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Growth and Yield of Glyphosate-Resistant Corn under Different Timing of Glyphosate Application

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Abstract: A field experiment was conducted in 2002 in Langkat, North Sumatra, to determine the effects of glyphosate application timing on the growth and grain yield of glyphosate-resistant corn. Glyphosate at 1,500 g ha^{-1} was applied at twelve different treatments namely at the V3 stage, the V4 stage, the V5 stage, the V6 stage, the V7 stage, the V8 stage, the V9 stage, the V10 stage, the V12 stage, the V3 stage followed by at the V7 stage, the V3 stage followed by at V12 stage and the V4 stage followed by at V8 stage of glyphosate-resistant corn growth. In addition to the twelve treatments, two other treatments (maintained weed free all season and weed infested all season) were provided for comparison. Competition between corn and weed at the beginning of growth prior to glyphosate application affected growth and yield of corn more than that of post application. Compared to yield resulted from weed-free plot all season, no significant grain yield were found when glyphosate was applied at the V3 stage, the V4 stage, the V3 and V7 stage, the V3 and V12 stage and the V4 and V8 stage. Single application of glyphosate at the V3 corn growth was found to be the best timing of glyphosate application for weed control in Langkat, North Sumatra conditions.

Key words: Glyphosate-resistant corn, glyphosate, application timing

INTRODUCTION

The crop development stage at which weed interference occurred is an important factor in determining potential yield loss. At specific stages of development, individual crop plants may have obtained a critical level of resources that is sufficient to impart a significant competitive advantage against weeds (Hall *et al*., 1992).

Hall *et al*. (1992) reported that the critical period of weed control in corn (*Zea mays* L.) occurred from the third to the 14th leaf stage. This indicates that corn tolerates the early season weed competition without yield loss only until the third leaf stage in the cool spring conditions of Ontario, Canada. The results from the study in Canada suggested that glyphosate can be applied as early as the three leaf stage to prevent yield losses from early season weed competition in regions with cool spring conditions. Gower *et al*. (2002) reported that the optimum timing for weed control to avoid corn grain yield loss for an initial application of glyphosate in north-central USA occurred by the V4 stage (four-leaf-stage at vegetative stage) when the weeds were less than 10 cm in height, no more than 23 days after corn planting. In another study, Dalley *et al*. (2004) reported that optimum timing, weed control and corn yield depended on specific annual growing conditions. In highly competitive conditions optimum glyphosate application for weed control and corn yield occurred by the four-leaf stage (V4 stage). Under the less competitive conditions, optimum glyphosate application for weed control and corn yield occurred by the V9 stage. Gower *et al*. (2002) found that glyphosate application should be done before weeds attain 15 cm in height to avoid the yield losses. Reinfestation of weed after early post-emergence (EPOST) application had less potential to reduce yield than delaying application and allowing weeds to compete with corn for long period before removal.

Cox *et al*. (2005) reported that season-long weed interference versus weed-free corn reduced dry matter yield by 70 to 75% but if the glyphosate sprayed at the V3-V6 stage the yield reduction decreased to 20 to 25% only. Weed removal time at the V5 stage and V6 stage of corn growth resulted in 10 and 20% of grain yield reduction, respectively. The time at which weeds begin to influence yields of corn is influenced by many factors such as weed interference period, weed species, weed densities and environment of the place to grow (Hall *et al*., 1992). But weed density probably has the greatest influence followed by soil moisture availability

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early in the growing season. Both weed categories, broadleaf and grass weeds may reduce corn growth and development significantly if leave uncontrolled (Kapusta *et al*., 1995). Grassy weed competition with corn can reduce corn yield about 50% (Hall *et al*., 1992). Cox *et al*. (2006) reported that early post treatment (EPOST) at the V3-V4 stage of corn growth and weed-free treatment had similar results in silking date, dry matter accumulation, leaf area index in silking date, kernel per plant and grain yield.

Most of the studies on weed-corn interaction and timing of weed removal were conducted in northern hemisphere (Dalley *et al*., 2004; Gower *et al*., 2002; Hall *et al*., 1992). The studies concluded that weed in corn should be removed by the V4 stage. On the other side, although glyphosate-resistant corn has been grown in a number of countries in the tropic regions, such as in the Philippine (James, 2007) no study on glyphosate timing has been reported. The objective of this study was to determine the effects of timing of weed removal by applying glyphosate in glyphosate-resistant corn (*Zea mays* L.) on corn plant's growth and yield level under the warm tropical conditions in Langkat, North Sumatra, Indonesia, during normal growing season anticipating glyphosate-resistant corn adoption in Indonesia in the near future.

MATERIALS AND METHODS

Field experiment was conducted in June through September 2002 on silt loam soil at Langkat Regency, North Sumatra Province, Indonesia. The experimental site was fallow in the previous year and ploughed two times prior to planting glyphosate-resistant corn. Soil test result of the experimental site indicated a pH of 7.2 with sandy loam texture. Glyphosate-resistant corn seeds were planted in 75 cm row spacing and 20 cm row distance in plot of 3×10 m. Plants were supplied with N, P, K fertilizers at panting date, 18th June 2002. Urea was applied at the rate of 300 kg ha^{-1} in three splits. First application was at the day of planting. The second application was 30 days after planting (DAP) and the third application was at 45 DAP. Phosphorus (SP36) and potassium (KCl) were applied at the dose of 150 and 100 kg ha^{-1}, respectively. Both fertilizers, SP36 and KCl, were applied at planting date. Glyphosate-resistant corn (RR) seeds were received from Monsanto.

Weed control treatments comprised of an untreated control, a weed-free plot and 12 post-emergence glyphosate treatments. The weed free plot was maintained during the growing season by handweeding twice in a week. Glyphosate treatments were 1,500 g ha^{-1} (applied as 2.0 kg ha^{-1} of Roundup 75 WSG) at the V3 stage, the V4 stage, the V5 stage, the V6 stage, the V7 stage, the V8 stage, the V9 stage, the V10 stage, the V12 stage, the V3 and the V7 stage, the V3 and the V12 stage, the V4 and the V8 stage of glyphosate-resistant corn growth. The applications were done according to and modified from Hall *et al*. (1992). The first nine treatments received single application of glyphosate only whereas the last three treatments (the V3 stage and V7 stage, the V3 and the V12 stage, the V4 stage and V8 stage of corn growth) received two applications. Herbicides were applied with hand-operated backpack sprayer (SOLO®) with flat fan nozzle at the height of 40 cm above the target vegetation. The sprayer was calibrated to deliver 200 L ha^{-1} at 200 kPa pressure at a speed of 1 m sec^{-1}.

The experimental design was a randomized complete block design with three replications. Weed population densities by species were counted within 100×100 cm in the center of plot area at the time of corn harvested.

The corn plants within the two rows in the middle part of plot were selected to determine the growth and yield. The ears were hand-shelled and grain yield was dried to 15% of moisture before weighing up. Grain yield was calculated from the weighed of the grain resulted from the two rows. Daily temperature during the study recorded at the Polonia Meteorological Station, Medan was ranging from 22 to 32°C. Statistical analysis was performed using analysis of variance and the mean of each treatment was tested with Duncan mean range test at 5% level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The density of weed population in the untreated control at the time of corn harvested was 705 weeds m^{-2} comprised of 18 species (Table 1). The three highest population densities of weed species found in the untreated plots were *Eleusine indica* (186 m^{-2}), *Digitaria ascendens* (125 m^{-2}) and *Ageratum conyzoides* (109 m^{-2}). Number of species and number of plants found in glyphoste treatments were less than those found in untreated control. The presence of weeds in full growing season (untreated control) can significantly cause yield reduction up to 31.4% compared to yield resulted from plot kept free of weed during the growing season.

The tallest corn plants (237.5 to 240.2 cm) were found in plots received glyphosate treatments at the V3 stage singly or repeated either at the V7 or the V12 stage of corn growth. The shortest plants were found in plots without weed control along the season. Plant height in plots received glyphosate application at the V3 were not significantly different from those in plot received glyphosate at the V4 and the V5 stage of corn growth.

Table 1: Number of weed m^{-2} found in each treatment counted at the harvest of corn

	Treatment[a)]													
Weed species	V3	V4	V5	V6	V7	V8	V9	V10	V12	V3+V7	V3+V12	V4+V8	WF	UC
Ageratum conyzoides	81	76	81	58	73	57	42	51	36	51	41	56	17	109
Borreria latifolia	17	24	17	0	13	22	9	0	10	0	0	0	0	29
Bracharia miliformis	1	0	5	0	0	0	0	0	0	0	0	0	0	47
Commelina difusa	0	1	0	0	0	0	0	30	29	0	0	0	0	6
Cleome rutidosperma	2	0	0	0	0	0	0	0	0	0	0	0	0	8
Cyperus rotundus	2	2	1	0	0	0	0	0	0	0	0	0	0	28
Digitaria ascendens	8	9	10	11	14	11	14	10	10	11	9	19	0	125
Dactyloctinium aegyptium	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Eleusine indica	5	2	3	0	0	0	0	0	2	4	0	0	0	186
Echinochloa colonum	0	1	0	0	0	0	0	0	0	0	0	0	0	21
Euphorbia hirta	5	4	4	5	3	0	1	0	0	0	0	0	0	12
Euphorbia prunifolia	0	1	0	0	0	0	0	0	0	0	0	0	0	8
Ludwigia hyssopifolia	0	0	0	3	3	0	3	0	0	0	0	0	0	10
Mimosa invisa	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Mimosa pudica	0	0	0	0	0	0	0	0	0	0	0	0	0	35
Phyllanthus niruri	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Synedrella nodiflora	6	4	2	3	0	0	0	0	15	4	0	0	0	16
Setaria plicata	0	0	0	0	0	0	0	0	0	0	0	0	0	37
Total	127	124	123	79	106	90	69	91	101	69	50	75	17	705

[a]V3 to V12 are denoted to the stages of corn growth; WF: Weed free; UC: Uncontrolled

Table 2: Yield of glyphosate-resistant corn under different weed control treatment at Langkat, North Sumatra, Indonesia

Treatment	Weed coverage (%)[1]	Height (cm)[2]	Yield (kg ha^{-1})[2]	Yield reduction (%)
Glyphosate application at V3	61.7(10.4)	240.2a	9,135.5 ab	1.8
Glyphosate application at V4	60.0(10.0)	236.3ab	8,577.7 b	7.8
Glyphosate application at V5	63.3(11.5)	234.7abc	7,723.5 c	17.0
Glyphosate application at V6	50.0(0)	231.6bcd	7,443.1 cd	20.0
Glyphosate application at V7	60.0(10)	230.3cd	7,222.2 cde	22.4
Glyphosate application at V8	48.3(10.4)	227.3de	6,864.3 def	26.2
Glyphosate application at V9	38.3(10.4)	222.8ef	6,744.5 ef	27.5
Glyphosate application at V10	38.3(10.4)	219.1f	6,731.7 ef	27.6
Glyphosate application at V12	40.0(8.7)	220.9f	6,720.0 ef	27.7
Glyphosate application at V3 fb V7	43.3(2.9)	238.7a	9,255.1 a	0.5
Glyphosate application at V3 fb V12	26.7(11.5)	237.5a	9,125.6 ab	1.9
Glyphosate application at V4 fb V8	46.7(2.9)	235.8abc	8,749.3 ab	5.9
Weed-free all season	5.0(0)	236.6ab	9,300.6 a	0.0
Weedy all season	100.0(0)	222.3ef	6,383.7 f	31.4

[1]Numbers in brackets are standard deviation. [2]The same letters following numbers in the same column are not significantly different at the 5% level

Weed coverage reached 100% in the untreated control. Whereas in the plots treated with glyphosate at the V3 stage, the V4 stage, the V5 stage and the V6 stage of corn growth the weed coverage ranged from 50 to 61.7%. The least coverage of weeds (26.7%) found in plots where glyphosate was applied twice, at the V3 and the V12 stage of corn growth. In general, the earlier glyphosate applied the more coverage of weed found (Table 2). However, weed coverage post application of glyphosate seems does not affect grain yield of glyphosate resistant-corn.

Grain yield (9135.5 kg) resulted from plots received glyphosate application at the V3 stage of corn growth (with the weed coverage of 61.7%) was not less than those grain yield resulted from other treatments with lower weed coverages. This indicates that weed coverage in glyphosate-resistant corn before weed control using glyphosate is much more affecting than that after glyphosate application.

Grain yield in weed-free treatment and the other three treatments (glyphosate applied at the V3 stage, the V3 stage and the V7 stage and the V3 stage and V12 stage of corn growth) were similar. This means that timing of weed removal at the V3 stage of glyphosate-resistant corn growth in Langkat environmental conditions gave the best result. Grain yield from the V3 stage application was not significantly different from that grain yield resulted from the V4 stage application. This finding agrees with Cox *et al*. (2006) who found that the critical period for weed control began shortly after the V3-V4 stage of corn growth. However, when the application of glyphosate delayed until the V5 stage it resulted in yield reduction of 17% grain yield. This indicates that weed interference between the V4 stage and the V5 stage may have directly affected reproductive development. The longer the period of weed interference from the earlier stage of corn growth the higher yield reduction occurred. Second application of glyphosate at the V7 stage or the V12 stage of growth following the application at the V3 stage of corn growth did not give significant effect on yield production when compared to the one only application at the V3 stage. This finding similar to those reported by Dalley *et al.* (2004) that sequential glyphosate applications in corn did not increase yield. The results from this study indicates that application of glyphosate for control of weed in glyphosate-resistant corn areas in Langkat, North Sumatra, should be conducted by the V3 to the V4 stage in order to avoid yield losses from early season weed competition.

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