Distribution And Frequency Of Paraquat-Resistant Goosegrass (Eleusine Indica) Population On Cornfields In Simalungun Regency, Indonesia

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Abstract: Corn is one of the important cereal crops in Simalungun, which is the second-largest corn production area in North Sumatera, Indonesia. Reaching optimal corn production were inseparable from area weed management activities. Goosegrass (E. indica) was one of the most common weeds that often associate with corn cultivation. For weed control growers have been commonly using paraquat in Simalungun Regency. This study aimed to map the distribution and frequency of paraquat-resistant goosegrass on cornfields across the Simalungun Regency. Samples were collected from the 13 largest corn producer districts in Simalungun Regency. Sampling was carried out in areas that have been sprayed with paraquat for a minimum of 2 years. Samples were collected in March-July 2019 from 59 cornfields and one sample of paraquat-susceptible goosegrass which had never been applied with herbicide. The paraquat resistance test used the highest dose of 600 g b.a. ha^{-1}. The results of the resistance test of 59 corn fields revealed 47 cornfields (80%) resistant to paraquat, 9 cornfields (15%) moderately resistant, and 3 cornfields (5%) susceptible. The level of paraquat resistance goosegrass was 20.83 - 100%.

Index Terms: Corn, Distribution, Eleusine indica, Frequency, Goosegrass, Paraquat, Resistance.

1. INTRODUCTION

Simalungun is the second-largest corn production in North Sumatra. In 2017, the total area of corn harvest in Simalungun Regency was 58,374 ha and the average production was 5.8 tons ha^{-1} [1]. Weed is an important factor in corn cultivation because it is detrimental as its competition with corn in utilizing nutrients, light, and water, and growing space [2]. Besides, weeds also complicate the work of maintaining plants, sometimes even becoming the host for pests, viruses and plant diseases [3]. Mohammadi [4] stated that the presence of weeds associated with corn could reduce corn yields by 37 to 75% if not controlled. Growers in Simalungun have been using herbicides to control weeds for years. Paraquat, a contact herbicide, is the most common herbicides they used for weed control in cornfields. Paraquat is applied at 200-1000 g a.i. per hectare at the stage of 7 leaf number. According to Sriyani [5], weed control in several areas of cultivated plants in Indonesia was done chemically using herbicides. As a result of using the same type of herbicides for years or repeatedly during the growing season to control one type of weed that is not interspersed with other herbicides can cause herbicide resistance [6]. The same thing also stated by Purba [7] that in a weed population that is controlled using one type of herbicide with satisfactory results, there is a possibility that one individual out of millions of individuals sprayed with a herbicide may have genes that make that individual resistant to the herbicide. Resistant individuals grow normally and regenerate some individuals which are also resistant to the same herbicide in subsequent herbicide applications. Each application of the same herbicide will control susceptible individuals and leave resistant individuals. The number of resistant individuals at one time became significant and caused failure in control. Weed resistance is an irreversible environmental impact that can result in increasing chemical control costs, crop yields that continue to decline and a reduction in the number of alternative herbicides [8],[7]. Weed resistance to paraquat herbicides has occurred in various parts of the world. According to Heap [9], cases of paraquat resistance have occurred in 32 weed species in 20 countries. Specifically, 8 cases of goosegrass (Eleusine indica) resistance had been reported in 5 countries, and in Indonesia, this case occurred in North Sumatra in 2012 on cornfields. Goosegrass (E. indica) is categorized as an important and most problematic weed in the agricultural environment [10] and [11]. The characteristic is vigorous growth and an extended root system that contributes this weed competitive highly [11].

One goosegrass plant can produce more than 140,000 seeds, which are easily spread by wind and water, attached to animal hair and agricultural machinery [12]. In Simalungun Regency, where corn is an important cereal crop, goosegrass is one of the important weeds in the field. Generally, corn growers applied paraquat herbicide to control weeds when the corn was 4-5 weeks after planting or the corn has reached one meter high or more to minimize crop injury caused by the herbicide. The objective of this study was to map the distribution and frequency of paraquat-resistant goosegrass populations in Simalungun Regency so that it can improve weed management of corn production in the region.

2 MATERIAL & METHODS

2.1 Collection of Goosegrass Seeds and Information

The weed population sampling location was in Simalungun Regency, which is geographically located between 02^0 36' - 03^0 18' North Latitude and between 98^0 32' - 99^0 35' East Longitude with an area of 4,372.5 km^2 at an altitude of 0 - 1400 meters above sea level. Weed sample collection was

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carried out from March to July 2019.

a. Sample Determinantion

District, where corn field visited for goosegrass seed collection, was 13 districts in Simalungun Regency (Table 1), which were categorized as the center of corn production in Simalungun Regency with an area of cornfields >1800 ha and a minimum of 2 years had been applied with paraquat.

Table 1. *Seeds Collection Area*

No.	District	Size of Corn Fields (ha)
1	Silimakuta	2.705
2	Purba	5.093
3	Dolok Pardamean	3.020
4	Sidamanik	3.920
5	Pamatang Sidamanik	4.263
6	Tanah Jawa	3.451
7	Dolok Panribuan	2.654
8	Panei	2.523
9	Raya	4.699
10	Dolok Silou	4.415
11	Hutabayu Raja	2.346
12	Jawa Maraja Bah Jambi	2.231
13	Pematang Silimahuta	1.810

Source: Central Bureau of Statistics, 2018

b. Collection of Seeds and Field History

Seeds samples were collected from at least 25 plants per population. Goosegrass seeds were collected if they were ripe, which were marked with brownish-yellow panicles and the seeds began to break free from panicles or seeds that were easily detached from panicles. Sampling of seeds in the cornfield was carried out by random method. The seeds were put into paper envelopes, and labeled with necessary information and transferred to campus for further works. The seeds were dried then by sunlight for 10 minutes. The seeds of goosegrass which have never been sprayed with paraquat are also collected from Raya District as a comparison population. Information gathering was also carried out by direct survey to the growers, where weed seeds were collected as samples, and gave questionnaires about the herbicides application historical, especially paraquat as herbicide to control weeds in cornfields [13]. Each sampling location coordinates were recorded by GPS.

2.2 Paraquat Resistance Test

Resistance testing of samples of goosegrass, that has been collected was conducted in the STIPAP research field in August – September 2019, using the bioassay method [14]. Resistance testing was carried out to classify the resistance categories of goosegrass populations from the Simalungun Regency.

a. Germinating Seeds

The nursery media in the form of a mixture of soil and sand (1: 1) that had been sterilized from the seed bank by 100°C for 3 hours [15]. The germinating media was placed in a seed tray measuring 33 x 24 cm. Each seed tray was described as weed seeds source. Weed seeds that have been collected from grower's fields are first soaked in a 2% KNO_3 solution for 30 minutes to break seed dormancy [16]. Furthermore, the seeds are spread into the seed tray and covered with soil with a thickness of 0.5 - 1 cm. The number of seeds that are sown around 100-200 seeds/tray.

b. Maintenance

Seeds that have been grown are watered every day. Insecticide application is carried out to prevent the disturbance of pests.

c. Transplanting to the Pot

Pot 20 cm in diameter was filled with a mixture of soil, sand, and compost (1: 1: 1) of 1.5 kg. Then doused with water so that the soil was moist. The goosegrass weeds were transplanted to pots that have 2-3 leaves and have good growth. The number per population of goosegrass was 12 plants per pot with 4 replications, so there were 48 weeds per population.

d. Paraquat Application

Seedlings at 4 – 5 leaf stage were sprayed with paraquat dichloride 276 g l^{-1} which is equivalent to the paraquat ion 200g/l with the trademark Gramoxone 276 SL. The paraquat application at the rate of 600 g b.a. ha^{-1}, using CO_2-pressurized backpack sprayer with a constant pressure 200kPa, with polyjet nozzle type, and spray volume 478 L ha^{-1}.

e. Resistance Parameter

The number of plants survived of paraquat application was determined 21 days after spraying (DAS) [17]. The parameters observed were:

Percentage of survival plants:

$$\frac{\text{Number of Survivor}}{\text{Total Plants Sprayed}} \times 100\%$$

The results of population resistance testing of goosegrass was divided into 3 categories, namely: S (susceptible), if <1% of the weed population can survive, R1 (moderate resistance), if 1 - 19% of the population can survive, and the R2 (resistant) category, if ≥20% of the population can survive, [18], [19], and [20]. The fresh weight weed was observed too by cut the weed above the soil level and then measured with the analytic scale.

3 RESULT AND DISCUSSION

Eighty cornfields from 13 districts were visited for seed sampling but only 59 fields (74%) were obtained from, which weed seeds suitable for sampling, and around 21 fields (26%) were not suitable because of goosegrass were immature, or the field just applied the herbicide.

Based on resistance testing that there were 47 samples of goosegrass resistant to paraquat (80%), 9 samples were moderate (15%), 3 samples were susceptible (5%). The distribution map of paraquat resistant goosegrass in Simalungun Regency could be seen in Figure 1. The case of paraquat-resistance goosegrass reported too by Ginting [21] in, Tiga Binanga District, Karo Regency, Indonesia, that 2 of the population of goosegrass were paraquat-resistance, 4 samples moderate, and 21 samples susceptible. Another case of paraquat-resistant goosegrass in cornfield had been reported in Colombia, Espinal, Tolima in 2016 and Indonesia in 2012 ([9].

Symptoms that arise after the paraquat application were desiccation leaves. That was as a result of the destroyed cell membrane and the spilled out contents [22]. However, this process can only occur in the leaves. In this study, the paraquat resistant goosegrass showed some symptoms where: only some leaves get chlorosis, necrosis spot on the leaves, and forming new leaves and even new tillers. All susceptible plants were completely controlled by paraquat herbicide.

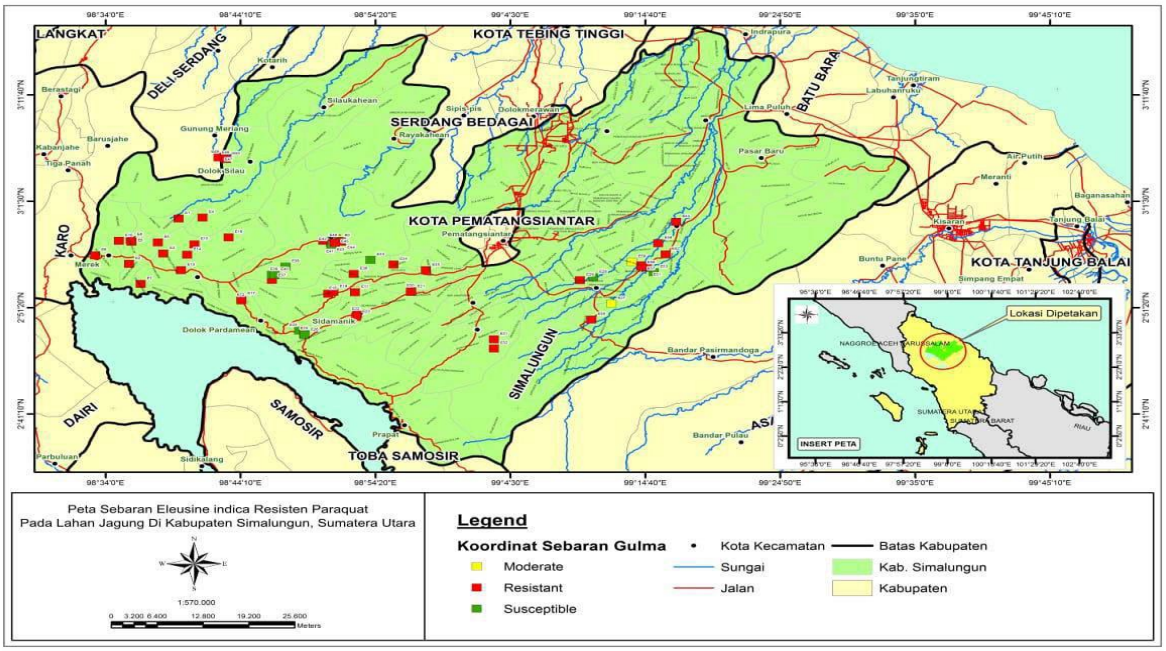

***Figure 1**. Distribution map of paraquat resistant goosegrass in Simalungun Regency, North Sumatera, Indonesia.*

Based on Figure 1 and Table 1 that paraquat resistant goosegrass in Simalungun Regency was widespread. Each district has the paraquat resistant goosegrass population. The district with the most paraquat resistant goosegrass was Silimakuta District with eight cornfields detected as paraquat resistance, the second was Purba District with seven corn fields detected, and the third was Raya District with six corn fields detected. The average number of survive goosegrass was 26 of 48 plants per sample, the range level of surviving goosegrass was 20,83 - 100%. The same study of Ginting [21], that the average number of survive goosegrass in paraquat resistance in Karo Regency was 43,86 – 100% from 60 plants per sample. Highly level of paraquat resistance occurred in Simalungun Regency. It was known that generally corn growers in Simalungun Regency used paraquat as a post-emergence herbicide that is usually applied on 4 - 5 weeks after planting, which is the vegetative phase in corn and effected to the corn production. This is in line with the corn critical period was 3 – 7 weeks after planting [23] and [24]. The same thing about critical period free weed in corn was also stated by Ghanizerdah [25] that weed must be controlled from 5 – 9 leaf stages to prevent yield loses 5% in corn. In the area of study, paraquat has been used repeatedly for 2 to 27 years at least 2 times per season without herbicide rotation. Based on Table 1, the combination of herbicide use frequency, rate of exposure and similar site of action is the most important factor in the enhance the herbicide resistance. This is in line with the opinion of Hager and Refsell [8] that using herbicides with the same type mode of action for many years or repeatedly during the growing season to control one type of weed that was not interspersed with other herbicides can result in herbicide resistance. Repeated used of herbicide will expose the weed population to a "selection pressure" which may lead to an increase in the number of surviving resistant individuals. As a consequence, the resistant weed population may increase to the point that adequate weed control cannot be achieved by the herbicide application [26]. Herbicide resistance is an evolutionary process which strongly depends on genetic factors (frequency and number of resistant genes, mechanisms of inheritance, fitness cost associated with resistant alleles), weed species (self – or cross-pollination, pollen movement, seed production, dispersion and longevity), herbicide (chemistry, mode of action, residual activity) and operational factors (herbicide dose, environmental variables) [27]. Herbicide resistance needed to be controlled even prevented with the proper field management strategies, especially for herbicide. There were three keys to the management of herbicide resistance: crop management, cultural technique and chemical herbicide [26]. Rotating plants was one of the alternatives in crop management for solving or minimize weed resistance. In this study, some samples (E10, E11, E16, and E17) usually rotated with some crops (chili, cabbage, potato, and tomato) but the goosegrass still indicated as paraquat resistance. This resistance case can occurred due to the use of the same mode of action of herbicides, especially for paraquat, even in different crops. Crop rotation aimed to avoid the successive crop which the needs of herbicide were the same. Besides that, the crop rotation with different growing period crops aimed for “breaking” the regular life cycle of the weed and for delaying the selection of resistant plants [28]. Based on Figure 2, which is the result of a paraquat resistance test, that generally the number of survive goosegrass was proportional to the fresh weight weed. This shows that the more resistant a population is, the fresh weight will increase. The higher of resistant weed percentage in cornfield showing the difficult level to controlling the goosegrass which can be affected to the decreasing of corn production and the increase of corn cost production. Besides, the moderate resistant goosegrass population potentially became resistant population. Knowing the distribution and frequency of paraquat resistant goosegrass population is important to minimize the distribution of resistant population and the impact of paraquat resistant goosegrass on production system by rotation some herbicide which have a different mode of action of herbicides, mixture some mode of action herbicides, or rotation to other weed

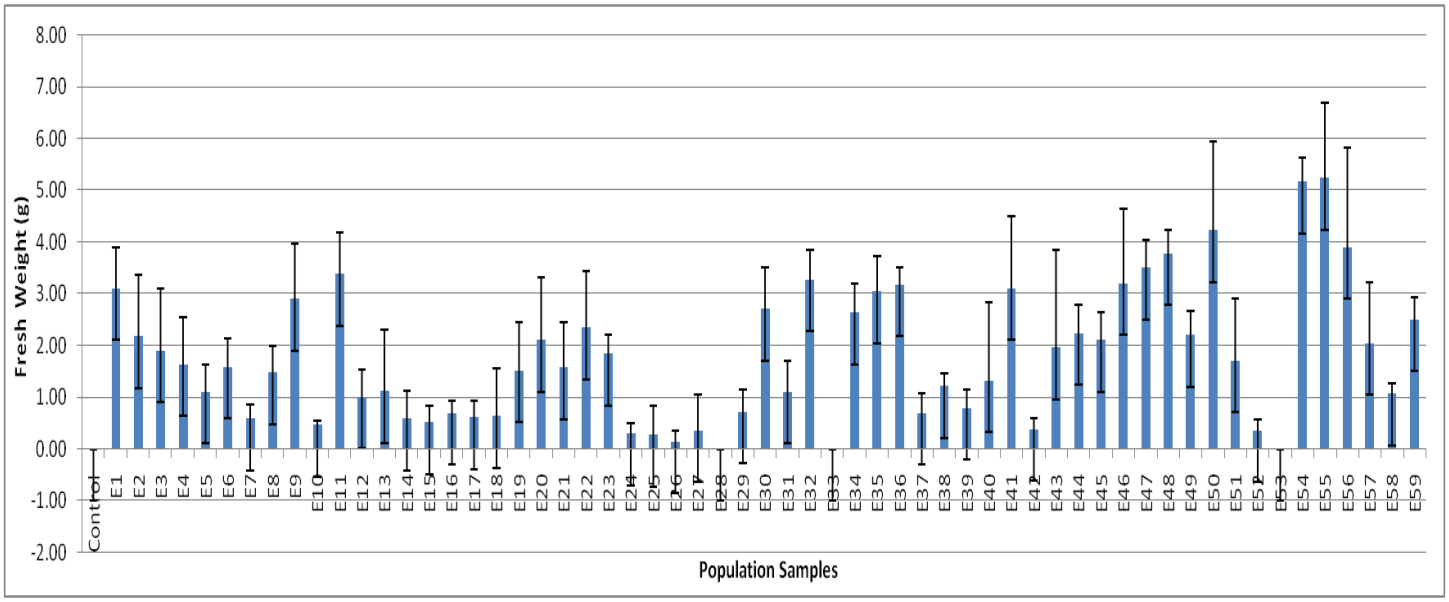

Figure 2. *Fresh weight of goosegrass at 21 days after spraying (DAS)*

control strategies. Because the herbicide resistance was an irreversible environmental impact, the field management strategies should do the prevent first then controlled it.

4 CONCLUSION

47 populations (80%) of goosegrass out of 59 populations surveyed indicated that they have developed resistance to paraquat herbicide. The resistant population percentage from three main districts was 45%, in which the most resistant population were Silimakuta District (17%), Purba District (15%), and Raya District (13%). This distribution of paraquat-resistant goosegrass was widespread in 13 districts in Simalungun Regency, North Sumatera, Indonesia. Generally, most of the growers were not aware of the herbicide resistance developed in their field.

5 ACKNOWLEDGEMENT

This research was fully funded by The Ministry of Research, Technology and National Innovation Research Agency of Indonesia Republic.

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***Table 1**. The Field Information and The Result of Resistant Paraquat Test*

# Treated	Coordinate		Rate of Exposure (year)	Crop Rotation	Applied Freq per Season	# Survivor	% Resistance	Category
	Latitude	Longtitude						
E0	2.96175	98.85906	0	-	0	0	0.0	Sensitive
E1	2.99761	98.65847	5	-	2	38	79.2	Resistant
E2	2.9253	98.5962	10	-	2	35	72.9	Resistant
E3	2.94172	98.63935	11	-	2	28	58.3	Resistant
E4	2.99904	98.68844	11	-	2	44	91.7	Resistant
E5	2.95935	98.63244	8	-	2	25	52.1	Resistant
E6	2.96056	98.59944	8	-	2	37	77.1	Resistant
E7	2.89333	98.61083	13	-	2	10	20.8	Resistant
E8	2.96338	98.59844	9	-	2	30	62.5	Resistant
E9	2.93889	98.55361	18	-	2	31	64.6	Resistant
E10	2.96194	98.58342	15	-	2	13	27.1	Resistant
E11	2.87989	98.70316	19	Tomato	2	44	91.7	Resistant
E12	2.86694	98.7375	27	Cabage, Potato	2	34	70.8	Resistant
E13	2.91528	98.66139	16	-	2	13	27.1	Resistant
E14	2.94	98.66917	14	-	2	15	31.3	Resistant
E15	2.95639	98.67833	20	-	2	17	35.4	Resistant
E16	2.9675	98.72139	21	Chili	2	17	35.4	Resistant
E17	2.86944	98.73722	20	Cabage, Potato	2	27	56.3	Resistant
E18	2.87778	98.84623	6	-	2	14	29.2	Resistant
E19	2.88052	98.85289	4	-	2	30	62.5	Resistant
E20	2.88194	98.95056	9	-	2	29	60.4	Resistant
E21	2.88056	98.95028	10	-	2	43	89.6	Resistant
E22	2.84472	98.8825	5	-	2	39	81.3	Resistant
E23	2.84071	98.88135	14	-	2	43	89.6	Resistant
E24	2.81901	98.80975	3	-	1	9	18.8	Moderate
E25	2.81352	98.81609	4	-	1	9	18.8	Moderate
E26	2.81167	98.81667	4	-	1	2	4.2	Moderate
E27	2.86194	99.20222	3	-	1	8	16.7	Moderate
E28	2.90395	99.17901	2	-	2	0	0.0	Sensitive
E29	2.89941	99.16246	20	-	2	25	52.1	Resistant

E30	2.83639	99.17694	11	-	2	44	91.7	Resistant
E31	2.80492	99.05434	19	-	2	16	33.3	Resistant
E32	2.79043	99.05444	13	-	2	46	95.8	Resistant
E33	2.9315	98.89933	3	-	2	0	0.0	Sensitive
E34	2.92417	98.92833	14	-	2	37	77.1	Resistant
E35	2.91529	98.96892	10	-	2	46	95.8	Resistant
E36	2.90927	98.87836	17	-	2	44	91.7	Resistant
E37	2.89972	98.77583	12	-	2	11	22.9	Resistant
E38	2.92085	98.79267	3	-	1	9	18.8	Moderate
E39	2.90778	98.77583	2	-	2	5	10.4	Moderate
E40	2.90778	98.77889	3	-	1	9	18.8	Moderate
E41	2.95833	98.85	10	-	2	36	75.0	Resistant
E42	2.95588	98.85059	3	-	2	8	16.7	Moderate
E43	2.96111	98.86167	3	-	2	31	64.6	Resistant
E44	2.96056	98.8625	12	-	2	27	56.3	Resistant
E45	2.95889	98.85472	4	-	2	46	95.8	Resistant
E46	2.96194	98.84	3	-	2	25	52.1	Resistant
E47	3.09653	98.70847	7	-	2	34	70.8	Resistant
E48	3.09497	98.70855	10	-	2	46	95.8	Resistant
E49	3.09394	98.71646	8	-	2	39	81.3	Resistant
E50	3.09229	98.71804	11	-	2	43	89.6	Resistant
E51	2.91972	99.24667	18	-	2	16	33.3	Resistant
E52	2.94056	99.27	18	-	2	11	22.9	Resistant
E53	2.912	99.2552	3	-	1	0	0.0	Sensitive
E54	2.99222	99.28306	3	-	2	48	100.0	Resistant
E55	2.96167	99.26278	16	-	2	44	91.7	Resistant
E56	2.95806	99.26083	20	-	2	44	91.7	Resistant
E57	2.92306	99.23917	13	-	2	41	85.4	Resistant
E58	2.92083	99.23944	10	-	2	10	20.8	Resistant
E59	2.92853	99.2276	4	-	2	5	10.4	Moderate