weed density is only affected by tillage. Similarly, Hossain et al. (2021) said a decrease in the seed bank of grasses weed during conventional tillage by 76.31% at a depth of 0-5 cm compared to the no-tillage.

Correlation of organic-C and CEC to dominant weeds at different tillage

Cation Exchange Capacity (CEC) was significantly and positively correlated (0.727) with an increase in the population of *E. heterophylla*. The content of CEC and organic-C was also positively correlated but had an insignificant effect on the populations of *C. rotundus*, *C. rutidosperma*, *A. conyzoides*, and *M. pudica*. This was due to the higher content of CEC and organic-C in T1 and T2 compared to the NT (Fig. 4). When the weed seed bank at T1 and T2 emerged to the surface and received light and soil fertility than NT, it tends to support the growth of more weeds as indicated in the total weed population, which grows higher with increasing tillage (Fig. 3). These results are similar to Pätzold et al. (2020) which reported that soil organic-C affects weed species variability by 8.4%, while Gaston et al. (2001); Nordmeyer

& Häusler (2004); Korres et al. (2017) reported that organic carbon, texture, and nutrients of soil affect the emergence of weeds. Furthermore, Dorneles et al. (2015) reported that reduced tillage had a higher CEC than the no-tillage at 0-5 cm and 5-10 cm depths.

Changes in weed due to the ammonium glufosinate herbicide at different tillage

There was an increase in populations of *B. alata* (49), *B. mutica* (30), and *E. indica* (24) after spraying the ammonium glufosinate herbicide at a dose of 150 g $ai.ha^{-1}$ with different tillage (NT, T1, T2), although *C. rotundus* (612) was more numerous than the other weeds. In general, four new weeds species, namely *G. maxima, L. oryzoides, S. dulcis*, and *A. oculatum* were found in NT, T1, and T2 due to the ammonium glufosinate herbicide. *Glyceria maxima* is a new weed species with the highest population in the NT, T1, and T2 tillage. Furthermore, the increase in population and new weed species was higher in the grasses weeds (*B. mutica, E. indica, G. maxima, L. oryzoides,* and *A. oculatum*) and two new species from the broadleaf weeds (*B. alata* and *S. dulcis*). Therefore, the ammonium glufosinate herbicide at different tillage decreased the abundance of broadleaf (Fig. 6) compared to the grasses weeds.

Using herbicides on tillage (T1 and T2) exposed the seed bank of grasses weeds to the soil surface to adequately obtain oxygen and light needed for growth. This is supported by Wibawa et al. (2009), which reported that the herbicide of dose 200 $g.ha^{-1}$ significantly suppressed broadleaf of 94.68% compared to the grasses weeds by 59.65% at two weeks after spraying. Tampubolon et al. (2019) also found that the herbicide at a dose of 300 g $ai.ha^{-1}$ significantly removed 100% of the glyphosate-susceptible *E. indica,* while Alridiwirsah et al. (2020) reported that the grasses was higher by 52.76% compared to the broadleaf and sedges weeds in guava plants. In addition, Głowacka (2011) stated that the number of *Echinochloa crus-galli* (grasses weed) was more dominant with mechanical control (18.0 populations) and herbicides (10.3 populations) in maize plants compared to other weeds including *G. parviflora, Chenopodium album, Cirsium arvense,* and *Polygonum lapathifolium*. Uddin et al. (2018) also added the abundance of grasses weeds was higher by 130.1% than broadleaf (108.5%) and sedges (61.4%) weeds in the rice and potato cropping pattern.

CONCLUSIONS

The 2-time tillage (T2) increased the *A. conyzoides* (2.81-folds), *C. dactylon* (41 population), and *E. heterophylla* (2.43-folds) compared to the no-tillage (NT). *C. rotundus* had the highest SDR at NT and T1, while *A. conyzoides* was found in T2 tillage with a moderate diversity index. Based on the classification, only grasses weeds decreased in T1 and T2 tillage. Furthermore, there was a significant and positive correlation between *E. heterophylla* weed with cation exchange capacity (0.727). A total of four new species of weeds, namely *G. maxima, L. oryzoides, S. dulcis,* and *A. oculatum* were found on NT, T1, and T2 tillage due to the application of ammonium glufosinate herbicide.

ACKNOWLEDGMENTS

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Research Article

Weed Diversity as Affected by Tillage and Ammonium Glufosinate Herbicide

ABSTRACT

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage. It was conducted on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan City, Indonesia, from March to July 2021. Furthermore, a non-factorial Randomized Block Design was used consisting of the no-tillage (NT), 1-time tillage (T1), and 2-times tillage (T2) with three replications. The procedures include identifying weed vegetation, sampling analysis of several soil chemical properties, and spraying the ammonium glufosinate herbicide at a dose of 150 g ai.ha^{-1}. Based on the result, the weed species of *Cyperus rotundus* and *Ageratum conyzoides* were dominant in different tillage with a moderate diversity index. The T2 showed increased *A. conyzoides*, *Cynodon dactylon*, and *Euphorbia heterophylla* compared to NT, while a decrease was observed in the grasses weed during one and 2-times tillage. Moreover, there was a positive and significant correlation between *E. heterophylla* weed on the soil cation exchange capacity (0.727). In contrast, four new weed species, namely *Glyceria maxima, Leersia oryzoides, Scoparia dulcis,* and *Anthoxanthum oculatum* were found due to ammonium glufosinate herbicide in different tillage.

Keywords: correlation; diversity index; dominance; tillage; weed abundance

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INTRODUCTION

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Uncontrolled weeds on farmlands reduce production up to 80% (Cousens & Mortimer, 1995). Therefore, sustainable agricultural practices affect its abundance and density. The weed abundance in the farmland is influenced by several factors such as seed bank buried in the soil (Norris 2007), environmental factors (Fried et al. 2008; Pinke et al. 2012), availability of nutrients and fertilization (Murphy & Lemerle 2006; Chemona et al. 2016), tillage and crop rotation (Ulber et al. 2009; Nichols et al. 2015), and weed control through herbicides (Derksen et al. 1995).

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Menalled et al. (2001) showed that different agricultural management systems significantly affect weed abundance, diversity, and consistency in the short and long term. Meanwhile, Derksen et al. (1995) reported that the germination of *Synapsis avensis* and *Brassica napus* weeds after spraying with herbicides was higher in the no-tillage, but there was a reduction in total weeds. Thomas et al. (2004) also reported perennial weed species such as *Cirsium arvense* and *Sonchus arvensis* was reduced tillage and no-tillage, while annual weeds were found in various tillage treatments. In addition, Trichard et al. (2013) stated that tillage favors weed seed bank germination and cause the extinction of other seeds.

On the other hand, different soil fertility in the planted area also affects the weed diversity (Yin et al. 2006). Fonge et al. (2013) reported that weed diversity is affected by organic-C content, nitrogen, calcium, and cation exchange capacity of the soil. Tang et al. (2014a) added that phosphorus+potassium (PK) fertilization increases the density of *Galium aparine*, *Vicia sativa*, *Veronica persica*, and *Geranium carolinianum* weeds compared to nitrogen+phosphorus (NP). Furthermore, Forcella et al. (2000) stated that the soil N concentration plays an important role in ending dormancy by removing germination constraints and stimulating seedling emergence. Tang et al. (2014b) reported that soil available-P is the primary nutrient, regulating the composition of weed species and diversity, followed by N and K nutrients.

The knowledge of farmers on the relationship between tillage and soil fertility status with weed diversity is relatively poor. The interviews conducted in this study showed that the farmers only carry out land clearing and manual tillage before planting, had never used herbicides, and unknowingly the soil fertility status. However, a new problem was found: weed growth was very rapid in a short time (2 days). Therefore, intensive control during one main crop cycle is highly needed. This problem persisted during crop rotation. Unnoticed by farmers, these activities impact the storage of the weed seed bank, and the tillage carried out, resulting in the weed seed bank at a certain depth of soil emerging to the soil surface. Studies on weed identification are needed to provide information on the relationship between soil fertility on the dominant weeds and the use of one herbicide with a recommended dose to suppress the presence of weeds. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage.

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MATERIAL AND METHODS

Area and plot of the tillage

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Was it just an assessment?

This study was carried out on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan (Indonesia) with the condition of continuous land use and a history of crop rotation for the last two years for corn, cucumber, and cowpea as well as manual tillage using a hoe, without the use of herbicides based on interviews with farmers. This study was conducted from March to July 2021. The land was cleared and then plotted with the square method of 1 m × 1 m and an interval of 2 m. Each plot was demarcated with plastic ropes at a distance of 0.2 m (Fig. 1).

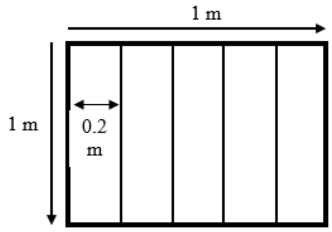


Figure 1. The size of plots with the square method.

This study used a non-factorial Randomized Block Design with three replications: no-tillage, 1-time and 2-times tillage systems. Tillage was carried out by hoeing as deep as 20 cm. Meanwhile, the land was incubated for a month and then identified for weed vegetation using the flora book and applying formulas according to Kent (2012) such as absolute density (defined as the number of individual weed species in the sample plot), relative density, absolute frequency (defined as the number of sample plots containing certain species), relative frequency, importance value, and the summed dominance ratio (SDR) as shown in equation 1-4.

Excluído: Weed analysis¶

$$\text{Relative Density (RD)} = \frac{\text{The absolute density of a certain species}}{\text{Total absolute density of all species}} \times 100\% \qquad (1)$$

$$\text{Relative Frequency (RF)} = \frac{\text{The absolute frequency of a certain species}}{\text{Total absolute frequencies of all species}} \times 100\% \qquad (2)$$

$$\text{Importance Value (IV)} = \text{Relative Density (RD)} + \text{Relative Frequency (RF)} \qquad (3)$$

$$\text{Summed Dominance Ratio} = \frac{\text{Relative Density (RD)} + \text{Relative Frequency (RF)}}{2} \qquad (4)$$

Weed populations based on morphology (broadleaf, grasses, sedges) and total weeds were calculated. The species diversity index was calculated using the Shannon-Wiener index formula (Shannon & Weaver 1949):

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right) \left(\ln \frac{ni}{N}\right)$$

Note:

H'= Species diversity index

ni = The proportion of species *i*

N = The total number of species

ln = natural logarithm

The classification of the diversity index value for each tillage was conducted based on Magurran (1988) stated that if H'<1 (low), 1<H'<3 (moderate) and H'>3 (high).

Soil samples at a depth of 0-20 cm were taken using a drill with a diagonal method on each plot. Then it performed analysis on organic-C (Walkley & Black method) and cation exchange capacity/CEC (ammonium acetate pH 7) using a spectrophotometer at Socfin Indonesia Inc., Medan (Indonesia). At first, a natural logarithm was carried out on the organic-C, CEC data, and the total of dominant weeds as well as analyzed using the Pearson correlation.

Excluído: **Correlation of organic-C and cation exchange capacity on dominant weeds¶**

The ammonium glufosinate herbicide was applied on 27 April 2021 at 10.00 to all plots at a dose of 150 g a.i.ha^{-1} after a spray calibration was carried out. Climatic data were recorded during spraying, such as temperature 28°C, humidity 83%, and air pressure 1002 hPa. Weed survival data were measured at six weeks after spraying (WAS).

Excluído: **Application of the ammonium glufosinate herbicide and data processing¶**

$$\text{The spray volume calibration} = \frac{\text{Land area per ha}}{\text{Length} \times \text{width of spray}} \times \text{water used} = 202.90\ \text{L ha}^{-1}$$

$$\text{Ammonium glufosinate} = \frac{\text{Ammonium glufosinate dose per ha}}{\text{The spray volume calibration}} = 4.93\ \text{ml L}^{-1}$$

The data of weeds (broadleaf, grasses, sedges, total) and soil (organic-C, CEC) were processed using ANOVA and followed by DMRT level 5% using IBM SPSS v.20 software.

RESULTS AND DISCUSSION

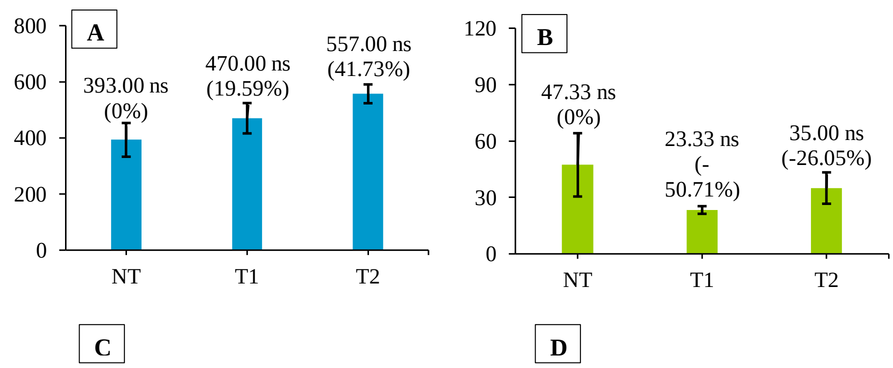
Comentado [A5]: I suggest that a more robust discussion of the results obtained be carried out, basing the arguments with current scientific works from recognized and respected journals by the scientific community and with relevance to the weed theme.

Excluído: Weed diversity due to tillage¶

The field observations obtained 16 species (*Ageratum conyzoides*, *Asystasia gangetica*, *Axonopus compressus*, *Borreria alata*, *Brachiaria mutica*, *Cleome rutidosperma*, *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Euphorbia heterophylla*, *Galinsoga parviflora*, *Mimosa pudica*, *Oxalis corniculata*, *Pennisetum purpureum*, *Polanisia icosandra*, and *Stylochaeton lancifolius*) with 6639 populations from three tillage systems (NT, T1, T2) as presented in Fig. 2. The result showed that three dynamic patterns due to tillage, such as (1) an increase in the weed diversity due to 2-time tillage for *A. conyzoides*, *C. dactylon*, and *E. heterophylla*, (2) a decrease in weed diversity due to 2-time tillage for *A. gangetica*, *A. compressus*, *B. alata*, *C. rutidosperma*, and *E. indica*, (3) a fluctuating pattern, indicating a decrease in weed species in 1-time tillage and then an increase in 2-time tillage or vice versa for *B. mutica*, *G. parviflora*, *M. pudica*, *O. corniculata*, *P. purpureum*, *P. icosandra*, and *S. lancifolius*.

Excluído: Weed population due to tillage based on morphology and total weed¶

The tillage had an insignificant effect on the number of broadleaf, grasses, sedges, and total weeds (Fig. 3). However, increasing the tillage by 2-times (T2) increased the broadleaf population and total weeds by 41.73% and 25.19%, respectively, compared to no-tillage (NT).



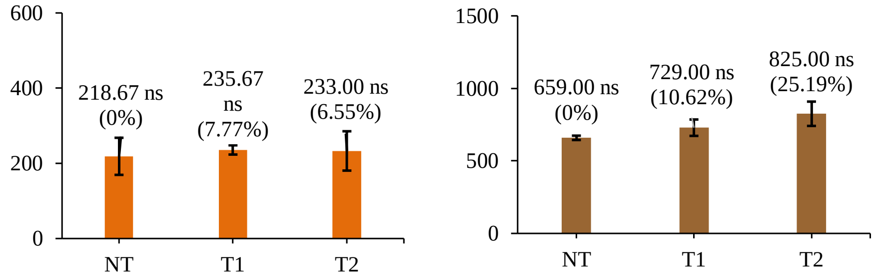


Figure 3. Weed populations based on morphology (A= broadleaf; B= grasses; C= sedges) and total weeds (D) due to tillage (NT=no tillage, T1= 1-time tillage, T2= 2-times tillage). The values followed by the ns (not-significant) in the graph are not significantly different at the 5% level based on the DMRT. The vertical line shows the standard error.

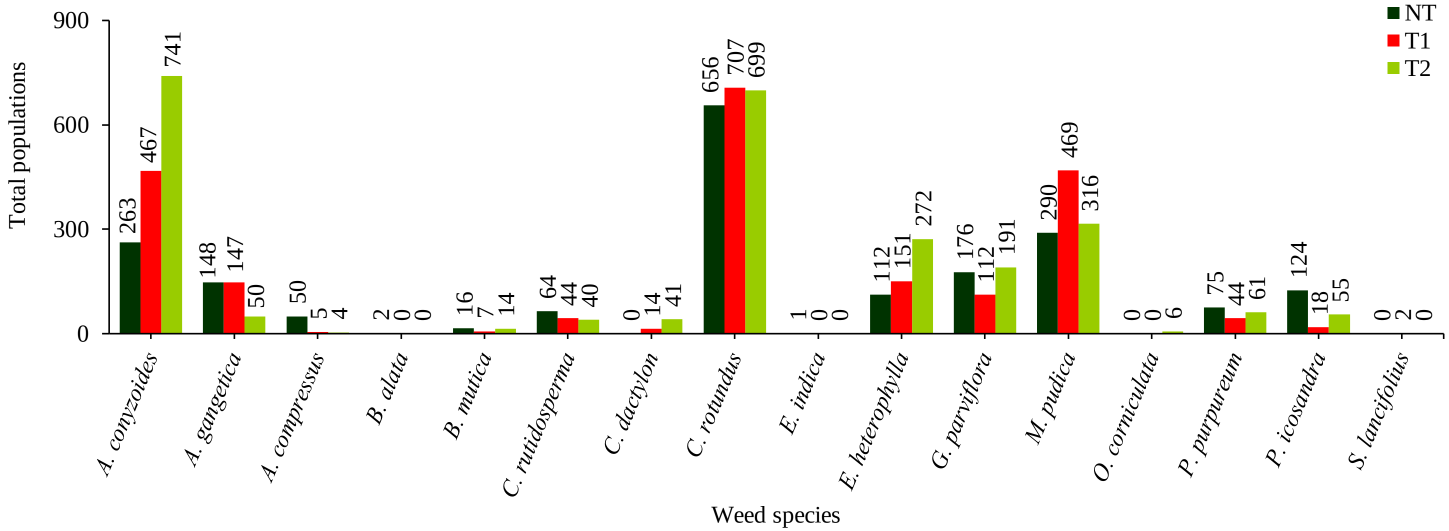


Figure 2. Total populations of weeds due to tillage. NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage.

Furthermore, the population of sedges weeds increased at 1-time tillage (T1) by 7.77% compared to NT and decreased to 6.55% at 2-times tillage (T2). The population of grasses weeds experienced the highest decrease in 1-time tillage (T1) of 50.71% compared to NT.

Excluído: **SDR and weed diversity index due to tillage¶**

The dominant weeds (SDR) and diversity index due to tillage are presented in Tab. 1-2. In the no-tillage (NT) treatment found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *C. rutidosperma*, and *P. icosandra* of 22.78%; 13.37%; 12.50%; 10.90%; and 10.49%, respectively. In the 1-time tillage (T1) found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *A. gangetica*, and *E. heterophylla* of 22.61%; 16.42%; 16.41%; 10.87%; and 9.63%, respectively. Moreover, in the 2-times tillage (T2) also found in five species with the highest SDR sequentially were *A. conyzoides*, *C. rotundus*, *M. pudica*, *E. heterophylla*, and *G. parviflora* by 22.20%; 18.76%; 12.67%; 11.36%; and 9.90%, respectively. The diversity index (H') due to tillage (NT, T1, T2) were 2.261; 2.196 and 2.234 respectively, therefore it was moderate.

Excluído: **Correlation of organic-C and cation exchange capacity on dominant weeds¶**

The tillage significantly increased cation exchange capacity (CEC) but it had insignificant effect on soil organic-C (Fig. 4). There was an increase in the CEC due to T1 and T2 by 16.56% and 13.14%, respectively. The correlation analysis of soil organic-C and CEC on the dominant weed population due to tillage is presented in Tab. 3. The results showed that only CEC had a significant and positive correlation in increasing the *E. heterophylla* by 0.727, but it was insignificant for *C. rotundus* and *C. rutidosperma*. Similarly, soil organic-C had an insignificant effect but was positively correlated to the population of *C. rotundus*, *A. conyzoides*, *M. pudica*, and *E. heterophylla*.

Table 1. SDR of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage).

Weeds Species	Replicate 1						Replicate 2						Replicate 3					
	AD	RD	AF	RF	IV	SDR	AD	RD	AF	RF	IV	SDR	AD	RD	AF	RF	IV	SDR
NT= no-tillage																		
A. conyzoides	19	2.94	5	11.90	14.84	7.42	148	20.87	5	12.20	33.07	16.53	96	15.46	5	11.63	27.09	13.54
A. gangetica	58	8.96	5	11.90	20.87	10.43	48	6.77	5	12.20	18.97	9.48	42	6.76	5	11.63	18.39	9.20
A. compressus	-	-	-	-	-	-	-	-	-	-	-	-	50	8.05	4	9.30	17.35	8.68
B. alata	-	-	-	-	-	-	2	0.28	1	2.44	2.72	1.36	-	-	-	-	-	-
B. mutica	4	0.62	3	7.14	7.76	3.88	-	-	-	-	-	-	12	1.93	4	9.30	11.23	5.62
C. rutidosperma	64	9.89	5	11.90	21.80	10.90	-	-	-	-	-	-	-	-	-	-	-	-
C. rotundus	387	59.81	5	11.90	71.72	35.86	109	15.37	5	12.20	27.57	13.78	160	25.76	5	11.63	37.39	18.70
E. indica	-	-	-	-	-	-	1	0.14	1	2.44	2.58	1.29	-	-	-	-	-	-
E. heterophylla	20	3.09	4	9.52	12.61	6.31	92	12.98	5	12.20	25.17	12.59	-	-	-	-	-	-
G. parviflora	24	3.71	5	11.90	15.61	7.81	112	15.80	5	12.20	27.99	14.00	40	6.44	5	11.63	18.07	9.03
M. pudica	49	7.57	5	11.90	19.48	9.74	96	13.54	5	12.20	25.74	12.87	145	23.35	5	11.63	34.98	17.49
P. purpureum	22	3.40	5	11.90	15.31	7.65	10	1.41	4	9.76	11.17	5.58	43	6.92	5	11.63	18.55	9.28
P. icosandra	-	-	-	-	-	-	91	12.83	5	12.20	25.03	12.52	33	5.31	5	11.63	16.94	8.47

Total	647		42			100	709		41			100	621		43			100
T1= 1-time tillage																		
A. conyzoides	181	27.18	5	11.63	38.81	19.40	73	12.17	5	11.90	24.07	12.04	213	23.13	5	12.50	35.63	17.81
A. gangetica	82	12.31	5	11.63	23.94	11.97	-	-	-	-	-	-	65	7.06	5	12.50	19.56	9.78
A. compressus	-	-	-	-	-	-	5	0.83	2	4.76	5.60	2.80	-	-	-	-	-	-
B. mutica	-	-	-	-	-	-	4	0.67	2	4.76	5.43	2.71	3	0.33	1	2.50	2.83	1.41
C. rutidosperma	-	-	-	-	-	-	21	3.50	5	11.90	15.40	7.70	23	2.50	5	12.50	15.00	7.50
C. dactylon	5	0.75	3	6.98	7.73	3.86	9	1.50	4	9.52	11.02	5.51	-	-	-	-	-	-
C. rotundus	193	28.98	5	11.63	40.61	20.30	255	42.50	5	11.90	54.40	27.20	259	28.12	5	12.50	40.62	20.31
E. heterophylla	53	7.96	5	11.63	19.59	9.79	54	9.00	5	11.90	20.90	10.45	44	4.78	5	12.50	17.28	8.64
G. parviflora	22	3.30	5	11.63	14.93	7.47	36	6.00	5	11.90	17.90	8.95	54	5.86	5	12.50	18.36	9.18
M. pudica	87	13.06	5	11.63	24.69	12.35	137	22.83	5	11.90	34.74	17.37	245	26.60	5	12.50	39.10	19.55
P. purpureum	25	3.75	5	11.63	15.38	7.69	4	0.67	3	7.14	7.81	3.90	15	1.63	4	10.00	11.63	5.81
P. icosandra	18	2.70	5	11.63	14.33	7.17	-	-	-	-	-	-	-	-	-	-	-	-
S. lancifolius	-	-	-	-	-	-	2	0.33	1	2.38	2.71	1.36	-	-	-	-	-	-
Total	666		43			100	600		42			100	921		40			100
T2= 2-times tillage																		

A. conyzoides	146	15.57	5	11.36	26.93	13.46	256	47.67	5	11.90	59.58	29.79	339	33.90	5	12.82	46.72	23.36
A. gangetica	-	-	-	-	-	-	-	-	-	-	-	-	50	5.00	5	12.82	17.82	8.91
A. compressus	2	0.21	2	4.55	4.76	2.38	2	0.37	2	4.76	5.13	2.57	-	-	-	-	-	-
B. mutica	3	0.32	3	6.82	7.14	3.57	1	0.19	1	2.38	2.57	1.28	10	1.00	4	10.26	11.26	5.63
C. rutidosperma	24	2.56	5	11.36	13.92	6.96	16	2.98	5	11.90	14.88	7.44	-	-	-	-	-	-
C. dactylon	26	2.77	4	9.09	11.86	5.93	-	-	-	-	-	-	-	-	-	-	-	-
C. rotundus	304	32.41	5	11.36	43.77	21.89	53	9.87	5	11.90	21.77	10.89	342	34.20	5	12.82	47.02	23.51
E. heterophylla	178	18.98	5	11.36	30.34	15.17	43	8.01	5	11.90	19.91	9.96	51	5.10	5	12.82	17.92	8.96
G. parviflora	76	8.10	5	11.36	19.47	9.73	43	8.01	5	11.90	19.91	9.96	72	7.20	5	12.82	20.02	10.01
M. pudica	150	15.99	5	11.36	27.36	13.68	85	15.83	5	11.90	27.73	13.87	81	8.10	5	12.82	20.92	10.46
O.corniculata	-	-	-	-	-	-	6	1.12	4	9.52	10.64	5.32	-	-	-	-	-	-
P. purpureum	29	3.09	5	11.36	14.46	7.23	32	5.96	5	11.90	17.86	8.93	-	-	-	-	-	-
P. icosandra	-	-	-	-	-	-	-	-	-	-	-	-	55	5.50	5	12.82	18.32	9.16
Total	938		44			100	537		42			100	1000		39			100

Table 2. Diversity index of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage).

Family	Weeds Species	NT				T1				T2			
		ni	ni/N	ln ni/N	H’	ni	ni/N	ln ni/N	H’	ni	ni/N	ln ni/N	H
Asteraceae	*A. conyzoides*	25.00	0.125	-2.079	0.260	32.83	0.164	-1.807	0.297	44.41	0.222	-1.505	0.334
	G. parviflora	20.56	0.103	-2.275	0.234	17.07	0.085	-2.461	0.210	19.80	0.099	-2.313	0.229
Acanthaceae	*A. gangetica*	19.41	0.097	-2.333	0.226	14.50	0.072	-2.624	0.190	5.94	0.030	-3.517	0.104
Araceae	*S. lancifolius*	-	-	-	-	0.90	0.005	-5.398	0.024	-	-	-	-
Capparaceae	*C. rutidosperma*	7.27	0.036	-3.315	0.120	10.13	0.051	-2.982	0.151	9.60	0.048	-3.036	0.146
Capparidaceae	*P. icosandra*	13.99	0.070	-2.660	0.186	4.78	0.024	-3.735	0.089	6.11	0.031	-3.489	0.107
Cyperaceae	*C. rotundus*	45.56	0.228	-1.479	0.337	45.21	0.226	-1.487	0.336	37.52	0.188	-1.673	0.314
Euphorbiaceae	*E. heterophylla*	12.60	0.063	-2.765	0.174	19.26	0.096	-2.340	0.225	22.72	0.114	-2.175	0.247
Fabaceae	*M. pudica*	26.73	0.134	-2.013	0.269	32.84	0.164	-1.807	0.297	25.34	0.127	-2.066	0.262
Oxalidaceae	*O. corniculata*	-	-	-	-	-	-	-	-	3.55	0.018	-4.032	0.072
Poaceae	*A. compressus*	5.78	0.029	-3.543	0.102	1.87	0.009	-4.675	0.044	3.30	0.016	-4.105	0.068
	B. mutica	6.33	0.032	-3.453	0.109	2.75	0.014	-4.286	0.059	6.99	0.035	-3.354	0.117
	C. dactylon	-	-	-	-	6.25	0.031	-3.466	0.108	3.95	0.020	-3.924	0.078
	E. indica	0.86	0.004	-5.449	0.023	-	-	-	-	-	-	-	-

	P. purpureum	15.01	0.075	-2.590	0.194	11.61	0.058	-2.847	0.165	10.77	0.054	-2.921	0.157
Rubiaceae	*B. alata*	0.91	0.005	-5.396	0.024	-	-	-	-	-	-	-	-
	Total			-39.350	2.261			-39.915	2.196			-38.110	2.234

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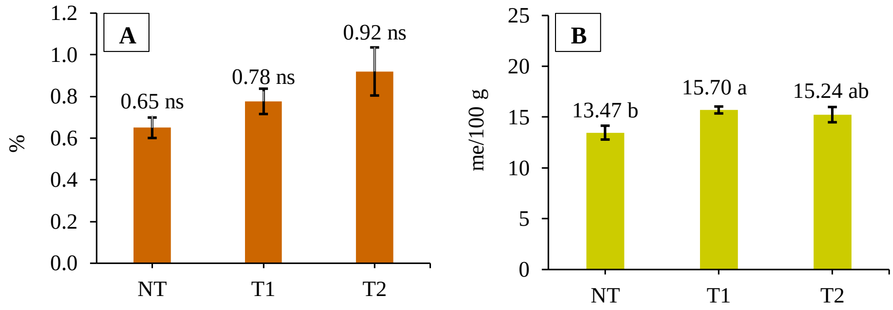

Figure 4. The soil organic-C (A) and cation exchange capacity (B) properties due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage). The values followed by the different letter in the graph are significantly at the 5% level based on the DMRT. The vertical line shows the standard error. ns= not-significant.

Table 3. Correlation analysis of organic-C and CEC of the soil on the dominant weed populations due to tillage.

Dominant weed species	Correlation coefficient	
	Organic-C	CEC
C. rotundus	0.449ns	0.262ns
A. conyzoides	0.132ns	-0.154ns
M. pudica	0.147ns	-0.054ns
E. heterophylla	0.127ns	0.727*
G. parviflora	-0.063ns	-0.240ns
A.gangetica	-0.298ns	-0.482ns
P. icosandra	-0.021ns	-0.646ns
C. rutidosperma	-0.095ns	0.591ns

Note: Correlation is significant at the 0.05 level (2-tailed). ns= not-significant.

Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g ai.ha^{-1} on different tillage (NT, T1, T2) by species are presented in Fig. 5. The results showed an increase in *B. alata* and *B. mutica* due to the ammonium glufosinate in NT and 2-times tillage (T2). Meanwhile, others decreased, and two new weed species were found in NT, such as *Glyceria maxima* and *Leersia oryzoides,* and one new weed species were found in T2 (*G. maxima*). Similarly, the 1-time tillage (T1) increased *B. alata, B. mutica,* and *E. indica*. At the same time, other populations decreased, and four new weed species were found, namely *G. maxima, L. oryzoides, Scoparia dulcis*, and *Anthoxanthum oculatum*.

Based on morphology, the effectiveness of ammonium glufosinate on the weed-type abundance at different tillage (NT, T1, T2) is presented in Fig. 6. The herbicide application can decrease the abundance of broadleaf weeds by 82.13-84.98% and sedges by 8.15-19.05%. However, there was an increase in the grasses weed abundance in T1 and T2 tillage by 167.74% and 26.67%, respectively.

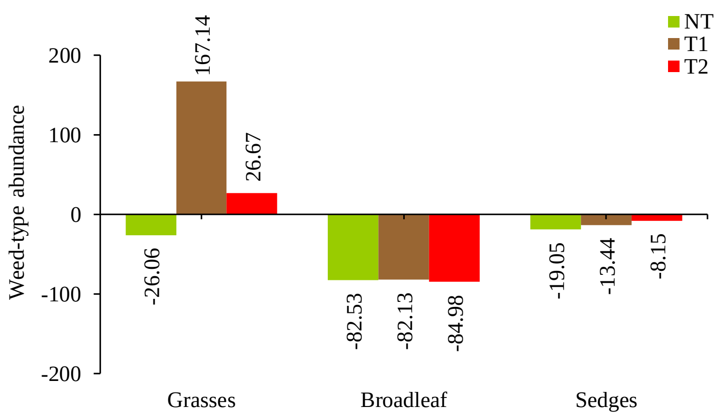

Figure 6. The effectiveness of ammonium glufosinate on the weed-type abundance at different tillage.

Excluído: **Changes in weed vegetation due to the ammonium glufosinate ¶**

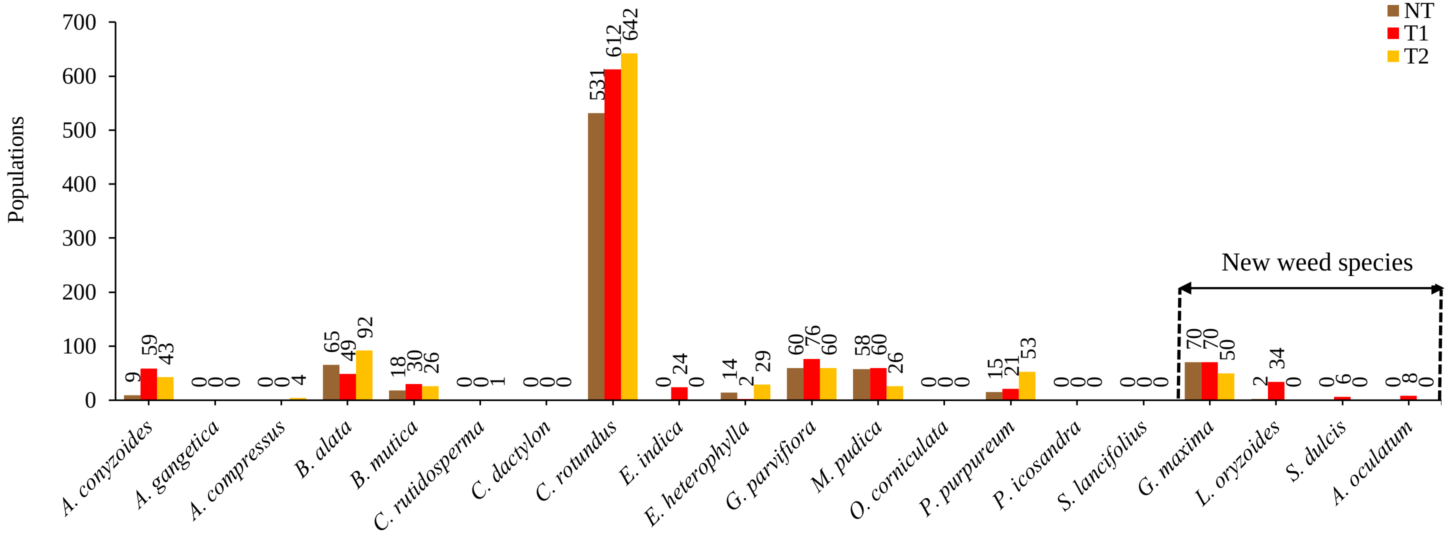

Figure 5. Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g a.i.ha^{-1} on different tillage.

Excluído: Effect of tillage on weed diversity¶

Based on the results, there were three dynamic patterns of weed diversity due to tillage, namely increasing, decreasing, and fluctuating patterns. The increasing weed species due to 2-times tillage (T2) include *A. conyzoides* (2.81-folds), *C. dactylon* (41 populations), and *E. heterophylla* (2.43-folds) compared to no-tillage (NT). It was caused by the seed banks of *A. conyzoides*, *C. dactylon*, and *E. heterophylla* during T2 tillage were triggered the emergence to the soil surface. Furthermore, soil fertility also supported its growth more rapidly. This was supported by the organic-C, which was positively correlated with the presence of *A. conyzoides* (0.132) and *E. heterophylla* (0.127). Besides, soil CEC was also significantly and positively correlated with the presence of *E. heterophylla* (0.727) (Tab. 3). These results are similar to Oziegbe et al. (2010); active weed seedbanks at deeper soil depths lead to lower oxygen availability and reduce the access to light required to support germination. In addition, Hossain et al. (2021) that the seed bank of *A. conyzoides* was not found at a depth of 0-10 cm, but 10-15 cm, and experienced an additional seed bank of 43.82% during conventional tillage. Horowitz (1972) reported that 88% of *C. dactylon* rhizomes were found at a depth of 30 cm. Ekeleme et al. (2019) added that *E. heterophylla* had the second-highest abundance of 19.53% after *Tridax procumbens* in Benue State, Nigeria.

Excluído: SDR, diversity index, weed population due to tillage¶

The results showed that *C. rotundus* had the highest SDR in NT and T1 tillage, while *A. conyzoides* was dominant in T2 tillage. This was due to the presence of higher seed bank of *C. rotundus* and *A. conyzoides* at certain depths. Therefore, when the soil is tilled, the seedbanks trigger emergence on the soil surface. These results are similar to Hossain et al. (2021) which reported that up to 24% of the *C. rotundus* seed bank were found at a depth of 5-10 cm, while 21% of the *A. conyzoides* were found between 10-15 cm. Furthermore, Santín-Montanyá et al. (2013) reported that the weed abundance, diversity, and evenness were greatly increased in the no-tillage treatment. In this study, the results showed that the diversity index due to tillage (NT, T1, T2) was 2.261; 2.196; and 2.234 (moderate) (Tab. 2). The decrease in diversity index due to T1 and T2 compared to NT indicates that tillage decrease weed diversity. Mas & Verdú (2003) reported that the highest value of the Shannon-Wiener diversity index was found in the no-tillage treatment, while Amuri et al. (2010) suggested that no-tillage treatment contributes to the suppression of several weed species. Sepat et al. (2017) also reported that the lowest weed population was found in untilled beds.

The results showed that T2 tillage increased the broadleaf and total weeds. The population of sedges weeds increased at T1, but decreased during T2 tillage. In general, only grasses weeds decreased during T1 and T2 compared to NT, and the highest decrease was found at T1 tillage. This is linear with the Shannon-Wiener diversity index at T1, lower than other tillage (Tab. 2). These results are supported by Murphy et al. (2006) which reported that the weed density is only affected by tillage. Similarly, Hossain et al. (2021) said a decrease in the seed bank of grasses weed during conventional tillage by 76.31% at a depth of 0-5 cm compared to the no-tillage.

Cation Exchange Capacity (CEC) was significantly and positively correlated (0.727) with an increase in the population of *E. heterophylla*. The content of CEC and organic-C was also positively correlated but had an insignificant effect on the populations of *C. rotundus*, *C. rutidosperma*, *A. conyzoides*, and *M. pudica*. This was due to the higher content of CEC and organic-C in T1 and T2 compared to the NT (Fig. 4). When the weed seed bank at T1 and T2 emerged to the surface and received light and soil fertility than NT, it tends to support the growth of more weeds as indicated in the total weed population, which grows higher with increasing tillage (Fig. 3). These results are similar to Pätzold et al. (2020) which reported that soil organic-C affects weed species variability by 8.4%, while Gaston et al. (2001); Nordmeyer & Häusler (2004); Korres et al. (2017) reported that organic carbon, texture, and nutrients of soil affect the emergence of weeds. Furthermore, Dorneles et al. (2015) reported that reduced tillage had a higher CEC than the no-tillage at 0-5 cm and 5-10 cm depths.

Excluído: Correlation of organic-C and CEC to dominant weeds at different tillage¶

There was an increase in populations of *B. alata* (49), *B. mutica* (30), and *E. indica* (24) after spraying the ammonium glufosinate herbicide at a dose of 150 g ai.ha^{-1} with different tillage (NT, T1, T2), although *C. rotundus* (612) was more numerous than the other weeds. In general, four new weeds species, namely *G. maxima, L. oryzoides, S. dulcis*, and *A. oculatum* were found in NT, T1, and T2 due to the ammonium glufosinate herbicide. *Glyceria maxima* is a new weed species with the highest population in the NT, T1, and T2 tillage. Furthermore, the increase in population and new weed species was higher in the grasses weeds (*B. mutica, E. indica, G. maxima, L. oryzoides,* and *A. oculatum*) and two new species from the broadleaf weeds (*B. alata* and *S. dulcis*). Therefore, the ammonium glufosinate herbicide at different tillage decreased the abundance of broadleaf (Fig. 6) compared to the grasses weeds.

Excluído: **Changes in weed due to the ammonium glufosinate herbicide at different tillage¶**

Using herbicides on tillage (T1 and T2) exposed the seed bank of grasses weeds to the soil surface to adequately obtain oxygen and light needed for growth. This is supported by Wibawa et al. (2009), which reported that the herbicide of dose 200 g.ha^{-1} significantly suppressed broadleaf of 94.68% compared to the grasses weeds by 59.65% at two weeks after spraying. Tampubolon et al. (2019) also found that the herbicide at a dose of 300 g ai.ha^{-1} significantly removed 100% of the glyphosate-susceptible *E. indica*, while Alridiwirsah et al. (2020) reported that the grasses was higher by 52.76% compared to the broadleaf and sedges weeds in guava plants. In addition, Głowacka (2011) stated that the number of *Echinochloa crus-galli* (grasses weed) was more dominant with mechanical control (18.0 populations) and herbicides (10.3 populations) in maize plants compared to other weeds including *G. parviflora, Chenopodium album, Cirsium arvense,* and *Polygonum lapathifolium*. Uddin et al. (2018) also added the abundance of grasses weeds was higher by 130.1% than broadleaf (108.5%) and sedges (61.4%) weeds in the rice and potato cropping pattern.

CONCLUSIONS

The 2-time tillage (T2) increased the *A. conyzoides* (2.81-folds), *C. dactylon* (41 population), and *E. heterophylla* (2.43-folds) compared to the no-tillage (NT). *C. rotundus* had the highest SDR at NT and T1, while *A. conyzoides* was found in T2 tillage with a moderate diversity index. Based on the classification, only grasses weeds decreased in T1 and T2 tillage. Furthermore, there was a significant and positive correlation between *E. heterophylla* weed with cation exchange capacity (0.727). A total of four new species of weeds, namely *G. maxima, L. oryzoides, S. dulcis*, and *A. oculatum* were found on NT, T1, and T2 tillage due to the application of ammonium glufosinate herbicide.

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Research Article

Weed Diversity as Affected by Tillage and Ammonium Glufosinate Herbicide

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ABSTRACT

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage. It was conducted on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan City, Indonesia, from March to July 2021.

Furthermore, a non-factorial Randomized Block Design was used consisting of the no-tillage (NT), 1-time tillage (T1), and 2-times tillage (T2) with three replications. The procedures include identifying weed vegetation, sampling analysis of several soil chemical properties, and spraying the ammonium glufosinate herbicide at a dose of 150 g $ai.ha^{-1}$. Based on the result, the weed species of *Cyperus rotundus* and *Ageratum conyzoides* were dominant in different tillage. The diversity index of weed caused by the NT; T1; and T2 were 2.261; 2.196 and 2.234 (moderate/stable condition). The T2 showed increased *A. conyzoides*, *Cynodon dactylon*, and *Euphorbia heterophylla* were 2.82-folds; 41 populations and 2.43-folds compared to NT, while a decrease was observed in the grasses weed during T1 and T2 were 50.71 and 26.05%. Moreover, there was a positive and significant correlation between *E. heterophylla* weed on the soil cation exchange capacity (0.727). In contrast, four new weed species, namely *Glyceria maxima*, *Leersia oryzoides*, *Scoparia dulcis*, and *Anthoxanthum oculatum* were found due to ammonium glufosinate herbicide in different tillage.

Keywords: correlation; diversity index; dominance; tillage; weed abundance

Diversidad de malezas afectadas por labranza y por el herbicida glufosinato de amonio

RESUMO

Los agricultores de Indonesia suelen rociar herbicidas para controlar las malas hierbas y utilizar la labranza durante las primeras etapas del cultivo; en consecuencia, estas actividades afectan a la composición y diversidad de las malas hierbas. Por lo tanto, los objetivos de este estudio fueron: (1) informar el índice de dominancia y diversidad de malezas debido a la labranza, (2) obtener correlaciones de la abundancia de malezas en varias características químicas del suelo debido a la labranza, (3) obtener el efecto del herbicida glufosinato de amonio en la abundancia de malezas en diferentes labranzas. Se llevó a cabo en tierras de cultivo en Padang Bulan, subdistrito de Medan Selayang, Medan, Indonesia, de marzo a julio de 2021.

Además, se utilizó un diseño de bloques aleatorios no factorial que consistía en la no labranza (NT), la labranza de 1 vez (T1) y la labranza de 2 veces (T2) con tres repeticiones. Los procedimientos incluyen la identificación de la vegetación de malas hierbas, el análisis de muestras de varias propiedades químicas del suelo y la pulverización del herbicida glufosinato de amonio a una dosis de 150 g ai.ha-1. Según los resultados, las especies de malas hierbas *Cyperus rotundus* y *Ageratum conyzoides* fueron dominantes en las diferentes labranzas con un índice de diversidad moderado. El T2 mostró un aumento de *A. conyzoides*, *Cynodon dactylon* y *Euphorbia heterophylla* en comparación con el NT, mientras que se observó una disminución de las malas hierbas durante el laboreo uno y dos veces. Además, hubo una correlación positiva y significativa entre la maleza *E. heterophylla* en la capacidad de intercambio catiónico del suelo (0.727). Por el contrario, se encontraron cuatro nuevas especies de malas hierbas, a saber, *Glyceria maxima*, *Leersia oryzoides*, *Scoparia dulcis* y *Anthoxanthum oculatum*, debido al herbicida glufosinato de amonio en diferentes labranzas.

Palabras clave: correlación; índice de diversidad; dominancia; labranza; abundancia de malas hierbas

INTRODUCTION

Uncontrolled weeds on farmlands reduce production up to 80% (Cousens & Mortimer, 1995). Therefore, sustainable agricultural practices affect its abundance and density. The weed abundance in the farmland is influenced by several factors such as seed bank buried in the soil (Norris 2007), environmental factors (Fried et al. 2008; Pinke et al. 2012), availability of nutrients and fertilization (Murphy & Lemerle 2006; Chemona et al. 2016), tillage and crop rotation (Ulber et al. 2009; Nichols et al. 2015), and weed control through herbicides (Derksen et al. 1995).

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Menalled et al. (2001) showed that different agricultural management systems significantly affect weed abundance, diversity, and consistency in the short and long term (6 years). Meanwhile, Derksen et al. (1995) reported that the germination of *Synapsis avensis* and *Brassica napus* weeds after spraying with herbicides was higher in the no-tillage, but there was a reduction in total weeds. Thomas et al. (2004) also reported perennial weed species such as *Cirsium arvense* and *Sonchus arvensis* were reduced by tillage and no-tillage of 100 and 28.21%, while annual weeds were found in various tillage treatments. In addition, Trichard et al. (2013) stated that tillage favors weed seed bank germination and cause the extinction of other seeds.

On the other hand, different soil fertility in the planted area also affects the weed diversity (Yin et al. 2006). Fonge et al. (2013) reported that weed diversity is affected by organic-C content, nitrogen, calcium, and cation exchange capacity of the soil. Tang et al. (2014a) added that phosphorus+potassium (PK) fertilization increases the density of *Galium aparine*, *Vicia sativa*, *Veronica persica*, and *Geranium carolinianum* weeds compared to nitrogen+phosphorus (NP). Furthermore, Forcella et al. (2000) stated that the soil N concentration plays an important role in ending dormancy by removing germination constraints and stimulating seedling emergence. Tang et al. (2014b) reported that soil available-P is the primary nutrient, regulating the composition of weed species and diversity, followed by N and K nutrients.

The knowledge of farmers on the relationship between tillage and soil fertility status with weed diversity is relatively poor. The interviews conducted in this study showed that the farmers only carry out land clearing and manual tillage before planting, had never used herbicides, and unknowingly the soil fertility status. However, a new problem was found: weed growth was very rapid in a short time (2 days). Therefore, intensive control during one main crop cycle is highly needed. This problem persisted during crop rotation. Unnoticed by farmers, these activities impact the storage of the weed seed bank, and the tillage carried out, resulting in the weed seed bank at a certain depth of soil emerging to the soil surface. Studies on weed identification are needed to provide information on the relationship between soil fertility on the dominant weeds and the use of one herbicide with a recommended dose to suppress the presence of weeds. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage.

MATERIAL AND METHODS

This study was carried out on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan (Indonesia) with the condition of continuous land use and a history of crop rotation for the last two years for corn, cucumber, and cowpea as well as manual tillage using a hoe, without the use of herbicides based on interviews with farmers. This study was conducted from March to July 2021.

This study used a non-factorial Randomized Block Design with three replications: no-tillage, 1-time and 2-times tillage systems. The land was cleared and then plotted with the square method of 1 m × 1 m and an interval of 2 m. Each plot was demarcated with plastic ropes at a distance of 0.2 m (Fig. 1).

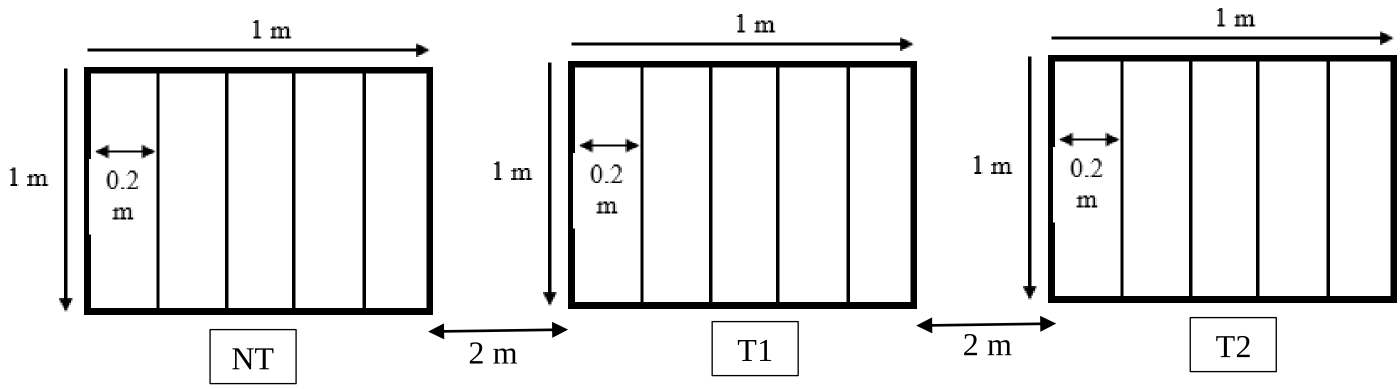


Figure 1. The size of tillage plots (NT; T1; T2) with the square method.

Tillage was carried out by hoeing as deep as 20 cm. Meanwhile, the land was incubated for a month and then identified for weed vegetation using the flora book and applying formulas according to Kent (2012) such as absolute density (defined as the number of individual weed species in the sample plot), relative density, absolute frequency (defined as the number of sample plots containing certain species), relative frequency, importance value, and the summed dominance ratio (SDR) as shown in equation 1-4.

$$\text{Relative Density (RD)} = \frac{\text{The absolute density of a certain species}}{\text{Total absolute density of all species}} \times 100\% \tag{1}$$

$$\text{Relative Frequency (RF)} = \frac{\text{The absolute frequency of a certain species}}{\text{Total absolute frequencies of all species}} \times 100\% \tag{2}$$

$$\text{Importance Value (IV)} = \text{Relative Density (RD)} + \text{Relative Frequency (RF)} \tag{3}$$

$$\text{Summed Dominance Ratio} = \frac{\text{Relative Density (RD)} + \text{Relative Frequency (RF)}}{2} \tag{4}$$

Weed populations based on morphology (broadleaf, grasses, sedges) and total weeds were calculated. The species diversity index was calculated using the Shannon-Wiener index formula (Shannon & Weaver 1949):

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right) \left(\ln \frac{ni}{N}\right)$$

Note:

H'= Species diversity index

ni = The proportion of species *i*

N = The total number of species

ln = natural logarithm

The classification of the diversity index value for each tillage was conducted based on Magurran (1988) stated that if $H'<1$ (low), $1<H'<3$ (moderate) and $H'>3$ (high). Soil samples at a depth of 0-20 cm were taken using a drill with a diagonal method on each plot. Then it performed analysis on organic-C (Walkley & Black method) and cation exchange capacity/CEC (ammonium acetate pH 7) using a spectrophotometer at Socfin Indonesia Inc., Medan (Indonesia). At first, a natural logarithm was carried out on the organic-C, CEC data, and the total of dominant weeds as well as analyzed using the Pearson correlation.

The ammonium glufosinate herbicide was applied on 27 April 2021 at 10.00 to all plots of tillage (NT; T1; T2) at a dose of 150 g a.i.ha^{-1} after a spray calibration was carried out. Climatic data were recorded during spraying, such as temperature 28°C, humidity 83%, and air pressure 1002 hPa. Weed survival data were measured at 6 weeks after spraying (WAS). The spraying by manual spray equipment (Solo Model) with an operating pressure and application volume were 2 kg cm^{-2} and 202.90 L ha^{-1}. Weeds are sprayed with a height up to 60 cm. The data of weeds (broadleaf, grasses, sedges, total) and soil (organic-C, CEC) were processed using an ANOVA and followed by the DMRT at P<0.05 using IBM SPSS v.20 software.

RESULTS AND DISCUSSION

The field observations obtained 16 species (*Ageratum conyzoides*, *Asystasia gangetica*, *Axonopus compressus*, *Borreria alata*, *Brachiaria mutica*, *Cleome rutidosperma*, *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Euphorbia heterophylla*, *Galinsoga parviflora*, *Mimosa pudica*, *Oxalis corniculata*, *Pennisetum purpureum*, *Polanisia icosandra*, and *Stylochaeton lancifolius*) with 6639 populations from three tillage systems (NT, T1, T2) as presented in Fig. 2. The result showed that three dynamic patterns due to tillage, such as (1) an increase in the weed diversity due to 2-time tillage for *A. conyzoides*, *C. dactylon*, and *E. heterophylla*, (2) a decrease in weed diversity due to 2-time tillage for *A. gangetica*, *A. compressus*, *B. alata*, *C. rutidosperma*, and *E. indica*, (3) a fluctuating pattern, indicating a decrease in weed species in 1-time tillage and then an increase in 2-time tillage or vice versa for *B. mutica*, *G. parviflora*, *M. pudica*, *O. corniculata*, *P. purpureum*, *P. icosandra*, and *S. lancifolius*.

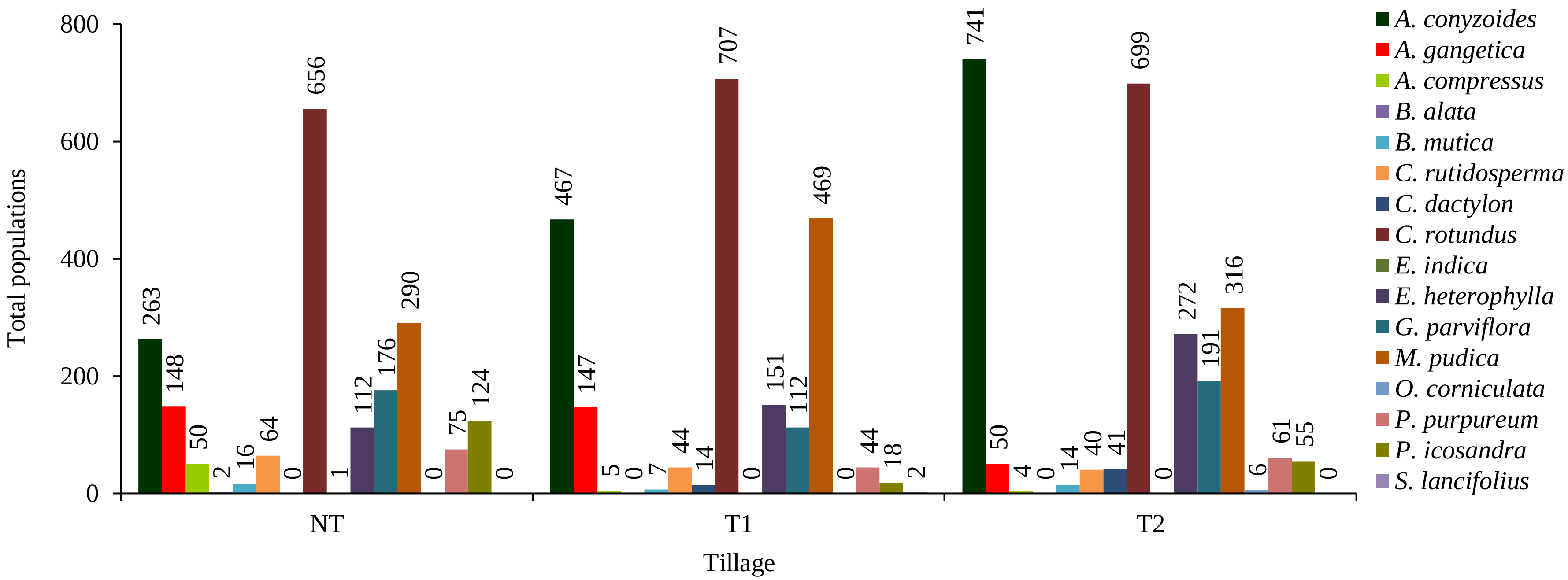


Figure 2. Total populations of weeds due to tillage. NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage.

The tillage had an insignificant effect on the number of broadleaf, grasses, sedges, and total weeds (Fig. 3). However, increasing the tillage by 2-times (T2) increased the broadleaf population and total weeds by 41.73% and 25.19%, respectively, compared to no-tillage (NT). Furthermore, the population of sedges weeds increased at 1-time tillage (T1) by 7.77% compared to NT and decreased to 6.55% at 2-times tillage (T2). The population of grasses weeds experienced the highest decrease in 1-time tillage (T1) of 50.71% compared to NT.

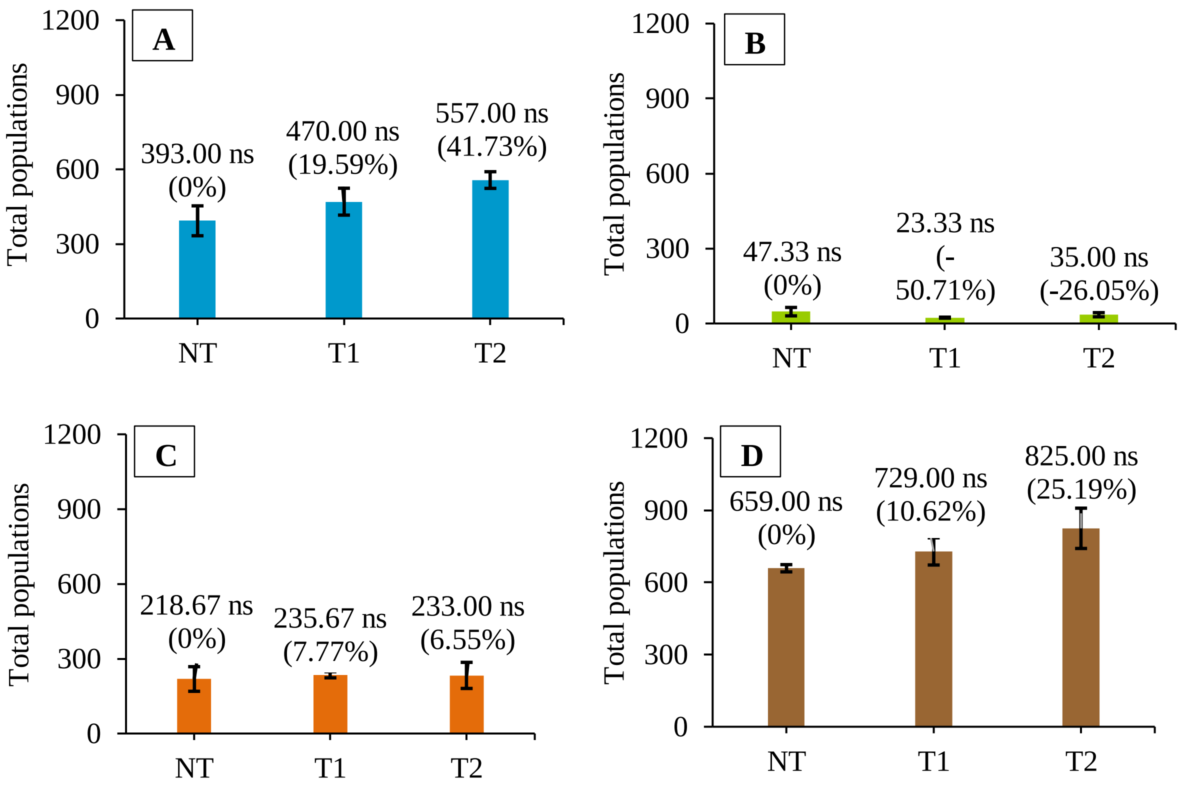
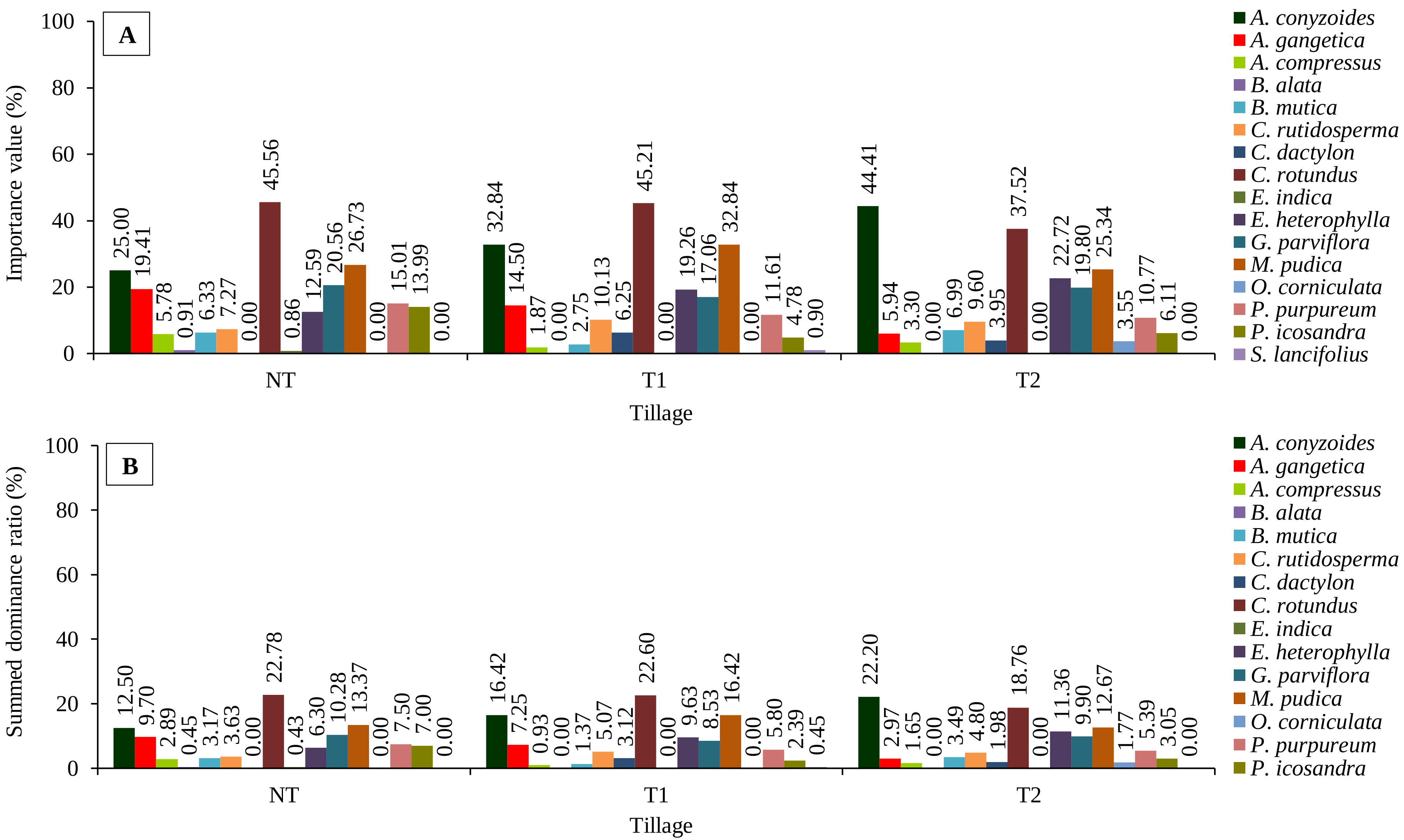


Figure 3. Weed populations based on morphology (A= broadleaf; B= grasses; C= sedges) and total weeds (D) due to tillage (NT=no tillage, T1= 1-time tillage, T2= 2-times tillage). The values followed by the ns (not-significant) in the graph are not significantly different at the 5% level based on the DMRT. The vertical line shows the standard error.

The dominant weeds (SDR) and diversity index due to tillage are presented in Fig. 4 and Tab 1. In the no-tillage (NT) treatment found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *C. rutidosperma*, and *P. icosandra* of

22.78%; 13.37%; 12.50%; 10.90%; and 10.49%, respectively. In the 1-time tillage (T1) found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *A. gangetica*, and *E. heterophylla* of 22.61%; 16.42%; 16.41%; 10.87%; and 9.63%, respectively. Moreover, in the 2-times tillage (T2) also found in five species with the highest SDR sequentially were *A. conyzoides*, *C. rotundus*, *M. pudica*, *E. heterophylla*, and *G. parviflora* by 22.20%; 18.76%; 12.67%; 11.36%; and 9.90%, respectively. The diversity index (H') due to tillage (NT, T1, T2) were 2.261; 2.196 and 2.234 respectively, therefore it was moderate.

The tillage significantly increased cation exchange capacity (CEC) but it had insignificant effect on soil organic-C (Fig. 5). There was an increase in the CEC due to T1 and T2 by 16.56% and 13.14%, respectively. The correlation analysis of soil organic-C and CEC on the dominant weed population due to tillage is presented in Tab. 2. The results showed that only CEC had a significant and positive correlation in increasing the *E. heterophylla* by 0.727, but it was insignificant for *C. rotundus* and *C. rutidosperma*. Similarly, soil organic-C had an insignificant effect but was positively correlated to the population of *C. rotundus, A. conyzoides, M. pudica*, and *E. heterophylla*.



205 Figure 4. Importance value (A) and summed dominance ratio (B) of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage).

Table 1. Diversity index of weeds due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage).

Family	Weeds Species	H’		
		NT	T1	T2
Asteraceae	*A. conyzoides*	0.260	0.297	0.334
	G. parviflora	0.234	0.210	0.229
Acanthaceae	*A. gangetica*	0.226	0.190	0.104
Araceae	*S. lancifolius*	-	0.024	-
Capparaceae	*C. rutidosperma*	0.120	0.151	0.146
Capparidaceae	*P. icosandra*	0.186	0.089	0.107
Cyperaceae	*C. rotundus*	0.337	0.336	0.314
Euphorbiaceae	*E. heterophylla*	0.174	0.225	0.247
Fabaceae	*M. pudica*	0.269	0.297	0.262
Oxalidaceae	*O. corniculata*	-	-	0.072
Poaceae	*A. compressus*	0.102	0.044	0.068
	B. mutica	0.109	0.059	0.117
	C. dactylon	-	0.108	0.078
	E. indica	0.023	-	-
	P. purpureum	0.194	0.165	0.157
Rubiaceae	*B. alata*	0.024	-	-
	Total	2.261	2.196	2.234

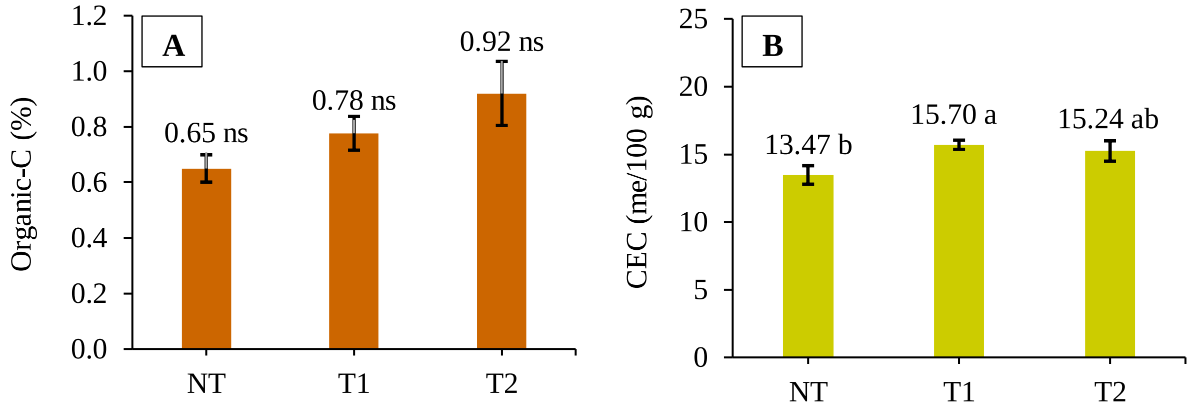


Figure 5. The soil organic-C (A) and cation exchange capacity (B) properties due to tillage (NT= no-tillage; T1= 1-time tillage; T2= 2-times tillage). The values followed by the different letter in the graph are significantly at the 5% level based on the DMRT. The vertical line shows the standard error. ns= not-significant.

Table 2. Correlation analysis of organic-C and CEC of the soil on the dominant weed populations due to tillage.

Dominant weed species	Correlation coefficient	
	Organic-C	CEC
C. rotundus	0.449^{ns}	0.262^{ns}
A. conyzoides	0.132^{ns}	-0.154^{ns}
M. pudica	0.147^{ns}	-0.054^{ns}
E. heterophylla	0.127^{ns}	0.727^{*}
G. parviflora	-0.063^{ns}	-0.240^{ns}
A.gangetica	-0.298^{ns}	-0.482^{ns}
P. icosandra	-0.021^{ns}	-0.646^{ns}
C. rutidosperma	-0.095^{ns}	0.591^{ns}

Note: Correlation is significant at the 0.05 level (2-tailed). ns= not-significant.

Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g ai.ha^{-1} on different tillage (NT, T1, T2) by species are presented in Fig. 6. The results showed an increase in *B. alata* and *B. mutica* due to the ammonium glufosinate in NT and 2-times tillage (T2). Meanwhile, others decreased, and two new weed species were found in NT, such as *Glyceria maxima* and *Leersia oryzoides,* and one new weed species were found in T2 (*G. maxima*). Similarly, the 1-time tillage (T1) increased *B. alata, B. mutica,* and *E. indica*. At the same time, other populations decreased, and four new weed species were found, namely *G. maxima*, *L. oryzoides, Scoparia dulcis,* and *Anthoxanthum oculatum*.

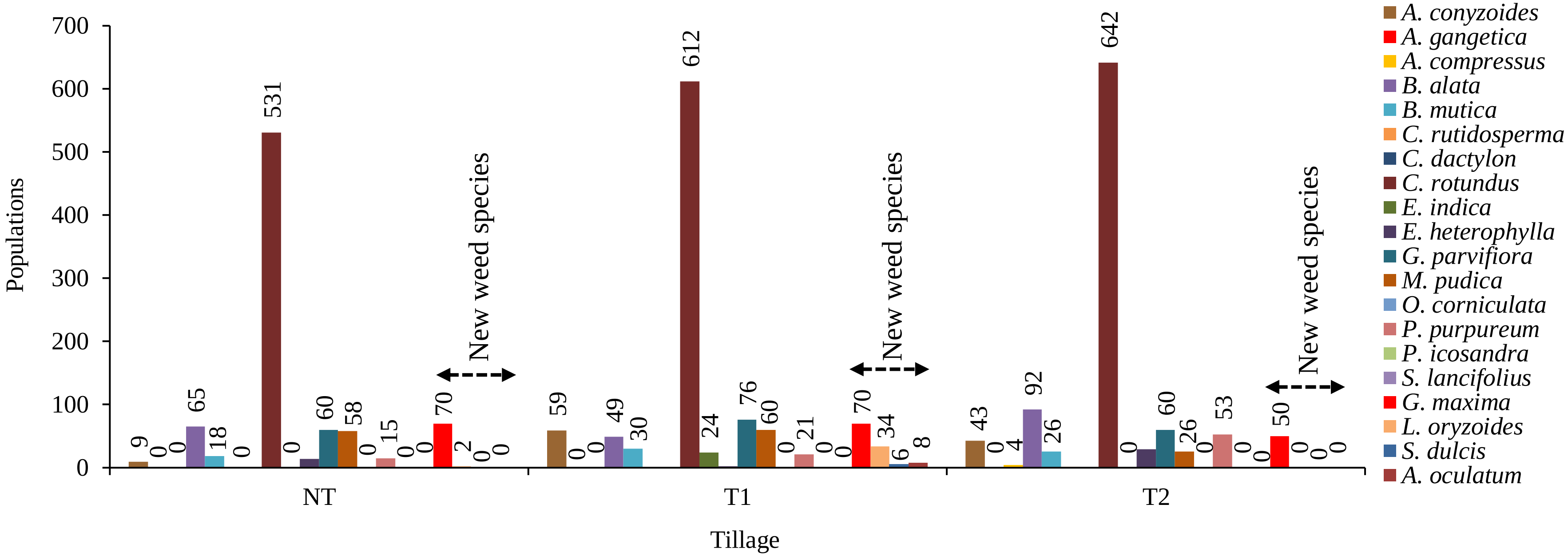


Figure 6. Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g a.i.ha^{-1} on different tillage.

Based on morphology, the effectiveness of ammonium glufosinate on the weed-type abundance at different tillage (NT, T1, T2) is presented in Fig. 7. The herbicide application can decrease the abundance of broadleaf weeds by 82.13-84.98% and sedges by 8.15-19.05%. However, there was an increase in the grasses weed abundance in T1 and T2 tillage by 167.74% and 26.67%, respectively.

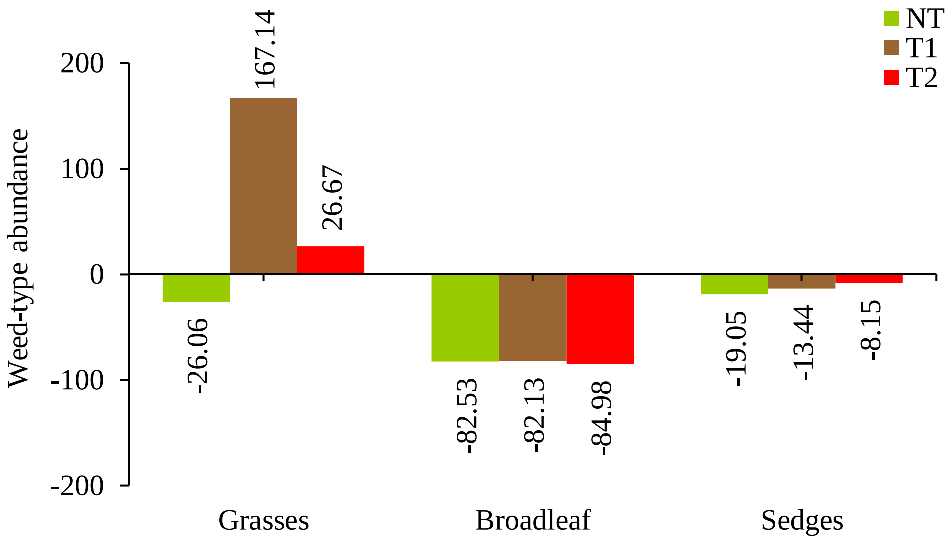


Figure 7. The effectiveness of ammonium glufosinate on the weed-type abundance at different tillage.

Based on the results, there were three dynamic patterns of weed diversity due to tillage, namely increasing, decreasing, and fluctuating patterns. The increasing weed species due to 2-times tillage (T2) include *A. conyzoides* (2.82-folds), *C. dactylon* (41 populations), and *E. heterophylla* (2.43-folds) compared to no-tillage (NT). It was caused by the seed banks of *A. conyzoides*, *C. dactylon*, and *E. heterophylla* during T2 tillage were triggered the emergence to the soil surface. Furthermore, soil fertility also supported its growth more rapidly. This was supported by the organic-C, which was positively correlated with the presence of *A. conyzoides* (0.132) and *E. heterophylla* (0.127). Besides, soil CEC was also significantly and positively correlated with the presence of *E. heterophylla* (0.727) (Tab. 2). These results are similar to

Oziegbe et al. (2010); active weed seedbanks at deeper soil depths lead to lower oxygen availability and reduce the access to light required to support germination. In addition, Hossain et al. (2021) that the seed bank of *A. conyzoides* was not found at a depth of 0-10 cm, but 10-15 cm, and experienced an additional seed bank of 43.82% during conventional tillage. Horowitz (1972) reported that 88% of *C. dactylon* rhizomes were found at a depth of 30 cm. Ekeleme et al. (2019) added that *E. heterophylla* had the second-highest abundance of 19.53% after *Tridax procumbens* in Benue State, Nigeria.

The results showed that *C. rotundus* had the highest SDR in NT and T1 tillage, while *A. conyzoides* was dominant in T2 tillage. This was due to the presence of higher seed bank of *C. rotundus* and *A. conyzoides* at certain depths. Therefore, when the soil is tilled, the seedbanks trigger emergence on the soil surface. These results are similar to Hossain et al. (2021) which reported that up to 24% of the *C. rotundus* seed bank were found at a depth of 5-10 cm, while 21% of the *A. conyzoides* were found between 10-15 cm. Furthermore, Santín-Montanyá et al. (2013) reported that the weed abundance, diversity, and evenness were greatly increased in the no-tillage treatment. In this study, the results showed that the diversity index due to tillage (NT, T1, T2) was 2.261; 2.196; and 2.234 (moderate) (Tab. 1). The decrease in diversity index due to T1 and T2 compared to NT indicates that tillage decrease weed diversity. Mas & Verdú (2003) reported that the highest value of the Shannon-Wiener diversity index was found in the no-tillage treatment, while Amuri et al. (2010) suggested that no-tillage treatment contributes to the suppression of several weed species. Sepat et al. (2017) also reported that the lowest weed population was found in untilled beds.

The results showed that T2 tillage increased the broadleaf and total weeds. The population of sedges weeds increased at T1, but decreased during T2 tillage. In general, only grasses weeds decreased during T1 and T2 compared to NT, and the highest decrease was found at T1 tillage. This is linear with the Shannon-Wiener diversity index at T1, lower than other tillage (Tab. 1). These results are supported by Murphy et al. (2006) which reported that the weed density is only affected by tillage. Similarly, Hossain et al. (2021) said a decrease in the seed bank of grasses weed during conventional tillage by 76.31% at a depth of 0-5 cm compared to the no-tillage.

Cation Exchange Capacity (CEC) was significantly and positively correlated (0.727) with an increase in the population of *E. heterophylla*. The content of CEC and organic-C was also positively correlated but had an insignificant effect on the populations of *C. rotundus*, *C. rutidosperma*, *A. conyzoides*, and *M. pudica*. This was due to the higher content of CEC and organic-C in T1 and T2 compared to the NT (Fig. 5). When the weed seed bank at T1 and T2 emerged to the surface and received light and soil fertility than NT, it tends to support the growth of more weeds as indicated in the total weed population, which grows higher with increasing tillage (Fig. 3). These results are similar to Pätzold et al. (2020) which reported that soil organic-C affects weed species variability by 8.4%, while Gaston et al. (2001); Nordmeyer & Häusler (2004); Korres et al. (2017) reported that organic carbon, texture, and nutrients of soil affect the emergence of weeds. Furthermore, Dorneles et al. (2015) reported that reduced tillage had a higher CEC than the no-tillage at 0-5 cm and 5-10 cm depths.

There was an increase in populations of *B. alata* (49), *B. mutica* (30), and *E. indica* (24) after spraying the ammonium glufosinate herbicide at a dose of 150 g ai.ha^{-1} with different tillage (NT, T1, T2), although *C. rotundus* (612) was more numerous than the other weeds. In general, four new weeds species, namely *G. maxima, L. oryzoides, S. dulcis,* and *A. oculatum* were found in NT, T1, and T2 due to the ammonium glufosinate herbicide. *Glyceria maxima* is a new weed species with the highest population in the NT, T1, and T2 tillage. Furthermore, the increase in population and new weed species was higher in the grasses weeds (*B. mutica, E. indica, G. maxima, L. oryzoides,* and *A. oculatum*) and two new species from the broadleaf weeds (*B. alata* and *S. dulcis*). Therefore, the ammonium glufosinate herbicide at different tillage decreased the abundance of broadleaf (Fig. 7) compared to the grasses weeds.

Using herbicides on tillage (T1 and T2) exposed the seed bank of grasses weeds to the soil surface to adequately obtain oxygen and light needed for growth. This is supported by Wibawa et al. (2009), which reported that the herbicide of dose 200 $g.ha^{-1}$ significantly suppressed broadleaf of 94.68% compared to the grasses weeds by 59.65% at two weeks after spraying. Tampubolon et al. (2019) also found that the ammonium glufosinate herbicide at a dose of 300 g $ai.ha^{-1}$ significantly removed 100% of the glyphosate-susceptible *E. indica*, while Alridiwirsah et al. (2020) reported that the grasses was higher by 52.76% compared to the broadleaf and sedges weeds in guava plants. In addition, Głowacka (2011) stated that the number of *Echinochloa crus-galli* (grasses weed) was more dominant with mechanical control (18.0 populations) and herbicides (10.3 populations) in maize plants compared to other weeds including *G. parviflora, Chenopodium album, Cirsium arvense,* and *Polygonum lapathifolium*. Uddin et al. (2018) also added the abundance of grasses weeds was higher by 130.1% than broadleaf (108.5%) and sedges (61.4%) weeds in the rice and potato cropping pattern.

CONCLUSIONS

The 2-time tillage (T2) increased the *A. conyzoides* (2.81-folds), *C. dactylon* (41 population), and *E. heterophylla* (2.43-folds) compared to the no-tillage (NT). *C. rotundus* had the highest SDR at NT and T1, while *A. conyzoides* was found in T2 tillage with a moderate diversity index. Based on the classification, only grasses weeds decreased in T1 and T2 tillage. Furthermore, there was a significant and positive correlation between *E. heterophylla* weed with cation exchange capacity (0.727). A total of four new species of weeds, namely *G. maxima, L. oryzoides, S. dulcis,* and *A. oculatum* were found on NT, T1, and T2 tillage due to the application of ammonium glufosinate herbicide.

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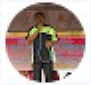

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I request that a careful reading be made, so that any problem, incidentally arising from the review process of the article, be identified and pointed out.

If the authors have a photo of the experiment, please send it to us, so that we can use it for advertising the article.

Best wishes,

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Weed diversity as affected by tillage and ammonium glufosinate herbicide

Weed diversity as affected by tillage and ammonium glufosinate herbicide

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Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage. Furthermore, a non-factorial Randomized Block Design was used consisting of the no-tillage (NT), 1-time tillage (T1), and 2-times tillage (T2) with three replications. The procedures include identifying weed vegetation, sampling analysis of several soil chemical properties, and spraying the ammonium glufosinate herbicide at a dose of 150 g ai ha^{-1}. Based on the result, the weed species of *Cyperus rotundus* and *Ageratum conyzoides* were dominant in different tillage. The diversity index of weed caused by the NT; T1; and T2 were 2.261; 2.196 and 2.234 (moderate/stable condition). The T2 showed increased *A. conyzoides*, *Cynodon dactylon*, and *Euphorbia heterophylla* were 2.82-folds; 41 populations and 2.43-folds compared to NT, while a decrease was observed in the grasses weed during T1 and T2 were 50.71 and 26.05 %. Moreover, there was a positive and significant correlation between *E. heterophylla* weed on the soil cation exchange capacity (0.727). In contrast, four new weed species, namely *Glyceria maxima, Leersia oryzoides, Scoparia dulcis*, and *Anthoxanthum oculatum* were found due to ammonium glufosinate herbicide in different tillage.

KEYWORDS: Correlation, diversity index, dominance, tillage [please, provide more meaningful words], weed abundance.

The Title, Abstract and Keywords should be presented in Portuguese, not Spanish!

Diversidad de malezas afectadas por labranza y por el herbicida glufosinato de amonio

Los agricultores de Indonesia suelen rociar herbicidas para controlar las malas hierbas y utilizar la labranza durante las primeras etapas del cultivo; en consecuencia, estas actividades afectan a la composición y diversidad de las malas hierbas. Por lo tanto, los objetivos de este estudio fueron: (1) informar el índice de dominancia y diversidad de malezas debido a la labranza, (2) obtener correlaciones de la abundancia de malezas en varias características químicas del suelo debido a la labranza, (3) obtener el efecto del herbicida glufosinato de amonio en la abundancia de malezas en diferentes labranzas. Además, se utilizó un diseño de bloques aleatorios no factorial que consistía en la no labranza (NT), la labranza de 1 vez (T1) y la labranza de 2 veces (T2) con tres repeticiones. Los procedimientos incluyen la identificación de la vegetación de malas hierbas, el análisis de muestras de varias propiedades químicas del suelo y la pulverización del herbicida glufosinato de amonio a una dosis de 150 g ai.ha-1. Según los resultados, las especies de malas hierbas *Cyperus rotundus* y *Ageratum conyzoides* fueron dominantes en las diferentes labranzas con un índice de diversidad moderado. El T2 mostró un aumento de *A. conyzoides*, *Cynodon dactylon* y *Euphorbia heterophylla* en comparación con el NT, mientras que se observó una disminución de las malas hierbas durante el laboreo uno y dos veces. Además, hubo una correlación positiva y significativa entre la maleza *E. heterophylla* en la capacidad de intercambio catiónico del suelo (0.727). Por el contrario, se encontraron cuatro nuevas especies de malas hierbas, a saber, *Glyceria maxima, Leersia oryzoides, Scoparia dulcis* y *Anthoxanthum oculatum*, debido al herbicida glufosinato de amonio en diferentes labranzas.

Palabras clave: correlación; índice de diversidad; dominancia; labranza; abundancia de malas hierbas

INTRODUCTION

Uncontrolled weeds on farmlands reduce production up to 80 % (Cousens & Mortimer 1995). Therefore, sustainable agricultural practices affect its abundance and density. The weed abundance in the farmland is influenced by several factors such as seed bank buried in the soil (Norris 2007), environmental factors (Fried et al. 2008, Pinke et al. 2012), availability of nutrients and fertilization (Murphy & Lemerle 2006, Cheimona et al. 2016), tillage and crop rotation (Ulber et al. 2009, Nichols et al. 2015), and weed control through herbicides (Derksen et al. 1995).

Farmers in Indonesia generally spray herbicides to control weeds and utilize tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Menalled et al. (2001) showed that different agricultural management systems significantly affect weed abundance, diversity, and consistency in the short and long term (6 years). Meanwhile, Derksen et al. (1995) reported that the germination of *Synapsis avensis* and *Brassica napus* weeds after spraying with herbicides was higher in the no-tillage, but there was a reduction in total weeds. Thomas et al. (2004) also reported perennial weed species such as *Cirsium arvense* and *Sonchus arvensis* were reduced by tillage and no-tillage of 100 and 28.21 %, while annual weeds were found in various tillage treatments. In addition, Trichard et al. (2013) stated that tillage favors weed seed bank germination and cause the extinction of other seeds.

On the other hand, different soil fertility in the planted area also affects the weed diversity (Yin et al. 2006). Fonge et al. (2013) reported that weed diversity is affected by organic-C content, nitrogen, calcium, and cation exchange capacity of the soil. Tang et al. (2014a) added that phosphorus+potassium (PK) fertilization increases the density of *Galium aparine, Vicia sativa, Veronica persica*, and *Geranium carolinianum* weeds compared to nitrogen + phosphorus (NP). Furthermore, Forcella et al. (2000) stated that the soil N concentration plays an important role in ending dormancy by removing germination constraints and stimulating seedling emergence. Tang et al. (2014b) reported that soil available-P is the primary nutrient, regulating the composition of weed species and diversity, followed by N and K nutrients.

The knowledge of farmers on the relationship between tillage and soil fertility status with weed diversity is relatively poor. The interviews conducted in this study showed that the farmers only carry out land clearing and manual tillage before planting, had never used herbicides, and unknowingly the soil fertility status. However, a new problem was found: weed growth was very rapid in a short time (2 days). Therefore, intensive control during one main crop cycle is highly needed. This problem persisted during crop rotation. Unnoticed by farmers, these activities impact the storage of the weed seed bank, and the tillage carried out, resulting in the weed seed bank at a certain depth of soil emerging to the soil surface. Studies on weed identification are needed to provide information on the relationship between soil fertility on the dominant weeds and the use of one herbicide with a recommended dose to suppress the presence of weeds. Therefore, this study aims were: (1) informing the dominance and diversity index of weeds due to tillage, (2) obtaining correlations of weed abundance on several soil chemical characteristics due to tillage, (3) obtaining the effect of the ammonium glufosinate herbicide on weed abundance in different tillage.

MATERIAL AND METHODS

This study was carried out on farmland in Padang Bulan, Medan Selayang Subdistrict, Medan (Indonesia) (please, present latitude, longitude, altitute and soil type) with the condition of continuous land use and a history of crop rotation for the last two years for corn, cucumber, and cowpea as well as manual tillage using a hoe, without the use of herbicides based on interviews with farmers. This study was conducted from March to July 2021.

This study used a non-factorial Randomized Block Design with three replications: no-tillage, 1-time and 2-times tillage systems. The land was cleared and then plotted with the square method of 1 m × 1 m and an interval of 2 m. Each plot was demarcated with plastic ropes at a distance of 0.2 m (Figure 1).

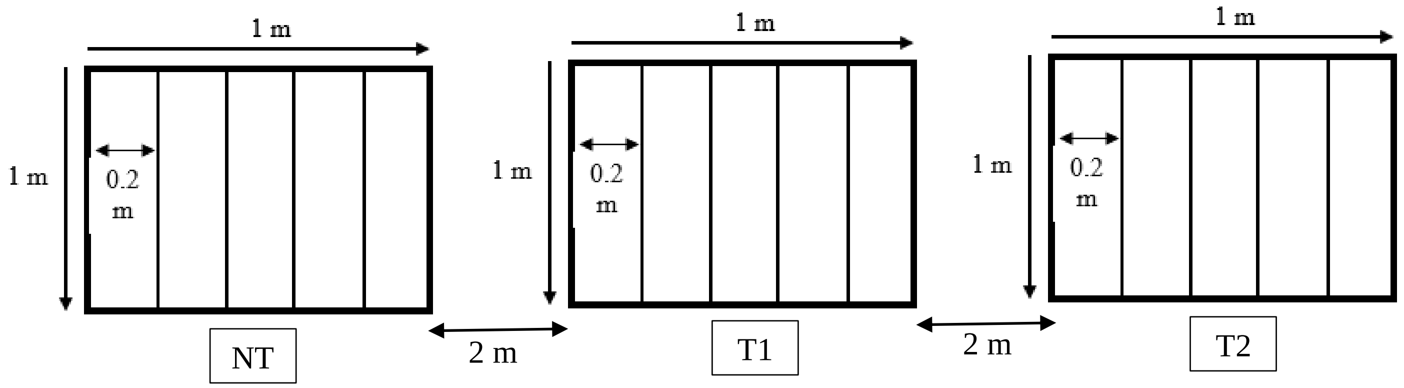

Figure 1. The size of tillage plots (NT; T1; T2) with the square method. [This Figure should be replaced by information presented directly in the text]

Tillage was carried out by hoeing as deep as 20 cm. Meanwhile, the land was incubated for a month and then identified for weed vegetation using the flora book and applying formulas according to Kent (2012) such as absolute density (defined as the number of individual weed species in the sample plot), relative density, absolute frequency (defined as the number of sample plots containing certain species), relative frequency, importance value, and the summed dominance ratio (SDR) as shown in equation 1-4.

$$\text{Relative Density (RD)} = \frac{\text{The absolute density of a certain species}}{\text{Total absolute density of all species}} \times 100\ \% \qquad (1)$$

$$\text{Relative Frequency (RF)} = \frac{\text{The absolute frequency of a certain species}}{\text{Total absolute frequencies of all species}} \times 100\ \% \qquad (2)$$

$$\text{Importance Value (IV)} = \text{Relative Density (RD)} + \text{Relative Frequency (RF)} \qquad (3)$$

$$\text{Summed Dominance Ratio} = \frac{\text{Relative Density (RD)} + \text{Relative Frequency (RF)}}{2} \qquad (4)$$

Weed populations based on morphology (broadleaf, grasses, sedges) and total weeds were calculated. The species diversity index was calculated using the Shannon-Wiener index formula (Shannon & Weaver 1949):

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right) \left(\ln \frac{ni}{N}\right)$$

where: H’ is the species diversity index; ni the proportion of species *I*; N the total number of species; and ln the natural logarithm.

The classification of the diversity index value for each tillage was conducted based on Magurran (1988) stated that if $H' < 1$ (low), $1 < H' < 3$ (moderate) and $H' > 3$ (high). Soil samples at a depth of 0-20 cm were taken using a drill with a diagonal method on each plot. Then it performed analysis on organic-C (Walkley & Black method) and cation exchange capacity/CEC (ammonium acetate pH 7) using a spectrophotometer at Socfin Indonesia Inc., Medan (Indonesia). At first, a natural logarithm was carried out on the organic-C, CEC data, and the total of dominant weeds as well as analyzed using the Pearson correlation.

The ammonium glufosinate herbicide was applied on 27 April 2021 at 10.00 to all plots of tillage (NT; T1; T2) at a dose of 150 g a.i. ha^{-1} after a spray calibration was carried out. Climatic data were recorded during spraying, such as temperature 28 ºC, humidity 8 3%, and air pressure 1002 hPa. Weed survival data were measured at 6 weeks after spraying (WAS). The spraying by manual spray equipment (Solo Model) with an operating pressure and application volume were 2 kg cm^{-2} and 202.90 L ha^{-1}. Weeds are sprayed with a height up to 60 cm. The data of weeds (broadleaf, grasses, sedges, total) and soil (organic-C, CEC) were processed using an Anova and followed by the DMRT at $p < 0.05$ using IBM SPSS v.20 software.

RESULTS AND DISCUSSION

The field observations obtained 16 species (*Ageratum conyzoides*, *Asystasia gangetica*, *Axonopus compressus*, *Borreria alata*, *Brachiaria mutica*, *Cleome rutidosperma*, *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Euphorbia heterophylla*, *Galinsoga parviflora*, *Mimosa pudica*, *Oxalis corniculata*, *Pennisetum purpureum*, *Polanisia icosandra* and *Stylochaeton lancifolius*) with 6639 populations from three tillage systems (NT, T1, T2) as presented in Figure 2. The result showed that three dynamic patterns due to tillage, such as (1) an increase in the weed diversity due to 2-time tillage for *A. conyzoides*, *C. dactylon* and *E. heterophylla*, (2) a decrease in weed diversity due to 2-time tillage for *A. gangetica*, *A. compressus*, *B. alata*, *C. rutidosperma* and *E. indica*, (3) a fluctuating pattern, indicating a decrease in weed species in 1-time tillage and then an increase in 2-time tillage or vice versa for *B. mutica*, *G. parviflora*, *M. pudica*, *O. corniculata*, *P. purpureum*, *P. icosandra* and *S. lancifolius*.

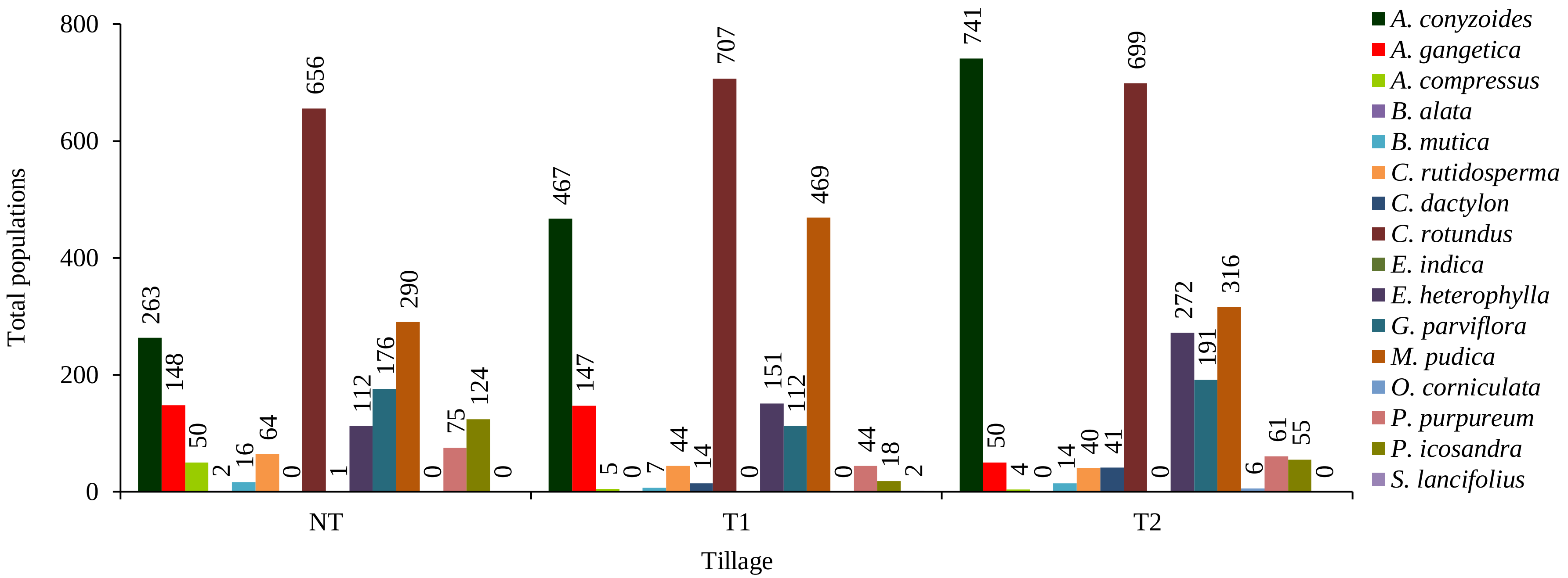

Figure 2. Total populations of weeds due to tillage. NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage.

[Please, do not abbreviate the species names]

The tillage had an insignificant effect on the number of broadleaf, grasses, sedges, and total weeds (Figure 3). However, increasing the tillage by 2-times (T2) increased the broadleaf population and total weeds by 41.73 and 25.19 %, respectively, compared to no-tillage (NT). Furthermore, the population of sedges weeds increased at 1-time tillage (T1) by 7.77 % compared to NT and decreased to 6.55 % at 2-times tillage (T2). The population of grasses weeds experienced the highest decrease in 1-time tillage (T1) of 50.71 % compared to NT.

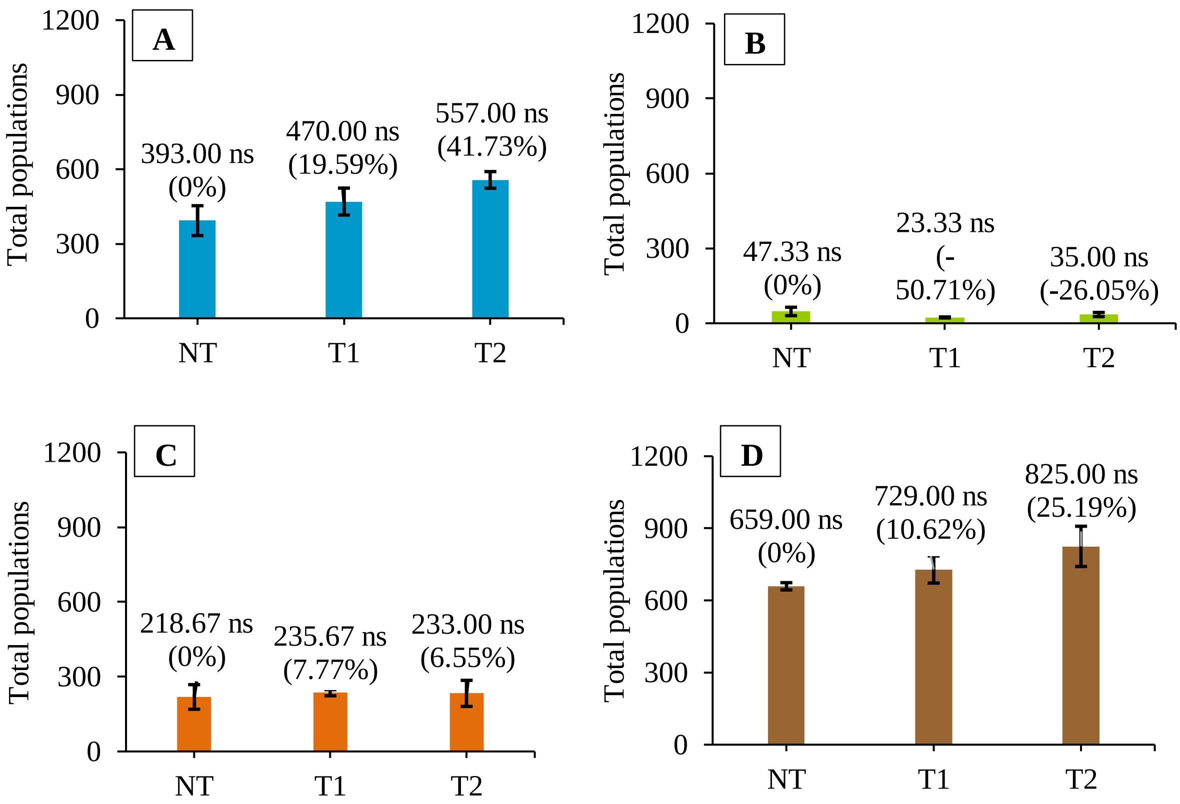

Figure 3. Weed populations based on morphology (A: broadleaf; B: grasses; C: sedges) and total weeds (D) due to tillage (NT: no tillage; T1: 1-time tillage; T2: 2-times tillage). The values followed by the ns (not-significant) in the graph are not significantly different at the 5 % level based on the DMRT. The vertical line shows the standard error.

The dominant weeds (SDR) and diversity index due to tillage are presented in Figure 4 and Table 1. In the no-tillage (NT) treatment found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *C. rutidosperma*, and *P. icosandra* of 22.78, 13.37, 12.50, 10.90 and 10.49 %, respectively. In the 1-time tillage (T1) found in five species with the highest SDR sequentially were *C. rotundus*, *M. pudica*, *A. conyzoides*, *A. gangetica*, and *E. heterophylla* of 22.61, 16.42, 16.41, 10.87 and 9.63 %, respectively. Moreover, in the 2-times tillage (T2) also found in five species with the highest SDR sequentially were *A. conyzoides*, *C. rotundus*, *M. pudica*, *E. heterophylla*, and *G. parviflora* by 22.20, 18.76, 12.67, 11.36 and 9.90 %, respectively. The diversity index (H') due to tillage (NT, T1, T2) were 2.261, 2.196 and 2.234 respectively, therefore it was moderate.

The tillage significantly increased cation exchange capacity (CEC) but it had insignificant effect on soil organic-C (Figure 5). There was an increase in the CEC due to T1 and T2 by 16.56 and 13.14 %, respectively. The correlation analysis of soil organic-C and CEC on the dominant weed population due to tillage is presented in Table 2. The results showed that only CEC had a significant and positive correlation in increasing the *E. heterophylla* by 0.727, but it was insignificant for *C. rotundus* and *C. rutidosperma*. Similarly, soil organic-C had an insignificant effect but was positively correlated to the population of *C. rotundus*, *A. conyzoides*, *M. pudica* and *E. heterophylla*.

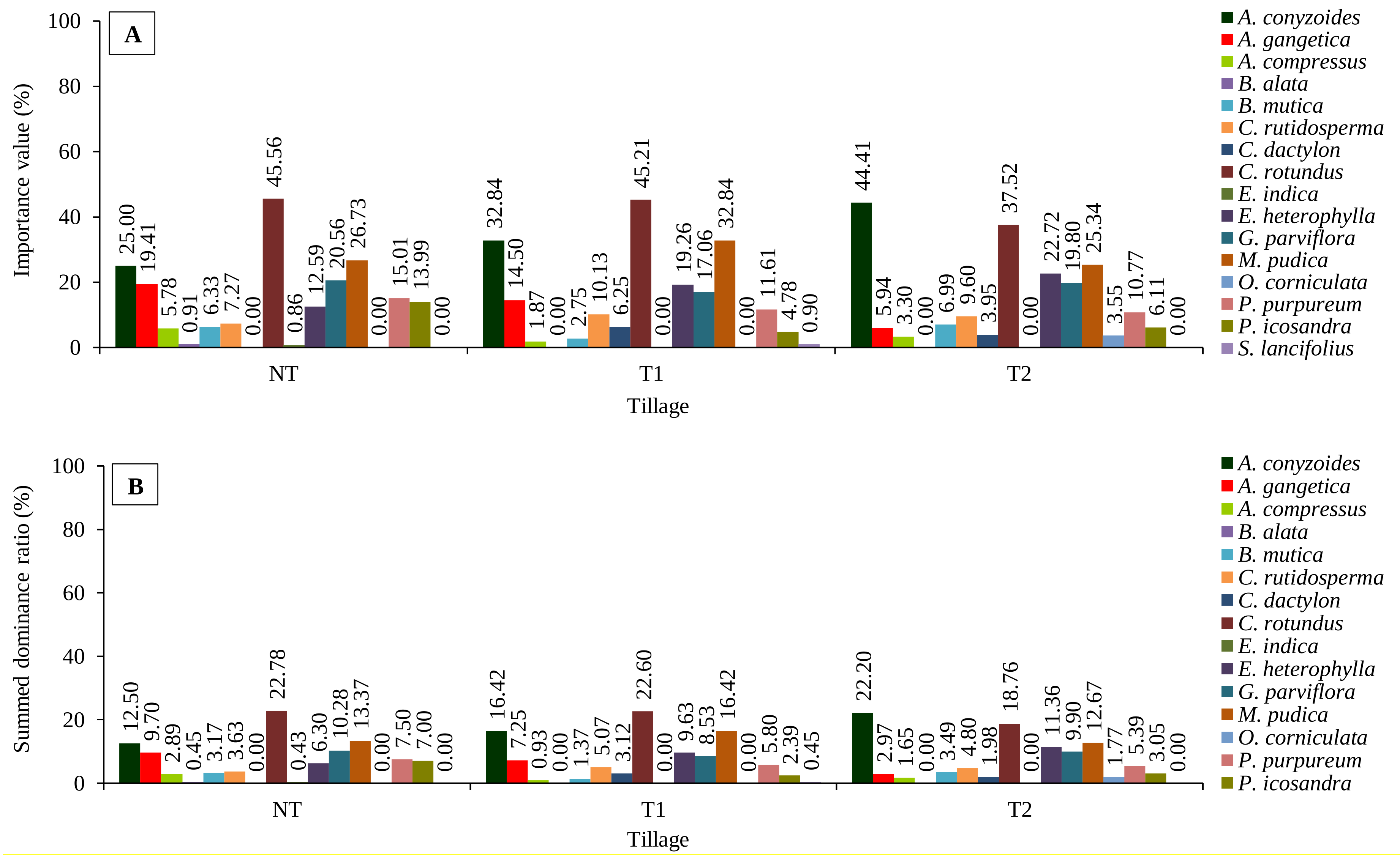
A
Importance value (%)
100
80
60
40
20
0
25.00
19.41
5.78
0.91
6.33
7.27
0.00
45.56
0.86
12.59
20.56
26.73
0.00
15.01
13.99
0.00
32.84
14.50
1.87
0.00
2.75
10.13
6.25
45.21
0.00
19.26
17.06
32.84
0.00
11.61
4.78
0.90
44.41
5.94
3.30
0.00
6.99
9.60
3.95
37.52
0.00
22.72
19.80
25.34
3.55
10.77
6.11
0.00
NT
T1
T2
Tillage
A. conyzoides
A. gangetica
A. compressus
B. alata
B. mutica
C. rutidosperma
C. dactylon
C. rotundus
E. indica
E. heterophylla
G. parviflora
M. pudica
O. corniculata
P. purpureum
P. icosandra
S. lancifolius
B
Summed dominance ratio (%)
100
80
60
40
20
0
12.50
9.70
2.89
0.45
3.17
3.63
0.00
22.78
0.43
6.30
10.28
13.37
0.00
7.50
7.00
0.00
16.42
7.25
0.93
0.00
1.37
5.07
3.12
22.60
0.00
9.63
8.53
16.42
0.00
5.80
2.39
0.45
22.20
2.97
1.65
0.00
3.49
4.80
1.98
18.76
0.00
11.36
9.90
12.67
1.77
5.39
3.05
0.00
NT
T1
T2
Tillage
A. conyzoides
A. gangetica
A. compressus
B. alata
B. mutica
C. rutidosperma
C. dactylon
C. rotundus
E. indica
E. heterophylla
G. parviflora
M. pudica
O. corniculata
P. purpureum
P. icosandra

Figure 4. Importance value (A) and summed dominance ratio (B) of weeds due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage).

[Please, do not abbreviate the species names]

Table 1. Diversity index of weeds due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage; H': species diversity index). [Please, do do not abbreviate the species names and remove the vertical lines]

Family	Weeds Species	H'		
		NT	T1	T2
Asteraceae	*A. conyzoides*	0.260	0.297	0.334
	G. parviflora	0.234	0.210	0.229
Acanthaceae	*A. gangetica*	0.226	0.190	0.104
Araceae	*S. lancifolius*	-	0.024	-
Capparaceae	*C. rutidosperma*	0.120	0.151	0.146
Capparidaceae	*P. icosandra*	0.186	0.089	0.107
Cyperaceae	*C. rotundus*	0.337	0.336	0.314
Euphorbiaceae	*E. heterophylla*	0.174	0.225	0.247
Fabaceae	*M. pudica*	0.269	0.297	0.262
Oxalidaceae	*O. corniculata*	-	-	0.072
Poaceae	*A. compressus*	0.102	0.044	0.068
	B. mutica	0.109	0.059	0.117
	C. dactylon	-	0.108	0.078
	E. indica	0.023	-	-
	P. purpureum	0.194	0.165	0.157
Rubiaceae	*B. alata*	0.024	-	-
	Total	2.261	2.196	2.234

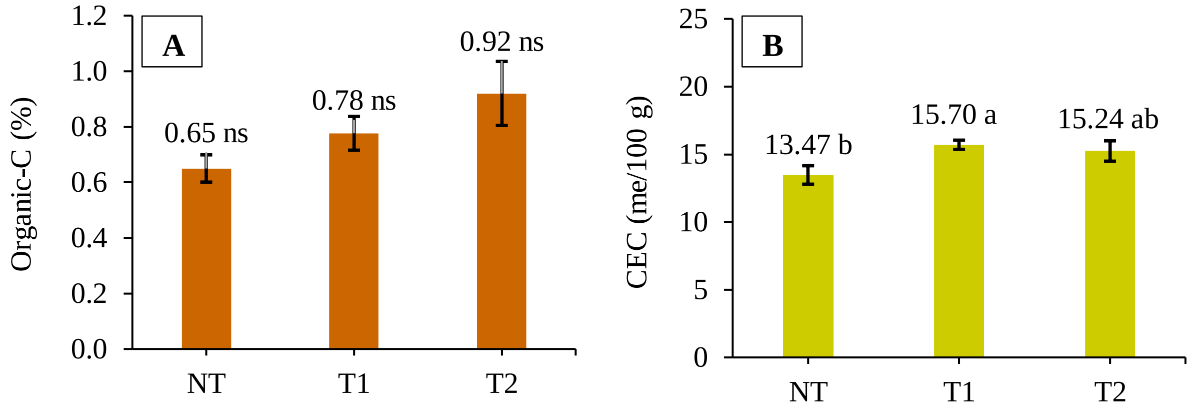

Figure 5. The soil organic-C (A) and cation exchange capacity (CEC) (B) properties due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage). The values followed by the different letter in the graph are significantly at the 5 % level based on the DMRT. The vertical line shows the standard error. ns: not significant.

Table 2. Correlation analysis of organic-C (%) and cation exchange capacity (CEC) of the soil on the dominant weed populations due to tillage. [Please, do do not abbreviate the species names]

Dominant weed species	Correlation coefficient	
	Organic-C (%)	CEC (me/100g)
C. rotundus	0.449^{ns}	0.262^{ns}
A. conyzoides	0.132^{ns}	-0.154^{ns}
M. pudica	0.147^{ns}	-0.054^{ns}
E. heterophylla	0.127^{ns}	0.727^{*}
G. parviflora	-0.063^{ns}	-0.240^{ns}
A.gangetica	-0.298^{ns}	-0.482^{ns}
P. icosandra	-0.021^{ns}	-0.646^{ns}
C. rutidosperma	-0.095^{ns}	0.591^{ns}

Note: Correlation is significant at the 0.05 level (2-tailed). ns: not significant.

Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g ai ha^{-1} on different tillage (NT, T1, T2) by species are presented in Figure 6. The results showed an increase in *B. alata* and *B. mutica* due to the ammonium glufosinate in NT and 2-times tillage (T2). Meanwhile, others decreased, and two new weed species were found in NT, such as *Glyceria maxima* and *Leersia oryzoides*, and one new weed species were found in T2 (*G. maxima*). Similarly, the 1-time tillage (T1) increased *B. alata*, *B. mutica*, and *E. indica*. At the same time, other populations decreased, and four new weed species were found, namely *G. maxima*, *L. oryzoides*, *Scoparia dulcis* and *Anthoxanthum oculatum*.

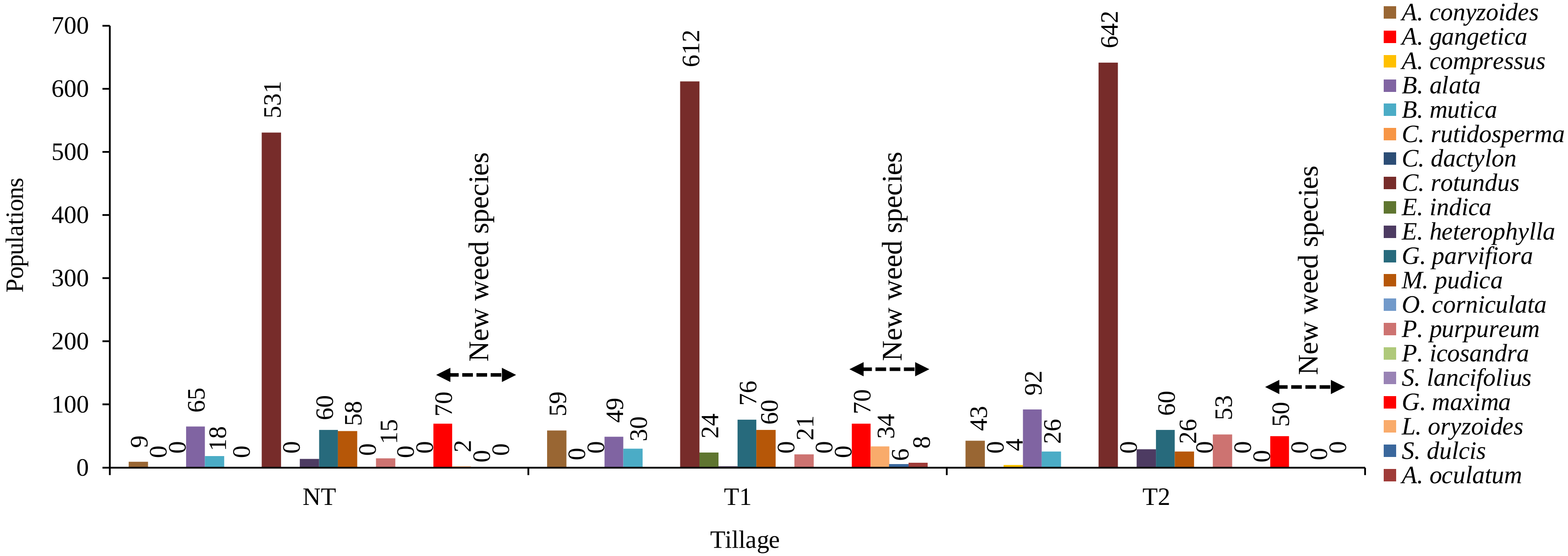

Figure 6. Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g a.i ha^{-1} on different tillage.

[Please, do do not abbreviate the species names]

Based on morphology, the effectiveness of ammonium glufosinate on the weed-type abundance at different tillage (NT, T1, T2) is presented in Figure 7. The herbicide application can decrease the abundance of broadleaf weeds by 82.13-84.98 % and sedges by 8.15-19.05 %. However, there was an increase in the grasses weed abundance in T1 and T2 tillage by 167.74 and 26.67 %, respectively.

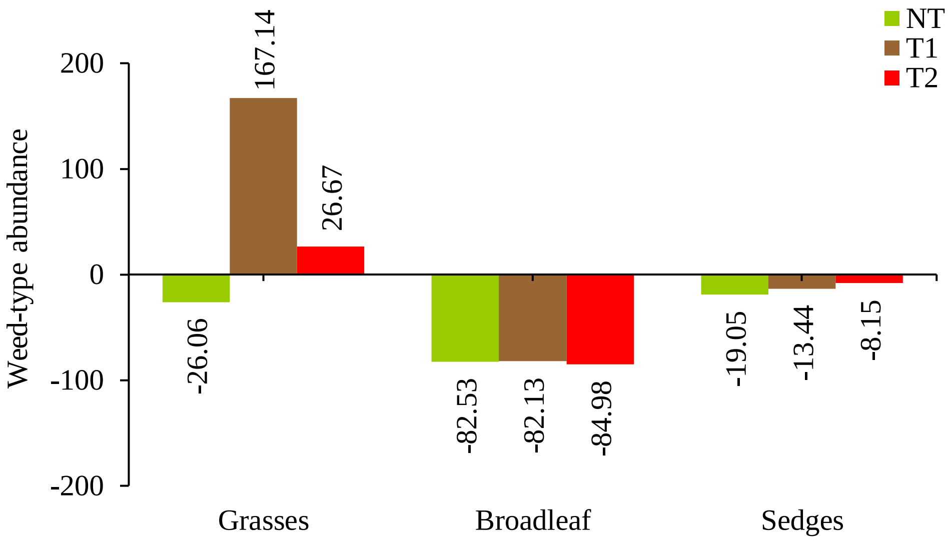

Figure 7. The effectiveness of ammonium glufosinate on the weed-type abundance at different tillage. (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage).

Based on the results, there were three dynamic patterns of weed diversity due to tillage, namely increasing, decreasing, and fluctuating patterns. The increasing weed species due to 2-times tillage (T2) include *A. conyzoides* (2.82-folds), *C. dactylon* (41 populations), and *E. heterophylla* (2.43-folds) compared to no-tillage (NT). It was caused by the seed banks of *A. conyzoides*, *C. dactylon*, and *E. heterophylla* during T2 tillage were triggered the emergence to the soil surface. Furthermore, soil fertility also supported its growth more rapidly. This was supported by the organic-C, which was positively correlated with the presence of *A. conyzoides* (0.132) and *E. heterophylla* (0.127). Besides, soil CEC was also significantly and positively correlated with the presence of *E. heterophylla* (0.727) (Table 2). These results are similar to

Oziegbe et al. (2010); active weed seedbanks at deeper soil depths lead to lower oxygen availability and reduce the access to light required to support germination. In addition, Hossain et al. (2021) that the seed bank of *A. conyzoides* was not found at a depth of 0-10 cm, but 10-15 cm, and experienced an additional seed bank of 43.82 % during conventional tillage. Horowitz (1972) reported that 88 % of *C. dactylon* rhizomes were found at a depth of 30 cm. Ekeleme et al. (2019) added that *E. heterophylla* had the second-highest abundance of 19.53 % after *Tridax procumbens* in Benue State, Nigeria.

The results showed that *C. rotundus* had the highest SDR in NT and T1 tillage, while *A. conyzoides* was dominant in T2 tillage. This was due to the presence of higher seed bank of *C. rotundus* and *A. conyzoides* at certain depths. Therefore, when the soil is tilled, the seedbanks trigger emergence on the soil surface. These results are similar to Hossain et al. (2021) which reported that up to 24 % of the *C. rotundus* seed bank were found at a depth of 5-10 cm, while 21 % of the *A. conyzoides* were found between 10-15 cm. Furthermore, Santín-Montanyá et al. (2013) reported that the weed abundance, diversity, and evenness were greatly increased in the no-tillage treatment. In this study, the results showed that the diversity index due to tillage (NT, T1, T2) was 2.261; 2.196; and 2.234 (moderate) (Tab. 1). The decrease in diversity index due to T1 and T2 compared to NT indicates that tillage decrease weed diversity. Mas & Verdú (2003) reported that the highest value of the Shannon-Wiener diversity index was found in the no-tillage treatment, while Amuri et al. (2010) suggested that no-tillage treatment contributes to the suppression of several weed species. Sepat et al. (2017) also reported that the lowest weed population was found in untilled beds.

The results showed that T2 tillage increased the broadleaf and total weeds. The population of sedges weeds increased at T1, but decreased during T2 tillage. In general, only grasses weeds decreased during T1 and T2 compared to NT, and the highest decrease was found at T1 tillage. This is linear with the Shannon-Wiener diversity index at T1, lower than other tillage (Table 1). These results are supported by Murphy et al. (2006) which reported that the weed density is only affected by tillage. Similarly, Hossain et al. (2021) said a decrease in the seed bank of grasses weed during conventional tillage by 76.31 % at a depth of 0-5 cm compared to the no-tillage.

Cation Exchange Capacity (CEC) was significantly and positively correlated (0.727) with an increase in the population of *E. heterophylla*. The content of CEC and organic-C was also positively correlated but had an insignificant effect on the populations of *C. rotundus*, *C. rutidosperma*, *A. conyzoides*, and *M. pudica*. This was due to the higher content of CEC and organic-C in T1 and T2 compared to the NT (Figure 5). When the weed seed bank at T1 and T2 emerged to the surface and received light and soil fertility than NT, it tends to support the growth of more weeds as indicated in the total weed population, which grows higher with increasing tillage (Figure 3). These results are similar to Pätzold et al. (2020) which reported that soil organic-C affects weed species variability by 8.4 %, while Gaston et al. (2001); Nordmeyer & Häusler (2004); Korres et al. (2017) reported that organic carbon, texture, and nutrients of soil affect the emergence of weeds. Furthermore, Dorneles et al. (2015) reported that reduced tillage had a higher CEC than the no-tillage at 0-5 cm and 5-10 cm depths.

There was an increase in populations of *B. alata* (49), *B. mutica* (30), and *E. indica* (24) after spraying the ammonium glufosinate herbicide at a dose of 150 g ai.ha^{-1} with different tillage (NT, T1, T2), although *C. rotundus* (612) was more numerous than the other weeds. In general, four new weeds species, namely *G. maxima, L. oryzoides, S. dulcis,* and *A. oculatum* were found in NT, T1, and T2 due to the ammonium glufosinate herbicide. *Glyceria maxima* is a new weed species with the highest population in the NT, T1, and T2 tillage. Furthermore, the increase in population and new weed species was higher in the grasses weeds (*B. mutica*, *E. indica*, *G. maxima*, *L. oryzoides* and *A. oculatum*) and two new species from the broadleaf weeds (*B. alata* and *S. dulcis*). Therefore, the ammonium glufosinate herbicide at different tillage decreased the abundance of broadleaf (Figure 7) compared to the grasses weeds.

Using herbicides on tillage (T1 and T2) exposed the seed bank of grasses weeds to the soil surface to adequately obtain oxygen and light needed for growth. This is supported by Wibawa et al. (2009), which reported that the herbicide of dose 200 g ha^{-1} significantly suppressed broadleaf of 94.68 % compared to the grasses weeds by 59.65 % at two weeks after spraying. Tampubolon et al. (2019) also found that the ammonium glufosinate herbicide at a dose of 300 g $ai.ha^{-1}$ significantly removed 100% of the glyphosate-susceptible *E. indica*, while Alridiwirsah et al. (2020) reported that the grasses was higher by 52.76 % compared to the broadleaf and sedges weeds in guava plants. In addition, Głowacka (2011) stated that the number of *Echinochloa crus-galli* (grasses weed) was more dominant with mechanical control (18.0 populations) and herbicides (10.3 populations) in maize plants compared to other weeds including *G. parviflora, Chenopodium album, Cirsium arvense,* and *Polygonum lapathifolium*. Uddin et al. (2018) also added the abundance of grasses weeds was higher by 130.1 % than broadleaf (108.5 %) and sedges (61.4 %) weeds in the rice and potato cropping pattern.

CONCLUSIONS

The 2-time tillage (T2) increased the *A. conyzoides* (2.81-folds), *C. dactylon* (41 population), and *E. heterophylla* (2.43-folds) compared to the no-tillage (NT). *C. rotundus* had the highest SDR at NT and T1, while *A. conyzoides* was found in T2 tillage with a moderate diversity index. Based on the classification, only grasses weeds decreased in T1 and T2 tillage. Furthermore, there was a significant and positive correlation between *E. heterophylla* weed with cation exchange capacity (0.727). A total of four new species of weeds, namely *G. maxima, L. oryzoides, S. dulcis,* and *A. oculatum* were found on NT, T1, and T2 tillage due to the application of ammonium glufosinate herbicide.

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Research Article

Weed diversity as affected by tillage and ammonium glufosinate herbicide[1]

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ABSTRACT

Farmers in Indonesia generally spray herbicides to control weeds and use tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. This study aimed to evaluate the dominance and diversity index of weeds and obtain abundance correlations according to the soil chemical characteristics, as well as the effect of the ammonium glufosinate herbicide, in different tillage systems. A non-factorial randomized block design was used, consisting of no-tillage (NT), 1-time tillage (T1) and 2-times tillage (T2), with three replications. The *Cyperus rotundus* and *Ageratum conyzoides* weed species were dominant in the tillages. The diversity indices were 2.261, 2.196 and 2.234 (moderate/stable condition), respectively for the NT, T1 and T2. For T2, there were increases of 2.82-folds, 41 populations and 2.43-folds, respectively for *A. conyzoides*, *Cynodon dactylon* and *Euphorbia heterophylla*, when compared to NT, while a decrease was observed in grasses for T1 and T2 (50.71 and 26.05 %, respectively). Moreover, there was a positive and significant correlation for *E. heterophylla* according to the soil cation exchange capacity (0.727). In contrast, four new weed species (*Glyceria maxima*, *Leersia oryzoides*, *Scoparia dulcis* and *Anthoxanthum oculatum*) were found due to the ammonium glufosinate application, in the different tillage systems.

KEYWORDS: Grasses, broadleaf weeds, sedges, weed abundance.

RESUMO

Diversidade de plantas daninhas em função do preparo do solo e da aplicação do herbicida glufosinato de amônio

Na Indonésia, os agricultores geralmente pulverizam herbicidas para controlar plantas daninhas e revolvem o solo durante as fases iniciais de cultivo; consequentemente, essas atividades afetam a composição e a diversidade das plantas daninhas. Objetivou-se avaliar a dominância e o índice de diversidade de plantas daninhas e obter correlações de abundância considerando-se as características químicas do solo, bem como o efeito do herbicida glufosinato de amônio, em diferentes sistemas de preparo do solo. Utilizou-se delineamento não-fatorial em blocos casualizados, consistindo de não revolvimento (NR), um revolvimento (R1) e dois revolvimentos (R2) do solo, com três repetições. As espécies *Cyperus rotundus* e *Ageratum conyzoides* foram dominantes nos revolvimentos. Os índices de diversidade foram de 2,261; 2,196; e 2,234 (condição moderada/estável), respectivamente para o NR, R1 e R2. Para o R2, houve aumento de 2,82 vezes, 41 populações e 2,43 vezes, respectivamente para *A. conyzoides*, *Cynodon dactylon* e *Euphorbia heterophylla*, em comparação com o NR, enquanto uma diminuição foi observada nas gramíneas para R1 e R2 (50,71 e 26,05 %, respectivamente). Além disso, houve correlação positiva e significativa para *E. heterophylla* em função da capacidade de troca catiônica do solo (0,727). Em contraste, foram encontradas quatro novas espécies de planta daninha (*Glyceria maxima*, *Leersia oryzoides*, *Scoparia dulcis* e *Anthoxanthum oculatum*) em resposta à aplicação de glufosinato de amônio, nos diferentes sistemas de preparo.

PALAVRAS-CHAVE: Gramíneas daninhas, plantas daninhas de folhas largas, ciperáceas, abundância de plantas daninhas.

INTRODUCTION

Uncontrolled weeds on farmlands reduce yield up to 80 % (Cousens & Mortimer 1995). Therefore, sustainable agricultural practices affect its abundance and density. The weed abundance in the farmland is influenced by several factors, such as seed bank buried in the soil (Norris 2007), environmental factors

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(Fried et al. 2008, Pinke et al. 2012), availability of nutrients and fertilization (Murphy & Lemerle 2006, Cheimona et al. 2016), tillage and crop rotation (Ulber et al. 2009, Nichols et al. 2015), and weed control using herbicides (Derksen et al. 1995).

Farmers in Indonesia generally spray herbicides to control weeds and use tillage during the early stages of crop cultivation; consequently, these activities affect the weed composition and diversity. Menalled et al. (2001) showed that different agricultural management systems significantly affect weed abundance, diversity and consistency in the short and long term (6 years). Meanwhile, Derksen et al. (1995) reported that the germination of *Synapsis avensis* and *Brassica napus* weeds after spraying with herbicides was higher in the no-tillage, but there was a reduction in total weeds. Thomas et al. (2004) also reported that perennial weed species such as *Cirsium arvense* and *Sonchus arvensis* were reduced by tillage and no-tillage (100 and 28.21 %, respectively), while annual weeds were found in various tillage treatments. In addition, Trichard et al. (2013) stated that tillage favors the weed seed bank germination and causes the extinction of other seeds.

On the other hand, different soil fertility levels in the planted area also affect the weed diversity (Yin et al. 2006). Fonge et al. (2013) reported that weed diversity is affected by soil organic-C content, nitrogen, calcium and cation exchange capacity. Tang et al. (2014a) added that phosphorus + potassium (PK) fertilization increases the density of *Galium aparine*, *Vicia sativa*, *Veronica persica* and *Geranium carolinianum*, when compared to nitrogen + phosphorus (NP). Furthermore, Forcella et al. (2000) stated that the soil N concentration plays an important role in ending dormancy by removing germination constraints and stimulating seedling emergence. Tang et al. (2014b) reported that soil available-P is the primary nutrient, regulating the composition of weed species and diversity, followed by N and K.

The knowledge of farmers on the relationship between tillage and soil fertility status with weed diversity is relatively poor. Interviews conducted in this study showed that the farmers only carry out land clearing and manual tillage before planting, had never used herbicides, and unknowingly the soil fertility status. However, a new problem was found: weed growth was very fast in a short time (2 days). Therefore, intensive control during one main crop cycle is highly needed. This problem persisted during crop rotation. Unnoticed by farmers, these activities impact the storage of the weed seed bank and the tillage carried out, resulting in the weed seed bank at a certain depth of soil emerging to the soil surface.

Studies on weed identification are needed to provide information on the relationship between soil fertility on the dominant weeds and the use of one herbicide with a recommended dose to suppress the presence of weeds. Therefore, this study aimed to evaluate the dominance and diversity index of weeds and obtain correlations of weed abundance on soil chemical characteristics, as well as the effect of the ammonium glufosinate herbicide on weed abundance, in different tillage systems.

MATERIAL AND METHODS

This study was carried out on farmland in Padang Bulan, Medan Selayang subdistrict, Medan, Indonesia (3º33.753'N, 98º38.890'E and altitude of 15 m a.s.l.), from March to July 2021, in Inceptisols (GMCG 2022). This is an area with continuous land use and a history of crop rotation for the last two years with corn, cucumber and cowpea, as well as manual tillage using hoe, without the use of herbicides, based on interviews with farmers.

A non-factorial randomized block design, with three replications, was used: no-tillage, 1-time tillage and 2-times tillage. The land was cleared and then plotted with the square method of 1 m × 1 m and spacing of 2 m between plots. Each plot was demarcated with plastic ropes with a distance of 0.2 m between rows.

Tillage was carried out by hoeing as deep as 20 cm. Meanwhile, the land was incubated for a month and then identified for weed vegetation using the flora book and applying formulas according to Kent (2012), such as absolute density (number of individual weed species in the sample plot), relative density [(absolute density of a certain species)/(total absolute density of all species) × 100 %], absolute frequency (number of sample plots containing certain species), relative frequency [(absolute frequency of a certain species)/(total absolute frequencies of all species) × 100 %], importance value (relative density + relative frequency) and summed dominance ratio [(relative density + relative frequency)/2].

The weed populations based on morphology (broadleaf, grasses and sedges) and total weeds were also calculated. The species diversity index was calculated using the Shannon-Wiener index formula (Shannon & Weaver 1949):

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right)\left(\ln \frac{ni}{N}\right)$$

where: H' is the species diversity index; ni the proportion of species *I*; N the total number of species; and ln the natural logarithm.

The classification of the diversity index value for each tillage was conducted based on Magurran (1988), who stated that it is low if H' < 1, moderate if 1 < H' < 3 and high if H' > 3. Soil samples at a depth of 0-20 cm were taken using a drill, with a diagonal method on each plot. Then, analysis was performed on organic-C (Walkley & Black method) and cation exchange capacity - CEC (ammonium acetate pH 7), using a spectrophotometer (Socfin Indonesia Inc., Medan, Indonesia). At first, a natural logarithm was carried out on the organic-C, CEC data and total of dominant weeds, as well as using the Pearson's correlation.

The ammonium glufosinate herbicide was applied on Apr. 27 (2021) at 10.00 a.m. to the plots of all tillage systems [no-tillage (NT), 1-time tillage (T1) and 2-times tillage (T2)], at a dose of 150 g a.i. ha^{-1}, after a spray calibration was carried out. The climatic data were recorded during spraying (temperature of 28 ºC, humidity of 83 % and air pressure of 1,002 hPa). The weed survival data were measured at 6 weeks after spraying. The spraying was carried out using a manual spray equipment (Solo Model) with operating pressure and application volume of 2 kg cm^{-2} and 202.90 L ha^{-1}, respetively. Weeds with height up to 60 cm were sprayed. The data of weeds (broadleaf, grasses, sedges and total) and soil (organic-C and CEC) were processed with Anova, followed by DMRT at $p < 0.05$ using the IBM SPSS v.20 software.

RESULTS AND DISCUSSION

The field observations obtained 16 species (*Ageratum conyzoides*, *Asystasia gangetica*, *Axonopus compressus*, *Borreria alata*, *Brachiaria mutica*, *Cleome rutidosperma*, *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Euphorbia heterophylla*, *Galinsoga parviflora*, *Mimosa pudica*, *Oxalis corniculata*, *Pennisetum purpureum*, *Polanisia icosandra* and *Stylochaeton lancifolius*), with 6,639 populations from three tillage systems (NT, T1 and T2) (Figure 1). The results showed that three dynamic patterns due to tillage, such as an increase in the weed diversity due to 2-times tillage for *A. conyzoides*, *C. dactylon* and *E. heterophylla*; a decrease in weed diversity due to 2-times tillage for *A. gangetica*, *A. compressus*, *B. alata*, *C. rutidosperma* and *E. indica*; and a fluctuating pattern, indicating a decrease in weed species in the 1-time tillage and then an increase in the 2-times tillage, or vice versa, for *B. mutica*, *G. parviflora*, *M. pudica*, *O. corniculata*, *P. purpureum*, *P. icosandra* and *S. lancifolius*.

The tillage had an insignificant effect on the number of broadleaf, grasses, sedges and total weeds (Figure 2). However, the increasing of tillage by 2-times (T2) also increased the broadleaf population and total weeds by 41.73 and 25.19 %, respectively, when compared to no-tillage (NT). Furthermore, the population of sedges increased at 1-time tillage

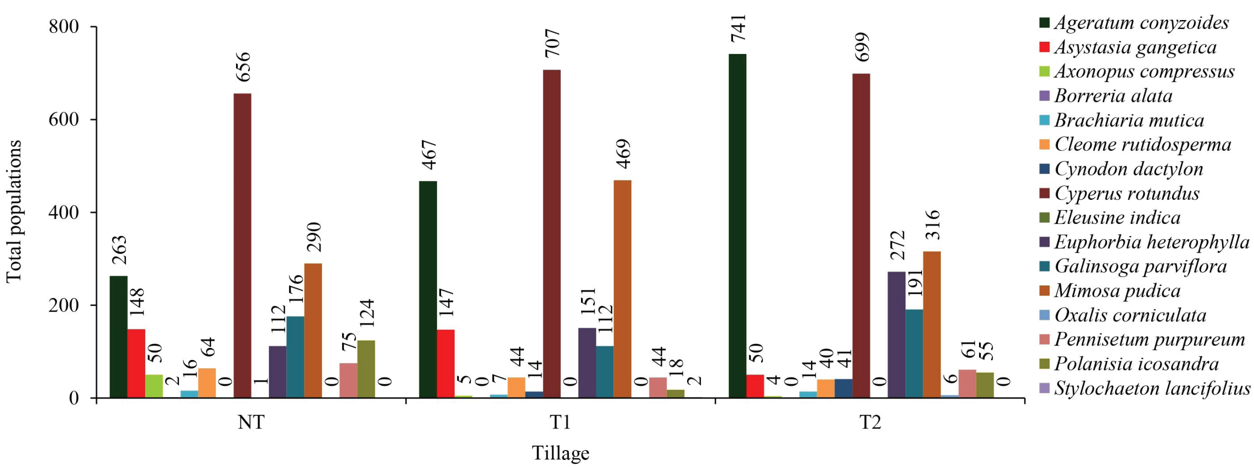

Figure 1. Total populations of weeds due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage).

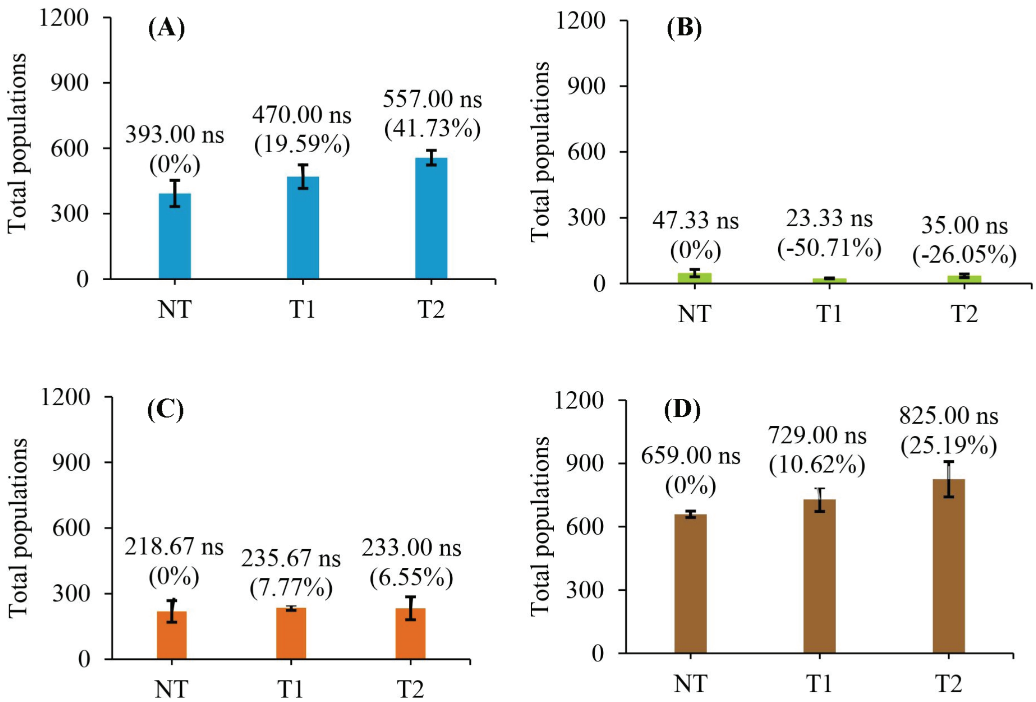

Figure 2. Weed populations based on morphology (A: broadleaf; B: grasses; C: sedges) and total weeds (D) due to tillage (NT: no tillage; T1: 1-time tillage; T2: 2-times tillage). Values followed by "ns" are not significantly different at the 5 % level, based on the DMRT. The vertical line shows the standard error.

(T1) by 7.77 %, if compared to NT, and decreased to 6.55 % at 2-times tillage (T2). The population of grasses experienced the highest decrease in the 1-time tillage (T1) of 50.71 %, when compared to NT.

The summed dominance ratio (SDR) and diversity index due to tillage are presented in Figure 3 and Table 1. In the no-tillage (NT) treatment, five species with the highest SDR were sequentially found (*C. rotundus*, *M. pudica*, *A. conyzoides*, *C. rutidosperma* and *P. icosandra*), with 22.78, 13.37, 12.50, 10.90 and 10.49 %, respectively. For the 1-time tillage (T1), five species with the highest SDR were sequentially found (*C. rotundus*, *M. pudica*, *A. conyzoides*, *A. gangetica* and *E. heterophylla*), with 22.61, 16.42, 16.41, 10.87 and 9.63 %, respectively. Moreover, in the 2-times tillage (T2), five species with the highest SDR were also sequentially found (*A. conyzoides*, *C. rotundus*, *M. pudica*, *E. heterophylla* and *G. parviflora*), with 22.20, 18.76, 12.67, 11.36 and 9.90 %, respectively. The diversity index (H') due to tillage (NT, T1 and T2) were 2.261, 2.196 and 2.234, respectively; therefore, it was moderate.

The tillage significantly increased the cation exchange capacity (CEC), but it had an insignificant effect on the soil organic-C (Figure 4). There was an increase in the CEC due to T1 and T2 by 16.56 and 13.14 %, respectively. The correlation analysis of soil organic-C and CEC on the dominant weed population due to tillage is presented in Table 2. The results showed that only CEC had a significant and positive correlation in increasing *E. heterophylla* by 0.727, but it was insignificant for *C. rotundus* and *C. rutidosperma*. Similarly, the soil organic-C had an insignificant effect, but was positively correlated to the populations of *C. rotundus*, *A. conyzoides*, *M. pudica* and *E. heterophylla*.

Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g a.i. ha^{-1} on different tillage systems (NT, T1 and T2) by species are presented in Figure 5. The results showed an increase for *B. alata* and *B. mutica* due to the ammonium glufosinate in the NT and 2-times tillage (T2). Meanwhile, others decreased, and two new weed species were found in the NT (*Glyceria maxima* and *Leersia oryzoides*) and one new weed species was found in the T2 (*G. maxima*). Similarly, the 1-time tillage (T1) increased *B. alata*, *B. mutica* and *E. indica*. At the same time, other populations decreased, and four new weed species were found:

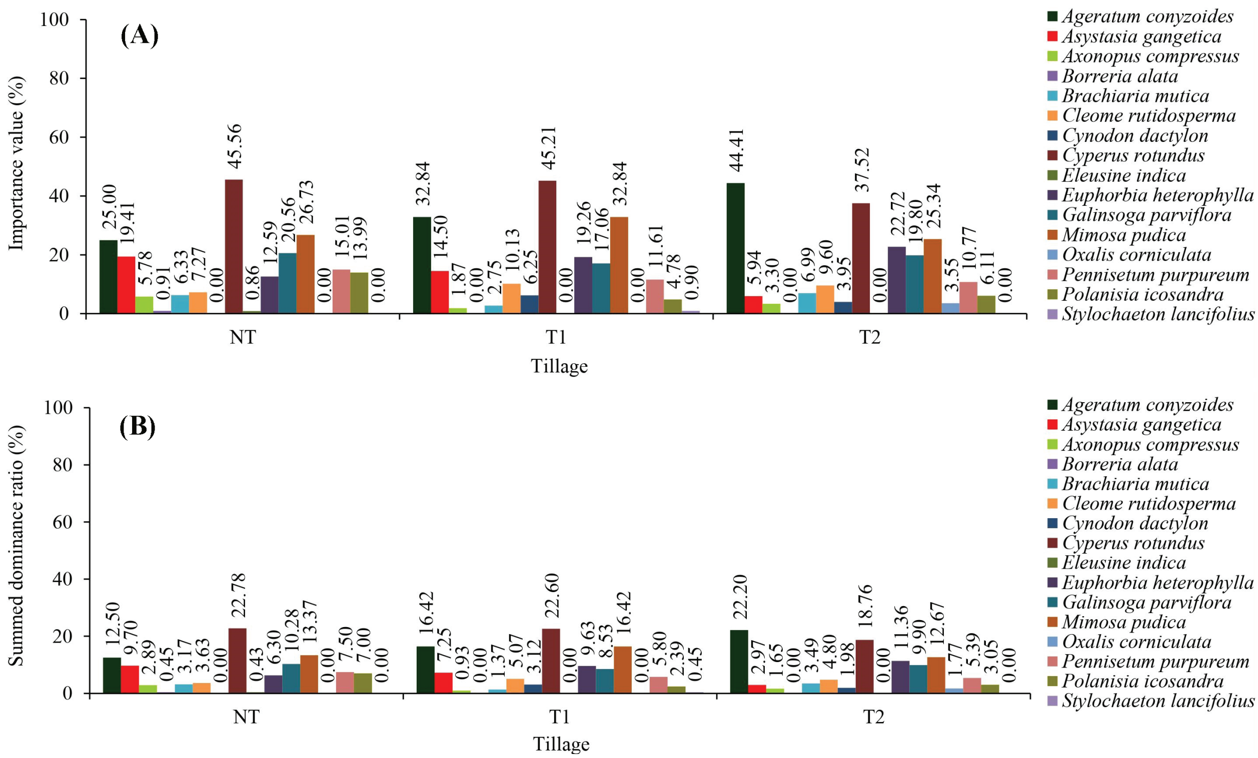

Figure 3. Importance value (A) and summed dominance ratio (B) of weeds due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage).

Table 1. Diversity index of weeds due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage; H': species diversity index).

Family	Weeds species	H'		
		NT	T1	T2
Asteraceae	*Ageratum conyzoides*	0.260	0.297	0.334
	Galinsoga parviflora	0.234	0.210	0.229
Acanthaceae	*Asystasia gangetica*	0.226	0.190	0.104
Araceae	*Stylochaeton lancifolius*	-	0.024	-
Capparaceae	*Cleome rutidosperma*	0.120	0.151	0.146
Capparidaceae	*Polanisia icosandra*	0.186	0.089	0.107
Cyperaceae	*Cyperus rotundus*	0.337	0.336	0.314
Euphorbiaceae	*Euphorbia heterophylla*	0.174	0.225	0.247
Fabaceae	*Mimosa pudica*	0.269	0.297	0.262
Oxalidaceae	*Oxalis corniculata*	-	-	0.072
Poaceae	*Axonopus compressus*	0.102	0.044	0.068
	Brachiaria mutica	0.109	0.059	0.117
	Cynodon dactylon	-	0.108	0.078
	Eleusine indica	0.023	-	-
	Pennisetum purpureum	0.194	0.165	0.157
Rubiaceae	*Borreria alata*	0.024	-	-
Total		2.261	2.196	2.234

G. maxima, *L. oryzoides*, *Scoparia dulcis* and *Anthoxanthum oculatum*.

Based on morphology, the effectiveness of ammonium glufosinate on the weed-type abundance at different tillage systems (NT, T1 and T2) is presented in Figure 6. The herbicide application can decrease the abundance of broadleaf weeds by 82.13-84.98 % and sedges by 8.15-19.05 %. However, there

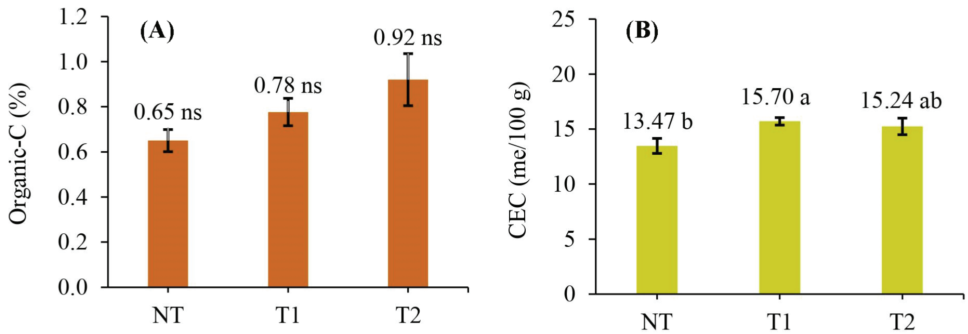

Figure 4. Soil organic-C (A) and cation exchange capacity (CEC) (B) properties due to tillage (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage). Values followed by different letters in the graph are significantly different at the 5 % level based on the DMRT. The vertical line shows the standard error. ns: not significant.

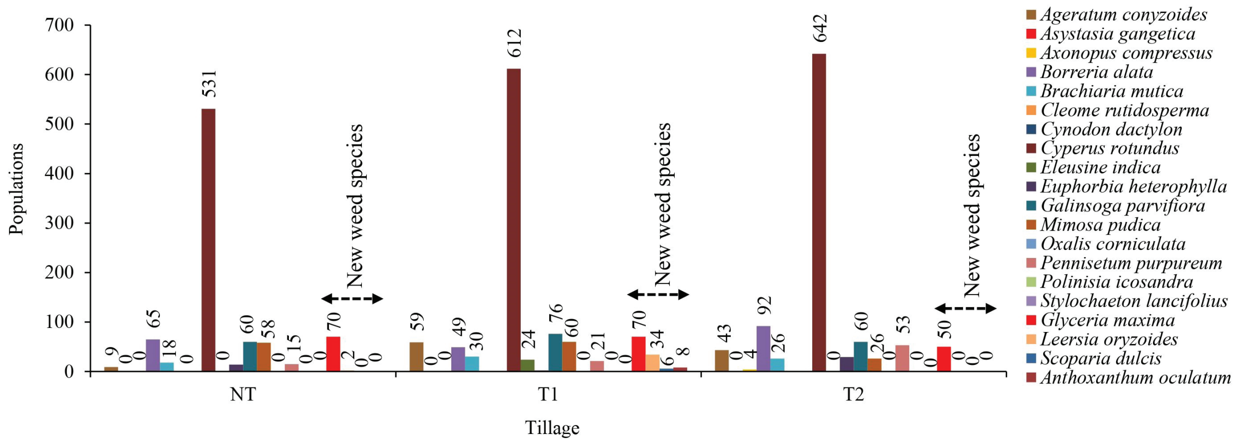

Figure 5. Changes in weed vegetation due to ammonium glufosinate application at a dose of 150 g a.i. ha^{-1} on different tillage systems (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage).

Table 2. Correlation analysis of soil organic-C (%) and cation exchange capacity (CEC) on the dominant weed populations due to tillage.

Dominant weed species	Correlation coefficient	
	Organic-C (%)	CEC (me 100 g^{-1})
Cyperus rotundus	0.449^{ns}	0.262^{ns}
Ageratum conyzoides	0.132^{ns}	-0.154^{ns}
Mimosa pudica	0.147^{ns}	-0.054^{ns}
Euphorbia heterophylla	0.127^{ns}	0.727*
Galinsoga parviflora	-0.063^{ns}	-0.240^{ns}
Asystasia gangetica	-0.298^{ns}	-0.482^{ns}
Polanisia icosandra	-0.021^{ns}	-0.646^{ns}
Cleome rutidosperma	-0.095^{ns}	0.591^{ns}

* Correlation is significant at the 0.05 level (2-tailed). ^{ns} not significant.

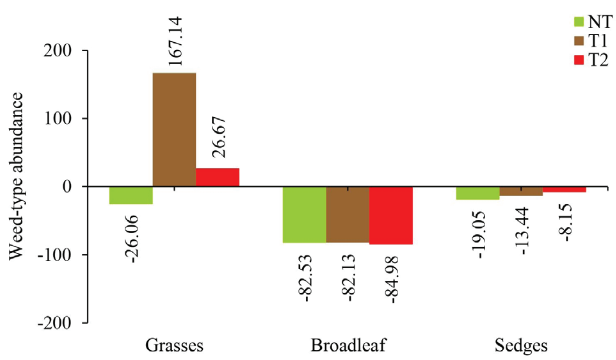

Figure 6. Effectiveness of ammonium glufosinate on the weed-type abundance at different tillage systems (NT: no-tillage; T1: 1-time tillage; T2: 2-times tillage).

was an increase in the grass weeds abundance in the T1 and T2 by 167.74 and 26.67 %, respectively.

Based on the results, there were three dynamic patterns of weed diversity due to tillage, namely increasing, decreasing and fluctuating patterns. The increasing weed species due to 2-times tillage (T2) include *A. conyzoides* (2.82-folds), *C. dactylon* (41 populations) and *E. heterophylla* (2.43-folds), when compared to no-tillage (NT). It was caused by the seed banks of *A. conyzoides*, *C. dactylon* and *E. heterophylla* during T2, which triggered the emergence to the soil surface. Furthermore, the soil fertility also supported its growth faster. This was supported by the organic-C, which was positively correlated with the presence of *A. conyzoides* (0.132) and *E. heterophylla* (0.127). Besides, the soil CEC was also significantly and positively correlated with the presence of *E. heterophylla* (0.727) (Table 2). These results are similar to those by Oziegbe et al. (2010), who observed that active weed seed banks at deeper soil depths lead to lower oxygen availability and reduce the access to the light required to support germination. In addition, Hossain et al. (2021) found that the seed bank of *A. conyzoides* was not found at a depth of 0-10 cm, but at 10-15 cm, and experienced an additional seed bank of 43.82 % during conventional tillage. Horowitz (1972) reported that 88 % of *C. dactylon* rhizomes were found at a depth of 30 cm. Ekeleme et al. (2019) added that *E. heterophylla* had the second-highest abundance (19.53 %) after *Tridax procumbens* in Benue state, Nigeria.

The results showed that *C. rotundus* had the highest SDR in the NT and T1, while *A. conyzoides* was dominant in T2. This was due to the presence of higher seed banks of *C. rotundus* and *A. conyzoides* at certain depths. Therefore, when the soil is tilled, the seed banks trigger emergence on the soil surface. These results are similar to those by Hossain et al. (2021), who reported that up to 24 % of the *C. rotundus* seed bank were found at a depth of 5-10 cm, while 21 % of the *A. conyzoides* were found between 10 and 15 cm. Furthermore, Santín-Montanyá et al. (2013) reported that the weed abundance, diversity and evenness were greatly increased in the no-tillage treatment. In this study, the results showed that the diversity index due to tillage (NT, T1 and T2) was, respectively, 2.261, 2.196 and 2.234 (moderate) (Table 1). The decrease in diversity index due to T1 and T2, when compared to NT, indicates that tillage decreases the weed diversity. Mas & Verdú (2003) reported that the highest value for the Shannon-Wiener diversity index was found in the no-tillage treatment, while Amuri et al. (2010) suggested that the no-tillage treatment contributes to the suppression of several weed species. Sepat et al. (2017) also reported that the lowest weed population was found in untilled beds.

The results showed that T2 increased the broadleaf and total weeds. The population of sedges increased at T1, but decreased during T2. In general, only grasses decreased during T1 and T2, in relation to NT, and the highest decrease was found at T1. This is linear with the Shannon-Wiener diversity index at T1, lower than other tillage systems (Table 1). These results are supported by Murphy et al. (2006), who reported that the weed density is only affected by tillage. Similarly, Hossain et al. (2021) observed a decrease in the seed bank of grasses during conventional tillage by 76.31 %, at a depth of 0-5 cm, if compared to no-tillage.

The cation exchange capacity (CEC) was significantly and positively correlated (0.727), with an increase in the population of *E. heterophylla*. The contents of CEC and organic-C were also positively correlated, but had an insignificant effect on the populations of *C. rotundus*, *C. rutidosperma*, *A. conyzoides* and *M. pudica*. This was due to the higher content of CEC and organic-C in T1 and T2, in relation to NT (Figure 4). When the weed seed bank at T1 and T2 emerged to the surface and received more light and soil fertility than the NT, it tended to support the growth of more weeds, as indicated in the total weed population, which grows higher with increasing tillage (Figure 2). These results are similar to those by Pätzold et al. (2020), who reported that soil organic-C affects weed species variability by 8.4 %; while Gaston et al. (2001), Nordmeyer & Häusler (2004) and Korres et al. (2017) reported that soil organic carbon, texture and nutrients affect the emergence of weeds. Furthermore, Dorneles et al. (2015) reported that the reduced tillage had a higher CEC than the no-tillage at 0-5 cm and 5-10 cm depths.

There was an increase in the populations of *B. alata* (49), *B. mutica* (30) and *E. indica* (24) after spraying the ammonium glufosinate herbicide at a dose of 150 g a.i. ha^{-1} with different tillage systems (NT, T1 and T2), although *C. rotundus* (612) was more numerous than the other weeds. Four new weed species, namely *G. maxima*, *L. oryzoides*, *S. dulcis* and *A. oculatum*, were found in NT, T1 and T2 due to the ammonium glufosinate herbicide. *Glyceria maxima* is a new weed species with the highest population in the NT, T1 and T2 tillage systems. Furthermore, the increase in population and new weed species was higher in the grasses (*B. mutica*, *E. indica*, *G. maxima*, *L. oryzoides* and *A. oculatum*) and two new species from the broadleaf weeds (*B. alata* and *S. dulcis*). Therefore, the ammonium glufosinate herbicide at different tillages decreased the abundance of broadleaf weeds (Figure 6), in relation to the grasses.

Using herbicides on tillage (T1 and T2) exposed the seed bank of grasses to the soil surface to adequately obtain oxygen and light needed for growth. This is supported by Wibawa et al. (2009), who reported that the herbicide at a dose of 200 g ha^{-1} significantly suppressed broadleaf weeds by 94.68 %, when compared to grasses (59.65 %), at two weeks after spraying. Tampubolon et al. (2019) also found that the ammonium glufosinate herbicide at a dose of 300 g a.i. ha^{-1} significantly removed 100 % of the glyphosate-susceptible *E. indica*, while Alridiwirsah et al. (2020) reported that the grasses were 52.76 % higher, if compared to broadleaf and sedges in guava plants. In addition, Głowacka (2011) stated that the number of *Echinochloa crus-galli* (grasses) was more dominant with mechanical control (18.0 populations) and herbicides (10.3 populations) in maize plants, when compared to other weeds, including *G. parviflora*, *Chenopodium album*, *Cirsium arvense* and *Polygonum lapathifolium*. Uddin et al. (2018) also added that the abundance of grasses was 130.1 % higher than broadleaf weeds (108.5 %) and sedges (61.4 %), in the rice and potato cropping pattern.

Based on these findings, it is recommended to spray ammonium glufosinate during land clearing to decrease the broadleaf and sedge weeds abundance, and then apply 1-time tillage (T1) to decrease the population of grass weeds.

CONCLUSIONS

1. The 2-times tillage (T2) system increased the *Ageratum conyzoides* (2.81-folds), *Cynodon dactylon* (41 population) and *Euphorbia heterophylla* (2.43-folds) populations, when compared to the no-tillage (NT) system;
2. *Cyperus rotundus* had the highest summed dominance ratio at NT and 1-time tillage (T1), while *A. conyzoides* was found in T2 with a moderate diversity index;
3. Based on the classification, only grasses decreased in T1 and T2. Furthermore, there was a significant and positive correlation between *E. heterophylla* and cation exchange capacity (0.727);
4. A total of four new weed species, namely *Glyceria maxima*, *Leersia oryzoides*, *Scoparia dulcis* and *Anthoxanthum oculatum*, were found for NT, T1 and T2, due to the application of the ammonium glufosinate herbicide.

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