



## Growth and Yield of Sweet Corn under Minimum Tillage Technology by Using Various Doses of Herbicide Mixtures of Glyphosate and 2,4-D

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### ABSTRACT

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Glyphosate is a widely used herbicide for minimum tillage technology because it effectively kills broadleaf and grass weeds. Mixing glyphosate with other herbicide that has a different mechanism, such as 2,4-D may increase control efficacy and prevent the evolved of resistant weeds. Research was conducted to obtain the effective dose of glyphosate and 2,4-D mixtures and to evaluate the effect of the herbicide mixtures on the growth rate and yield of sweet corn. Depression on summed dominance ratios (SDR) and increased number of dominant weeds were observed after the application of glyphosate and 2,4-d mixtures. The interaction of the herbicide mixtures was observed optimum at the doses of glyphosate and 2,4-D of 1.94 and 1.5 L ha<sup>-1</sup>, respectively, with maximum of net assimilation rates (NAR) at 4-6 weeks after planting of 0.0003617 g cm<sup>-2</sup> days<sup>-1</sup>. Plant growth rates (PGR) and NAR were observed maximum by a single treatment of glyphosate at a dose of 1.5 L ha<sup>-1</sup> which were 2.23614 and 2.23607813 g cm<sup>-2</sup> days<sup>-1</sup>, respectively. Yield of sweet corn observed as fresh-weight of cobs was found maximum of 129.41 g with a single treatment of glyphosate at 2,018 L ha<sup>-1</sup>.

### INTRODUCTION

Soil cultivation for growing sweet corn on dry land is usually carried out intensively, where this method may not only requires high cost but also can cause damage on soil. When the field open to the intensive rainfall, the structure of soil will be damaged and causes erosion. To prevent these damages, a minimum tillage technology was introduced known as a soil conservation tillage which is only cultivating the soil at the planting points, while weeds are killed by herbicides (Adnan *et al.*, 2012; Burhanudin *et al.*, 2015). This

conservation tillage can minimize soil surface erosion and at the same time increase soil fertility because the dead weeds will function as sources of organic materials (Derpsch *et al.*, 2010; Kumari *et al.*, 2018).

Glyphosate (*isopropyl amine salt*) is a widely used herbicide for minimum tillage technology because it is a broad spectrum herbicide and effectively kills weed populations including broadleaf and grass weeds (Tu *et al.*, 2001; Shaner, 2014). Glyphosate is a systemic herbicide and applied foliarly. The mechanism of action of glyphosate is inhibiting the enzyme *5-enolpyruvylshikimate-3-phosphate synthase*

(EPSPS) which is function in amino acid biosynthesis. This enzyme biosynthesize three essential amino acids including *phenylalanine*, *tyrosine*, and *tryptophan* (Shaner, 2014). The active ingredients of glyphosate are translocated to all parts of the plant and if the herbicide does not exposed to the target, it will be decomposed in a few weeks, so it does not have a residual effects to the environment. The symptoms of glyphosate herbicide on target weeds appear in 2-3 weeks after application (Tu *et al.*, 2001).

Intensive use of herbicide such as glyphosate in certain periods of planting seasons either by increasing the application doses or the frequency of application may raise a negative effect on agricultural ecosystems such as the evolved of resistant weeds or superweeds (Tu *et al.*, 2001; OMAFRA, 2017). Integrated weed management by combining control practices or by mixing more than two herbicides with different mechanism can be overcome these problems. However, compatibility of the mixed herbicide is required, so that no chemical impacts and harmful physical effects found on the mixtures (Damalas, 2004; Barcelo and Cruz, 2015; Choudhary *et al.*, 2016). An application of the mixing herbicides can be done by the ingredients mixed in herbicide solutions or by simultaneous application times. One type of herbicide that has been mixed with glyphosate is a herbicide 2,4-D (*2,4-dichlorophenoxy acetic acid*) (Robinson *et al.*, 2012). Glyphosate and 2,4-D herbicides have a different mechanism but a mixture of both had been reported compatible and showed a synergistic effects on the target weeds (Wehtje and Gilliam, 2012). Mixtures of these two herbicides may increase herbicide efficacy, reduce a dose of application either on glyphosate or 2,4-D, and also prevent the evolve of resistant weeds (Robinson *et al.*, 2012; Soltani *et al.*, 2018).

Herbicide of 2,4-D is a systemic and foliarly applied, but only inhibits the growth of broadleaf weeds. The mechanism of 2,4-D inhibit the growth of young tissue or growing meristematic tissue. By mixing 2,4-D and glyphosate can accelerate the death of weeds. According to Wehtje and Gilliam (2012), the effectiveness of mixing herbicides is determined by the precise dose of mixed

herbicides, where the mixing herbicide technology is expected to reduce the doses and increase its efficacy. If efficacy to kill weeds increased, the growth of the main crops will be better and the yield of crops will also increase. Therefore, it is necessary to study the optimal level of glyphosate and 2,4-D mixtures in order to increase the effectiveness of weed control in the conservation tillages in cultivation of sweet corn (Utomo *et al.*, 2014). The aim of this study was to determine the effective doses of the herbicide mixtures of glyphosate and 2,4-D and also to study the effect of these mixtures on the growth rate and yield of sweet corn grew on dry land with a minimum tillage system.

## MATERIALS AND METHODS

The study was conducted in Bengkulu from January to April 2017. The geographical location is 3° 72' 74" South, 102° 24' 44" East, and the altitude is 10 meters above the sea level. The field was fed in 4 months and overgrown with various weeds. The weed vegetations were analyzed to determine the composition of weeds on the site field. The analysis was divided into three blocks based on visual weed stratification, and 5 sample plots for each block sized of 0.5 m x 0.5 m were randomly assigned in each group. Enumeration of weeds included density, frequency of occurrence, and dry biomass of a weed species in each sample plot. The value of SDR (Summed Dominance Ratio) was calculated according to the Simarmata *et al.* (2017).

$$SDR = \frac{Dr + Fr + Br}{3} \quad (1)$$

Where, SDR is summed dominance ratio; DR, FR, and BR is relative density, frequency, and biomass of each weed species, respectively

Based on the results of the initial analysis, the three observation blocks had an average similarity coefficient >85%, so the study was arranged in a completely randomized design (CRD) with 3 replications. A total of 27 plots based on the combination of herbicide mixtures with 3 replications were formed. Each plot sized of 3 m x 3.5 m. Mixture of 2 types of herbicides was combined factorially with 3 levels of each, including glyphosate consisting of 3 levels of

1.5, 2.0, and 2.5 L ha<sup>-1</sup>, and 2,4-D consisting of 3 levels of 0.5, 1.0, and 1.5 L ha<sup>-1</sup> (Table 1).

The herbicide mixtures were dissolved in water solution with a spray volume of 200 L ha<sup>-1</sup>. Herbicide solutions were applied in a back sprayer at a pressure of 15 psi using a blue Tjet nozzle. The planting hole were prepared based on the planting distance of 75 cm x 25 cm. Minimum tillage was conducted by cultivating the soil only around planting holes with a size of 20 cm x 20 cm. Then, 2 seeds of sweet corn *var.* Secada were planted in planting hole with a depth of 3 cm.

Table 1. Doses's mixtures of glyphosate and 2,4 D.

No	Glyphosate (L ha <sup>-1</sup> )	2,4-D (L ha <sup>-1</sup> )
1	1.5	0.5
2	1.5	1.0
3	1.5	1.5
4	2.0	0.5
5	2.0	1.0
6	2.0	1.5
7	2,5	0.5
8	2,5	1.0
9	2,5	1.5

*Carbofuran* were added 1 gram to prevent insects before closing the planting holes.

Plants were maintained by watering, thinning, fertilizing, pest controlling, and weeding. Watering was done daily if there was no rain until 2 weeks after planting (WAP). Thinning was carried out one WAP by leaving one of the most vigorous plant in each planting hole. Fertilization with Urea, TSP and KCl fertilizers was carried out one WAP with doses of 150, 100, and 100 kg ha<sup>-1</sup>, respectively. Weeds were controled mechanically at 3 and 6 WAP, while insects and and diseases were controlled as needed using a commercial insecticide and fungicide. Plants were harvested at 10 WAP which were characterized by dry and sticky brown hair of cob.

Data observed included herbicide efficacy and variables of growth and yield of sweet corn, while analysis of weed vegetation was carried out after corn harvested following the Equation 1. Growth variables of sweet corn observed included leaf area index (LAI), plant growth rate (PGR), and net assimilation rate (NAR) following the equations 2, 3, and 4,

which were conducted at the ages of 2-4, 4-6, and 6-8 WAP (Hunt, 1981). Yield variable was observed as fresh weight of cobs.

$$LAI = \frac{1}{PD} \times \frac{(LA2 + LA1)}{2} \tag{2}$$

$$PGR = \frac{1}{PD} \times \frac{(W2 - W1)}{(T2 - T1)} \tag{3}$$

$$NAR = \frac{W2 - W1}{T2 - T1} \times \frac{(\ln LA2 - \ln LA1)}{LA2 - LA1} \tag{4}$$

Notes: Where, LAI is leaf area index, PD is planting distance, LA<sub>1</sub> and LA<sub>2</sub> is leaf area at the 1st and 2nd observations; PGR is plant growth rate, W<sub>1</sub> and W<sub>2</sub> is weight of dry biomass at the 1st and 2nd observations, T<sub>1</sub> and T<sub>2</sub> are week of 1st and 2nd observations; NAR = net assimilation rate; ln = logarithm (log).

Data observed of growth and yields were statistically analyzed with analysis of varians (ANOVA). If the observed variables were significantly influenced by the treatments at P < 0.05, the data were further separated by orthogonal polynomial analysis to determine the most effective herbicide level.

## RESULTS AND DISCUSSIONS

### Weed Analysis

The initial weed analysis on the research site showed the homogenous distribution of weed species in three observed groups, which were indicated by the closed distance of similarity coefficient (C) by comparing the SDR values among the block I, II, and II of 0.85, 0.87, and 0.82 percent, respectively. Therefore, the the research was carried out in a completely randomized design (CRD). However the similarity decreased to 64, 67, and 54 comparing with the final weed analysis (Table 2).

Table 2. Similarity Coefficient of weeds among 3 blocks and final analysis

Blocks	Block			
	I	II	III	Final
I	-			
II	0.85	-		
III	0.87	0.82	-	
Final	0.64	0.67	0.54	-

According to Simarmata (2015) a weed species can be categorized dominant if the

value of summed dominant ratio (SDR) was similar to or more than 10 percent. SDR of weeds in each analysis showed that the number of species of dominant weeds increased from 2, 4 and 4 species in block I, II, and III, respectively to become 5 species at the end of the study (Figure 1). Two species of dominant weeds in block I were *Colopogonium mucunoides*, *Borreria latifolia* with SDR 33.6 and 22.9, respectively; four species of dominant weeds in block II were *Colopogonium mucunoides*, *Borreria latifolia*, *Imperata cylindrica*, and *Croton hirtus* with SDR 26.4, 20.4, 15.5, and 10.6, respectively; and 4 species of dominant weeds in block III were *Colopogonium mucunoides*, *Imperata cylindrica*, *Croton hirtus*, and *Borreria latifolia* with SDR 23.5, 17.8, 13.1, and 10.6. The dominant weeds at the end of the study increased to 5 species which were *Imperata cylindrica*, *Borreria latifolia*, *Colopogonium mucunoides*, *Croton hirtus*, and *Axonopus compressus* with SDR 19.9, 15.8, 12.1, 12.0, and 11.8.

The differences of weed number or weed species distributions indicated the shifting of vegetation after exposed to the herbicide mixtures of glyphosate and 2,4-D (Simarmata, 2015).

### Interaction Effects of Glyphosate and 2,4-D Mixtures

Analysis of variances (ANOVA) showed that the mixtures of glyphosate and 2,4-D at various doses were interact significantly on net assimilation rate (NAR) at 4-6 WAP (Table 3). The interactions of 2,4-D at 0.5 L ha<sup>-1</sup> and Glyphosate from 1.5 to 2.5 L ha<sup>-1</sup> significantly affected NAR at 4-6 WAP in a quadratic response pattern of  $Y_{0.5} = -0.00051 x^2 + 0.00198 x - 0.00156$  ( $R^2 = 0.353$ ). The optimum dose of glyphosate was 1.94 L ha<sup>-1</sup> resulted an average maximum of NAR of 0.0003617 g cm<sup>-2</sup> days<sup>-1</sup> (Figure 2). On the other hand, at the dose of 2,4-D 1.0 L ha<sup>-1</sup>, the response pattern is  $Y_{1.0} = 0.00049x^2 - 0.00211 x + 0.00242$  ( $R^2 = 0.474$ ). Glyphosate at the

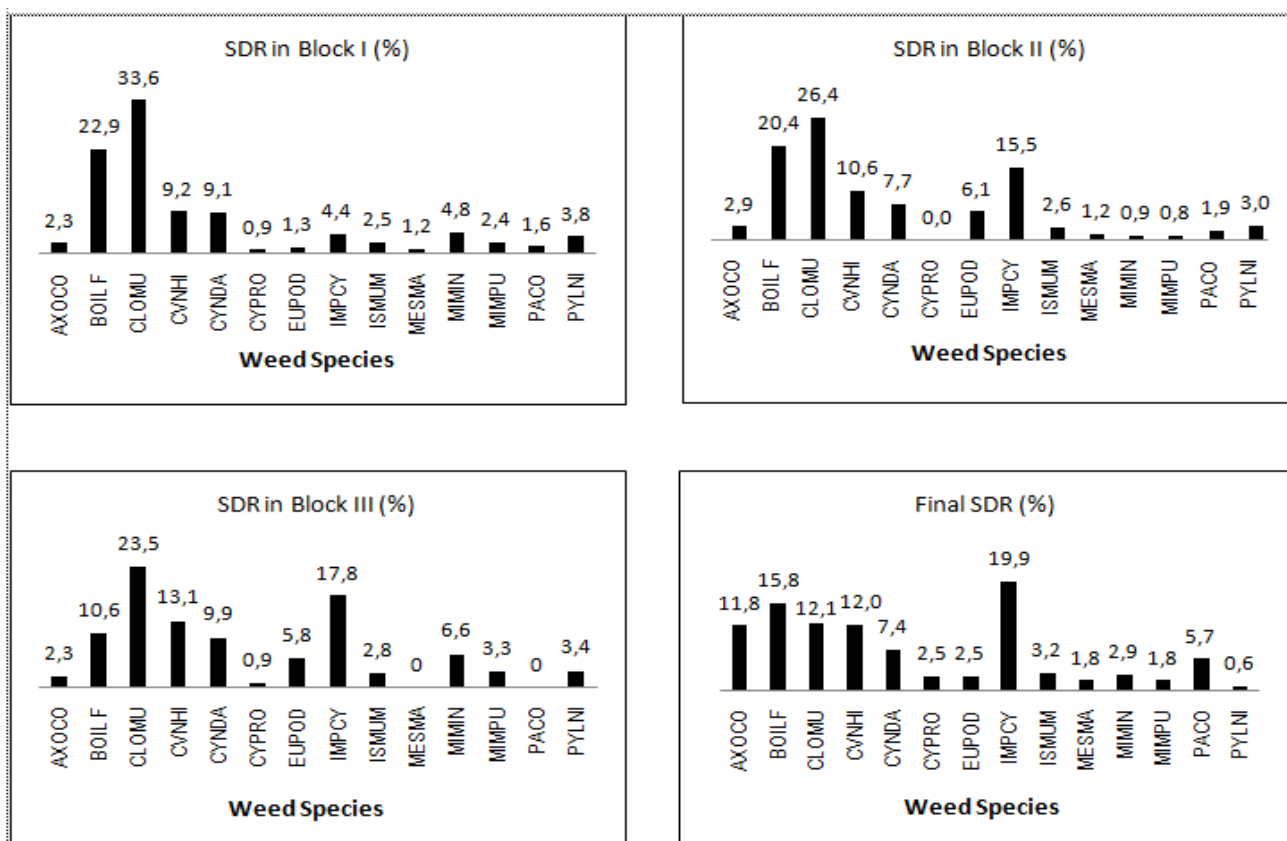


Figure 1. Analysis of weed in the experiment site based on the SDR values among block I, II, and III, and analysis at the end of experiment. (AXOCO = *Axonopus compressus*, BOILF = *Borreria latifolia*, CLOMU = *Colopogonium mucunoides*, CVNHI = *Croton hirtus*, CYNDA = *Cynodon dactylon*, CYPRO = *Cyperus rotundus*, EUPOD = *Eupathorium odoratum*, IMPCY = *Imperata cylindrica*, ISMUM = *Ischaemum muticum*, MESMA = *Melastoma malabathricum*, MIMIN = *Mimosa invisa*, MIMPU = *Mimosa pudica*, PACO = *Paspalum Conjugatum*, PYLNI = *Phylanthus niruri*).

Table 3. Recapitulation of F-test from analysis of varians (ANAVA)

Variable	Time Observed (WAP)	F-test (5%)		
		Glyphosate doses	2,4-D doses	Interaction
LAI	2-4	0.21 ns	2.82 ns	1.94 ns
	4-6	0.26 ns	2.57 ns	1.71 ns
	6-8	0.02 ns	2.01 ns	0.95 ns
PGR	2-4	12.15 *	1.97 ns	0.55 ns
	4-6	2.75 ns	0.20 ns	1.16 ns
	6-8	0.12 ns	0.83 ns	1.12 ns
NAR	2-4	24.18 *	1.40 ns	1.34 ns
	4-6	1.67 ns	0.76 ns	7.79 **
	6-8	0.06 ns	0.48 ns	0.60 ns
YC	14	7.43 *	1.07 ns	0.18 ns

Notes : LAI = Leaf Area Index; PGR = Plant Growth Rate; NAR = (Net Assimilation Rate); YC = Yield Fresh Cob Weight; WAP = week after plant, \* = significantly effects at 5% level; ns = not significant influence

dose of 2.15 L ha<sup>-1</sup> resulted an average minimum NAR of 0.0001485 g cm<sup>-2</sup> days<sup>-1</sup>. The mixing of 2,4-D at 1.5 L ha<sup>-1</sup> resulted of the net assimilation rate in linear response pattern  $Y_{1.5} = -0.00003x + 0.00023$  (R<sup>2</sup> = 0.00948).

This study showed the effect of dose combination of glyphosate and 2,4-D, in mixing dose of 2,4-D at 0.5 L ha<sup>-1</sup> and glyphosate from 1.5 o 1.94 L ha<sup>-1</sup> can increase NAR as a ratio of leaf area and plant dry weight of 0.0003617 g cm<sup>-2</sup> days<sup>-1</sup>. This is presumably because the combination of the dose of the herbicide mixture of glyphosate and 2,4-D was able to control weeds so that the competition between crops and weeds was minimized which resulted in the growth of

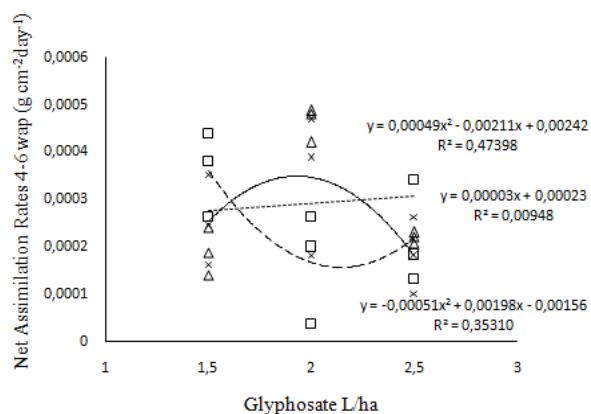


Figure 2. The interaction effect of glyfosate and 2,4-D mixtures with various doses on net assimilation rates (NAR); 2,4-D 0,5 L/ha (x), 2,4-D 1 L/ha (□) and 2,4-D 1,5 L/ha (Δ).

plants. Increasing the dose of 2,4-D up to 1.5 L ha<sup>-1</sup> and glyphosate 1.5 o 1.94 L ha<sup>-1</sup> tended to reduce the rate of NAR of sweet corn. Mixture of 2,4-D at 1.0 L ha<sup>-1</sup> and glyphosate at 1.5 to 2.15 L ha<sup>-1</sup> can decrease the net assimilation rate with a minimum value of 0.0001485 g cm<sup>-2</sup> days<sup>-1</sup>. However, increasing the dose of glyphosate from 2.15 to 2.5 L ha<sup>-1</sup> can increase the net assimilation rate to 0.0002 g cm<sup>-2</sup> days<sup>-1</sup>.

### The Effect of Glyphosate

The results of ANAVA showed that the dose of glyphosate singly had significant effect on PGR, NAR, weight of fresh cobs (Table 3). The increased dose of glyphosate from 1.5 to 2.5 L ha<sup>-1</sup> affected the PGR significantly at 2-4 WAP in a quadratic response pattern  $Y = 0.000003 x^2 - 0.000015 x + 2.236094$  (R<sup>2</sup> = 0.161) (Figure 3). The highest PGR were seen at 1.5 L ha<sup>-1</sup> glyphosate of 2.23607813 g cm<sup>-2</sup> days<sup>-1</sup>. Utomo (2014) stated that glyphosate at 1.0 L ha<sup>-1</sup> was able to increase the dry weight of plants by 60.14%. But, increasing glyphosate doses up to 2.5 L ha<sup>-1</sup> reduced PGR as discussed in previous reports by Faqihudin *et al.*, (2014) stated that increasing the dose of glyphosate herbicides above 2.0 L ha<sup>-1</sup> decreased both the growth variable and the yield of corn plants.

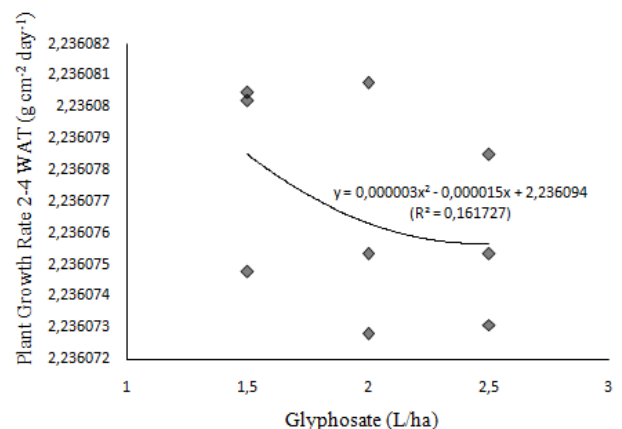


Figure 3. Relationship between glyphosate doses and plant growth rates (PGR).

Similarly, the effects of glyphosate doses decreased the NAR (Figure 4). The NAR at 2-4 WAP was found in a quadratic response pattern  $Y = -0.00001x^2 + 0.00002x + 2.23613$  (R<sup>2</sup> = 0.25762). The highest NAR of 2.23614 g cm<sup>-2</sup> days<sup>-1</sup> was observed at 1.5 L ha<sup>-1</sup> glyphosate. Increasing the dose of glyphosate up to 2.5 L

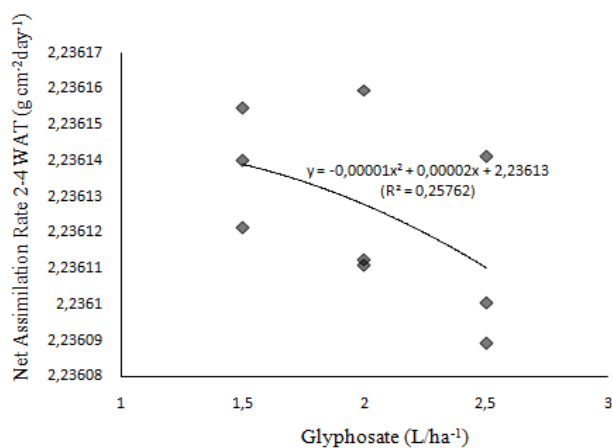


Figure 4. Relationship between glyphosate doses and net assimilation rates (NAR).

ha<sup>-1</sup> tends to reduce the values of NAR. This result was described in previous study by Wardoyo *et al.*, (2001) showed that an increase in glyphosate doses above 2 L ha<sup>-1</sup> caused a decrease in the number of leaves and height of corn plants. This was presumably because glyphosate absorbed by clay particles has exceeded the absorption capacity of glyphosate, so that glyphosate is active in the soil solution and is eventually absorbed by the corn plant.

The contribution of glyphosate as weed control to plant growth was very small at an average of 25% (Faqihhudin *et al.*, 2014). The herbicide application can not control weeds totally. Weed species in the study area varied so that competition with sweet corn still showed an effect on the growth and yield of plants. The results of ANAVA on fresh weight of cobs showed that an increase dose of glyphosate from 1.5 to 2.5 L ha<sup>-1</sup> affected the weight of the cob significantly in a quadratic pattern  $y = -79.88x^2 + 322.5x - 196.1$  ( $R^2 = 0.185$ ). The optimum glyphosate dose of 2.01 L ha<sup>-1</sup> resulted in a maximum weight of cob of 129.41 g (Figure 5). The dose of glyphosate from 1.5 to 2.018 L ha<sup>-1</sup> increased the fresh weight of cob. Glyphosate applied at this dose was able to suppress weed growth, so the competition between corn plants and weeds was minimized. However, increasing the dose of glyphosate from 2.018 to 2.5 L ha<sup>-1</sup> actually decreased the weight of cob. The residue of glyphosate in the soil might be absorbed by the sweet corn plant which resulted in a

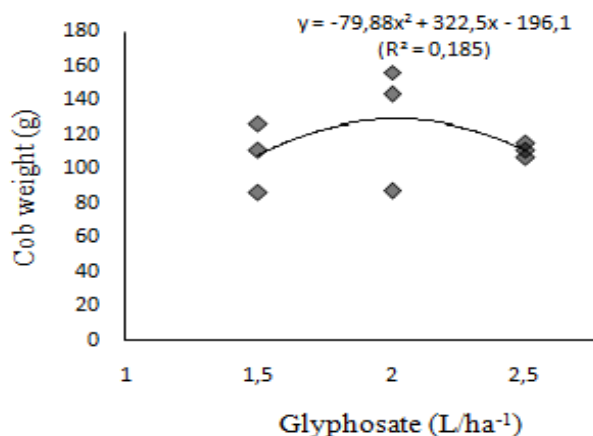


Figure 5. Relationship between glyphosate doses and fresh-weight of cobs

decrease in crop yield (Faqihhudin *et al.*, 2014). Triyono (2010) in his research stated that weed control with precised dose would suppress weed growth at the beginning of the growth of sweet corn plants so that plants could grow optimally.

## CONCLUSIONS

The interaction of the herbicide mixtures of glyphosate and 2,4-D at the doses of 1.94 and 1.5 L ha<sup>-1</sup>, respectively, was found significantly at 4-6 weeks after planting with the optimum net assimilation rates (NAR) of 0.0003617 g cm<sup>-2</sup> days<sup>-1</sup>. Plant growth rates (PGR) and NAR were observed maximum by a single treatment of glyphosate at a dose of 1.5 L ha<sup>-1</sup>, which were 2.23614 and 2.23607813 g cm<sup>-2</sup> days<sup>-1</sup>, respectively. Yield of sweet corn observed as fresh-weight of cobs was found maximum of 129.41 g per plant with a single treatment of glyphosate at 2,018 L ha<sup>-1</sup>.

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