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Efficacy of s-Triazines as Influenced by Adsorption and Mobility of Various Soils

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ABSTRACT

Field experiments were conducted on Kampang Saen clay, Kampang Saen silty loam and Nampong sand in 1987 and 1988 to study the efficacy of atrazine, ametryn, dimethametryn, and simazine and the influence of various soil parameters on s-triazine efficacy. The average rates of all herbicides were required to produce 80% weed control at 8 weeks after application were in the order simazine > dimethametryn > atrazine = ametryn. The average rates of all herbicides required for 80% weed control across herbicides were in the order Kampang Saen clay > Kampang Saen sitly loam > Nampong sand. The efficacy of herbicides were correlated with CEC values but negatively correlated with % sand contents. These results indicated that soil with high CEC value required high rate of s-triazines. But soil with high sand content required low rate of herbicides. Laboratory experiments indicated that adsorption of herbicides were in the order dimethametryn > simazine > atrazine = ametryn. While adsorption of dimethametryn and simazine were correlated with CEC values. The adsorption of atrazine and ametryn were correlated with % clay, % organic matter content, and CEC values respectively but negatively correlated with % sand content. Rf values indicated that mobility of herbicides were in the order atrazine > simazine > ametryn > dimethametryn. Furthermore the movement of herbicides were correlated with % sand content but negatively correlated with all soil parameters. The herbicide efficacy, adsorption, and mobility did not get into the same order suggested that efficacy of herbicides could not only be attributed to differences in soil adsorption and mobility but also molecular toxicity and environmental factors.

INTRODUCTION

Atrazine, ametryn, dimethametryn, and simazine are s-triazines that exhibit similar tolerance on crops and also control a similar spectrum of weeds. They persist in soil for 7, 5, 4 and 3 months respectively under tropical condition. In Thailand although these s-triazines are widely used, there is relatively little information available on how soil properties infleunce the effectiveness of this class of herbicides.

The recommended rates of these preemergence herbicides are 2.25 kg ai/ha for sandy soil and 4.50 kg ai/ha for clay soil (Anonymous, 1983). The rate of a herbicide required to achieve a certain level of weed control on particular soil has often been related to the capacity of the soil to adsorb the herbicides. The amount and type of clay particles and organic matter fraction in soils governed adsorbability and mobility of s-triazines (Hayes 1970; Weber, 1970). Moreover the molecules of s-triazines will be protonated under acid condition and subsequently adsorbed to clay particle (Weber 1970).

The objectives of this study were to examine : (1) the efficacy of s-triazines when applied on different soil types, (2) the relationship between efficacy of s-triazines and selected soil parameters, (3) the adsorption and mobility of s-triazines on different soil types, (4) the relationship between adsorption and mobility of s-triazines and selected soil parameters.

MATERIALS AND METHODS

Field experiments Experiments were conducted at 3 locations in Kanchanaburi. They were Tung Tong, Nong Wah and Phanom Tuan where the soils were Kampang Saen clay, Kampang Saen silty loam and Nampong sand respectively (Table 3). Two cane cuttings per hill of variety F-140 were planted on June 1987 and 1988 with the spacing of 1.30 x 0.50 m in a plot size of 5.2 x 6 m. Fertilizers and insecticides were applied as recommended.

Treatments consisted of untreated plot and 5 rates of atrazine, ametrym, dimethametryn and simazine. Herbicides were applied 3 days after planting

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while soil moisture was at field capacity. The experiments were arranged in randomized complete block design with 4 replications.

Visual weed control rating were recorded at 8 weeks after application. Rating was based on scale of 0 to 100 with 0 representing no control and 100 indicating complete control. The weed seeds were sown in the plot before herbicide application to make sure that they were avialable. Planted weed species as well as those species growing indigenously in the plots were included in the rating. All weed species occured in each location were recorded on Table 1. The rating at each site were pooled across two years and subject to regression analysis. Both linear and quadratic model were tested and the model achieving the highest degree of fit was used. The rates of herbicides required for 80% grass and broadleaf control were calculated from the regression equations. These calculated rate values were then used to correlate herbicide activity with the various soil parameters. The 80% value was selected because it provided the most sensitive level for estimating herbicide rates, and the value was available for all soils.

Adsorption experiments The adsorption of four ^{14}C-s-triazines (Table 2) on seven soil types of Thailand (table 3) were determined under room temperature (28 ±2°C) and followed the methods as described by Peter and Weber (1985). Soils were randomly collected at 0-15 cm level. One gram samples of air dried soil sieved through a 2 mm mesh sieve were weighed in 10.0 ml screw top vials. Solution containing 2,000 dpm/ml of ^{14}C-herbicide was prepared in 0.01 M $CaC1_2$ along with the non-labled herbicide at two, three, four and five times the concentration of herbicide associated with its respective ^{14}C-labeled herbicide. Aliquots (5.0 ml) of herbicide solution were pipetted into the vials. The vials were capped and placed on a shaker for 12 hours. Preliminary studied shown that all chemicals reached equilibrium with the soils after shaking for this period of time.

After shaking, the vails were centrifuged and a 1.0 ml aliquot of the supernatant liquid was placed in a scintillation vial with 4.5 ml of counting cocktail (60.0 g napthalene, 5.0 g PPO and 5.0 g POPOP per L of dioxane). The quantity of herbicide adsobed was determined by calculating the difference between the initial herbicide concentration (dpm/ml) and the concentration present in the equilibrium solution after the herbicide was adsorbed onto the soil. K values were

Table 1 **Weed species at different locations.**

Weed psecies	Tung Tong (Kampang Sean clay)	Nong Wah (Kampang Saen silty loam)	Phanom Tuan (Nampong Sand)
Dactyloctenium eagyptium Willd.	+	+	+
Echinochloa colonum (L.) Link	+	+	+
Eleusine indica (L.) Gaertn.	+	+	+
Brachearia reptans (L.) Gard at Hubb	+	-	-
Leptochloa chinensis Nees	+	-	-
Digitaria adscendens (HBK) Henr	-	+	-
Amaranthus spinosus L.	+	+	+
Portulaca oleraceae L.	+	+	+
Trianthema portulacastum L.	+	+	+
Ipomoea gracillis R.Br.	+	+	-
Tribulus terrestris L.	+	+	-
Euphorbia heterophylla L.	+	-	-

Table 2 **Properties of ^{14}C-s-triazines.**

Herbicides	Specific activity (μ ci/mg)	Label position	Water solubility (ppm) (Anonymous, 1983)
Atrazine	27.2	ring	33.0
Ametryn	26.7	ring	185.0
Dimethametryn	13.9	ring	50.0
Simazine	17.6	ring	3.5

determined by using the Freundlich equation. Each treatment was replicated four times in a completely randomized design. The K values were used to correlate these herbicides adsorption with various soil parameters.

Mobility experiments Mobility of herbicides in soil was studied following the methods as described by Peter and Weber (1985). Soils were collected from the same locations and by the same methods as described in adsorption experiments. Soil thin layer chromatography plate (TLC) was prepared by mixing each of soil type (Table 2) with sufficient water to form a paste. Glass plates, 20 x 20 cm were partitioned into four 4 x 20 cm columns. The soil paste was spread over the glass plates and allowed to dry under room temperature. After drying, four independent soil columns with 0.1 cm thick were obtained. Approximately 0.5 M µci of the four ^{14}C-labeled herbicides (Table 2) were applied to their respective columns on the soil TLC plates at 3.0 cm from the bottom. The plates were placed in a TLC developing tank containing water at a depth of 1.0 cm. The plates were left in the tank until the water saturated the soil column at least 15.0 cm up the plate. The movement of water from the point of herbicide application to the position of the wetting front was recorded and the plates were allowed to dry for one day under room temperature. The dry plates were exposed to x-ray film for 4 weeks to trace the movement of ^{14}C-labeled herbicides. The movement of herbicides were compared by determining their retention factor (Rf). Rf values can be calculated by dividing the distance of herbicide movement by the distance of water movement (solvent front). Each treatment was replicated four times in a completely randomized design. The Rf values were used to correlate these herbicide mobility with various soil parameters.

RESULTS AND DICUSSION

Field experiments Atrazine and simazine were slightly more effective in controlling broadleaf weeds than grasses in sugarcane at 8 weeks after application (Table 4). However ametryn and dimethametryn were much more effective in controlling grass than broadleaf weeds at 8 week after application (Table 4). Only 2.82 kg (ai)/ha of ametryn and 3.54 kg (ai)/ha of dimethametryn were required to provided 80% control of broadleaf weeds at 8 week respectively (Table 4). The average rate of atrazine, ametryn, and dimethametryne required to provided 80% of both grass and broadleaf weeds were slightly different at 8 weeks after application (Table 4). Simazine required higher rate than other herbicides to produce 80% weed control (Table 4). It might be the effect of simazine properties which was adsorbed more than other herbicides, environmental factors (Walker, 1980), and molecular toxicity (Dubach, 1970).

The average rate of s-triazine herbicides required to produce 80% weed control in sugarcane at 8 weeds were Kampang Saen clay > Kampang Saen silty loam > Nampong sand (Table 4). The rate of s-triazines required for 80% weed control at 8 weeks after application were correlated with CEC values but negatively correlated with % sand content (Table 5). These results similar to previous reports (Anonymous,

Table 3 **Physical and chemical properties of seven soils.**

Soil types	Particle size distribution			pH	CEC	Organic matter
	Sand	Silt	Clay			
	(%)				(mg/100 g)	(%)
Bangkhen clay (Bangkhen series)	17	26	57	5.6	25.7	2.9
Kampang Saen clay (Kampang Saen series)	19	32	49	7.1	14.2	2.7
Pakchong clay loam (Pakchong series)	23	40	37	6.8	15.3	2.0
Kampang Saen loam (Kampang Saen series)	47	36	17	6.0	6.4	1.1
Kampang Saen silty loam (Kampang Saen series)	57	34	9	5.6	4.2	0.7
Sattahip loamy sand (Sattahip series)	81	14	5	5.2	1.2	0.6
Nampong sand (Nampong series)	87	12	1	6.5	1.2	0.3

Table 4 **Rates of s-triazine herbicides required for 80% grass and broadleaf weed control at 8 weeks after application on three soils in the field. (1987-1988**

Locations and Soil types	Atrazine			Ametryn			Dimethametryn			Simazine			
	Grass	Broad-leaf	$\bar{X}$	Grass	Broad-leaf	$\bar{X}$	Grass	Broad-leaf	$\bar{X}$	Grass	Broad-leaf	$\bar{X}$	$\bar{X}$
	(kg (ai)/ha)												
Tung Tong, Kampang Sean clay	4.33	3.28	3.79 a[1]	3.30	4.01	3.66 a	3.78	4.10	3.94 a	5.24	4.38	4.81 a	4.05
Nong Wah, Kampang Saen silty loam	3.78	3.37	3.58 b	3.02	3.38	3.20 b	3.76	3.50	3.63 b	4.88	3.63	4.26 b	3.67
Phanom Tuan, Nampong sand	1.81	2.82	2.32 c	2.13	3.12	2.63 c	2.17	3.03	2.60 c	2.54	3.06	2.80 c	2.59
$\bar{X}$	3.31	3.16	3.23 C[2]	2.82	3.50	3.16 C	3.24	3.54	3.39 B	4.22	3.69	3.96 A	

1 Means within column in similar letters are not significantly different at the 5% level by Duncan's Multiple range test.
2 Means within the line in similar letters are not significantly different at the 5% level by Duncan's Multiple range test.

1983).

Adsorption experiments The Fruendlich K-values of triazines adsorbed onto a soils shown relatively degree of variability (Table 6). The average K values across soil types revealed that the greatest amount of dimethametryn was adsorbed onto soils followed by simazine, ametryn, and atrazine (Table 6). The differences in adsorption between s-triazines could be explained that ametryn and dimethametryn a methylthio-s-triazine were reported to be adsorbed by clay particle more than atrazine and simazine a chloro-s-triazine (Harris, 1970; Bailey and White, 1970; Weber, 1970). When comparing within the same subclass of chloro-s-triazine, simazine was adsorbed more than atrazine. It might be explained by difference in water solubility between atrazine and simazine (Table 2) (Nearpass, 1967). For methylthio-s-triazine it was indicated that dimethametryn was adsorbed more than ametryn. Beacause the type and length of alkyl groups in the 4- and 6- positions also influenced the amount of adsorption (Weber, 1970). Furthermore water solubility of ametryn was also higher than dimethametryn (Table 2).

Correlation coefficient between K-values of s-triazines and soil parameters shown that adsorption of dimethametryn and simazine were correlated to CEC values (Table 7). While adsorption of atrazine and ametryn were correlated to % clay, % organic matter content and CEC values (Table 7). These results were supported by results of field experiment that higher rate of simazine was required to produce 80% weed control comparing to other herbicides (Table 4). Furthermore the rate of dimethametryn required to produce 80% weed control was higher than those of atrazine and ametryn (Table 4). However negatively correlation between K-values of atrazine and ametryn and % sand content were obtained (Table 7). These

Table 5 Correlation coefficients (r) of s-triazine herbicide rates (kg (ai)/ha) required for 80% grass and broadleaf weed control at 3 weeks after application with various soil paramenters.

	Herbicides							
	Atrazine		Ametryn		Dimethametryn		Simazine	
	Grass	Broadleaf	Grass	Broadleaf	Grass	Broadleaf	Grass	Broadleaf
	(r)							
Sand (%)	-0.93**[1]	-0.74*	-0.93**	-0.99**	-0.84*	-0.99**	-0.89*	-0.99**
Silt (%)	0.96	0.99	0.95	0.66	0.99	0.78	0.98	0.77
Clay (%)	0.78	0.51	0.79	0.99	0.64	0.96	0.72	0.96
Organic matter (%)	0.78	0.51	0.79	0.99	0.64	0.96	0.72	0.96
pH	0.09	0.26	0.11	0.61	-0.10	0.46	0.01	0.47
CEC (meg/100 g)	0.82**	0.56*	0.83**	0.99**	0.69*	0.98**	0.76*	0.98**

1 An asterisk denotes significance at the 5% level. Two asterisks donote significance at the 1% level.

Table 6 Freundilich K values (adsorption capacity indices) for s-triazine herbicide adsorption on seven soils.

Soil type	Atrazine	Ametryn	Dimethametryn	Simazine	$\overline{X}$
	(K)				
Bangkhen clay	10.6 a[1]	14.1 a	18.9 a	16.9 a	15.1 a
Kampang Saen clay	7.2 b	6.2 b	10.5 b	7.1 b	7.8 b
Pakchong clay loam	5.5 c	4.9 c	8.6 c	4.6 d	5.9 d
Kampang Saen loam	5.8 c	6.4 b	9.3 c	5.7 c	6.8 c
Kampang Saen silty loam	4.1 d	3.7 d	6.7 d	4.3 d	4.7 e
Sattahip loamy sand	2.8 f	2.5 f	5.4 e	2.7 f	3.3 f
Nampong sand	4.0 e	3.5 e	4.1 f	3.8e	3.9 f
$\overline{X}$	5.7 C[2]	5.9 C	9.1 A	6.4 B	

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2 Means within the line in similar letters are not significantly different at the 5% level by Duncan's multiple range test.

results suggested that low rate of both herbicides were required to be applied on soils with high % sand content.

Moreover the average K-value across herbicides shown that the greatest amount of herbicides were adsorbed by Bangkhen clay, followed by Kampang Saen clay, Kampang Saen loam, Pakchong clay loam, Kampang Saen silty loam, Nampong sand and Sattahip loamy sand respectively (Table 3). However the average K-value of Kampang Saen loam was higher than Pakchong clay loam (Table 3). These results indicated that not only % clay and % organinc matter content governed herbicide adsorption but type of clays and organic matter might also governed herbicide adsorption (Weber, 1970; Hayes, 1970).

Mobility experiment Herbicides mobility was influenced by soil types. The greatest movement of herbicides were occured on Sattahip loamy sand followed by Nampong sand, Pakchong clay loam, Kampang Saen clay and Bangkhen clay respectively (Table 8). It was found that movement of herbicides were occured in Pakchong clay loam more than in Kampang Saen loam and in Sattahip loamy sand more than in Nampong sand respectively (Table 8). The organic matter and clay content of Pakchong clay loam were also higher than of Nampong sand respectively (Table 3). However these results were agreed with the previous results which shown that s-triazines were adsorbed on Kampang Saen loam more than on Pakchong clay loam and on Nampong sand equal to on Sattahip loamy sand respectively (Table 6).

Upon comparing average herbicide mobility across soil types, the most mobile herbicide was atrazine followed by simazine, ametryn and dimethametryn respectively (Table 8).

Highly significant correlation between Rf values of s-triazine herbicides and % sand content in soils (Table 9) suggested that great movement of all s-triazine herbicides will be occured in soils of high

Table 7 Correlation coefficients (r) of Freundlich K values (adsorption capacity indices) for s-triazine herbicides adsorption on seven soils with various soil parameters.

Soil parameters	Atrazine	Herbicides: Ametryn	Dimethametryn	Simazine
	r			
Sand (%)	-0.85**[1]	-0.78*	-0.53	-0.57
Silt (%)	0.35	0.37	-0.01	0.03
Clay (%)	0.94**	0.84**	0.69	0.73
Organic matter (%)	0.93**	0.82**	0.66	0.70
pH	0.25	0.15	-0.28	-0.20
CEC (meg/100 g)	0.92**	0.86**	0.81**	0.84**

1 An asterisk denotes significance at the 5% level, two asterisk denote significace at the 1% level.

Table 8 The mobility of s-triazine herbicides in seven soils as indicated by soil TLC Rf values.

Soil types	Herbicides: Atrazine	Ametryn	Dimethametryn	Simazine	$\bar{X}$
	(Rf)				
Bangkhen clay	0.30 e[1]	0.10 f	0.16 e	0.19 d	0.19 f
Kampang Saen clay	0.29 e	0.21 e	0.16 e	0.20 d	0.21 e
Pakchong clay loam	0.49 c	0.36 b	0.22 d	0.39 c	0.37 c
Kampang Saen loam	0.37 d	0.23 e	0.17 e	0.20 d	0.24 d
Kampang Saen silty loam	0.50 c	0.33 c	0.25 c	0.40 e	0.37 c
Sattahip loamy sand	0.90 a	0.71 a	0.49 a	0.79 a	0.72 a
Nampong sand	0.73 b	0.31 d	0.36 b	0.52 b	0.49 b
$\bar{X}$	0.52 A[2]	0.32 C	0.26 D	0.38 B	

1 Means within columns in similar letters are not significantly different at the 5% level by Duncan's multiple range test.
2 Means within the line in similar letters are not significantly different at the 5% level by Duncan's multiple range test.

Table 9 Correlation coefficients (r) of Rf values for s-triazine herbicide mobility on seven soils with various soil parameters.

Soil parameters	Herbicides			
	Atrazine	Ametryn	Dimethametryn	Simazine
	r			
Sand (%)	0.89**[1]	0.63**	0.84**	0.83**
Silt (%)	-0.72**	-0.43**	-0.73**	-0.61**
Clay (%)	-0.81**	-0.61**	-0.73**	-0.78**
Organic matter (%)	-0.80**	-0.58**	-0.71**	-0.77**
pH	-0.33	-0.38*	-0.45*	-0.45*
CEC (meg/100 g)	-0.79**	-0.64**	-0.71**	-0.75**

1 An asterisk denotes significance at the 5% level, two asteriks denote significane at the 1% level.

sand content.

The negatively correlation between Rf values of s-triazines and soil parameters indicated that the movement of all herbicides were governed by soil parameters. The coefficient of determination values (r^2) were calculated for percent clay and percent organic matter content vs. Rf values of four herbicides in soils. Percent clay vs. Rf values resulted in r^2 = 0.66, 0.37, 0.53 and 0.61 and percent organic matter vs. Rf vlaues resulted in r^2 = 0.64, 0.34, 0.50 and 0.59 for atrazine, ametryn, dimethametryn, and simazine respectively. These results indicated that clay fraction were slightly more influence on mobility of s-triazine herbicides than organic matter content. However pH values shown negatively correlated with Rf values.

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