Metolachlor Effects on Peanut Growth and Development

J. Cardina* and C. W. Swann[1]

ABSTRACT

Growth and yield responses of peanuts *(Arachis hypogaea* L.) to preplant incorporated applications of metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide] herbicide were studied at two locations in Georgia. At Sycamore, GK-7 peanuts which received 3.8 cm irrigation immediately following herbicide incorporation and planting were generally stunted and yielded less than non-irrigated peanuts. Metolachlor rates from 2.2 to 6.7 kg ai/ha reduced early and late season growth of irrigated peanuts in 1985 and 1986 but non-irrigated peanuts recovered by mid-August. Yields were suppressed only at the highest rate of metolachor in 1985, but there was no yield response in 1986 or 1987. At Tifton, emergence of Florunner peanuts was delayed and canopy height and width were reduced by metolachlor. Initial flower, peg and pod production were reduced in a linear response to metolachlor rate, resulting in differences in pod development 95 days after planting. There was a rate response for pod yield in 1985 but not in 1986 and grade did not differ either year. In general, emergence and growth were delayed and reduced by preplant incorporated metolachlor when rainfall or irrigation followed application, but yields were not reduced at labeled rates.

Key Words: *Arachis hypogaea,* L., herbicide injury, weed control.

Metolachlor is a chloroacetanilide herbicide that is widely used in preplant incorporated (PPI), preemergence, and early postemergence applications for weed control in peanuts. One of the advantages of metolachlor over other similar herbicides is efficacy, in PPI applications, against yellow nutsedge *(Cyperus esculentus* L.), which is considered one of the most troublesome weeds in peanuts and rotation crops (7). Metolachlor controls numerous weeds that occur in peanuts including Florida pusley *(Richardia scabra* L.), several species of *Amaranthus,* and most annual grasses with the exception of Texas panicum *(Panicum texanum* Buckl.) (3).

Occasionally, treatment with metolachlor results in delayed peanut emergence and seedling growth. Severely injured seedlings may fail to emerge from the soil. This injury appears to be related to non-uniform soil incorporation or to rainfall or irrigation soon after planting. Cool and dry or warm and wet conditions increased the injury to snap beans *(Phaseolus vulgaris* L.) caused by alachlor [2-chloro-N̲-(2,6-diethylphenyl)-N̲-(methoxymethyl)acetamide], a herbicide similar to metolachlor (9). Additional injury may result when a "contact" herbicide like dinoseb [2-(1-methylpropyl)-4,6-dinitrophenol] is applied early postemergence following metolachlor applied PPI as part of a system approach to weed control (3).

Herbicide injury symptoms are associated with the mechanism of herbicide action at the cellular level (10). Metolachlor causes symptoms characteristic of plant-immobile cell division inhibitors (8). Metolachlor is absorbed through shoots and roots of dicots and may have several sites and modes of action depending on plant species and type of application (8, 10). Activities of α-amylase increased and peroxidase decreased in peanuts following preemergence applications of alachlor (4).

The significance of early season herbicide injury has been the subject of debate (5). Visual ratings of crop injury are standard components of herbicide evaluation trials but stunting and developmental responses are more difficult to rate than are other injury symptoms (5). Moderate injury, which the crop appears to outgrow under most conditions, may cause significant yield reduction under less favorable growing conditions. Herbicide injury also reduces canopy growth rendering the crop less competitive with weeds.

Peanut plant growth models are being developed in an effort to better understand how environmental and cultural practices interact in crop production (2, 12). These models must account for effects of herbicides on crop emergence, canopy development, and reproductive development. There are no previous reports on the growth response of peanuts to metolachlor or possible interactions with irrigation or early postemergence herbicides. Therefore, research was initiated to determine the interaction of metolachlor with irrigation and early postemergence herbicides on peanut growth and development.

Materials and Methods

Experiments were conducted at the Coastal Plain Experiment Station, Tifton, GA, in 1985 and 1986, and at the Agratech Research Farm, Sycamore, GA, from 1985 to 1987. Soils at both locations were Tifton loamy sands (fine-loamy, siliceous, thermic Plinthic Paleudults) containing less than 1% organic matter, with pH 6.0 at Tifton and 6.2 at Sycamore. GK-7 peanuts were planted at Sycamore on May 6, 1985, May 23, 1986, and April 16, 1987 at 182,000 seeds per ha in rows 81 cm apart on 6.1 x 1.8 m plots. In experiments at Tifton, Florunner peanuts were planted on June 10, 1985 and June 6, 1986 at 201,000 seeds per ha in rows 78 cm apart on 10 x 1.8 m plots. All treatments were kept weed-free by periodic hand weeding.

Experiments at Sycamore

Two experiments, each with the same herbicide treatments, were conducted at Sycamore in adjacent fields. One experiment received 3.8 cm water from a cable tow irrigation system immediately after planting (hereafter referred to as preemergence irrigation). The other experiment differed only in the absence of this initial irrigation and in treatment randomization. The experiments were arranged in a split plot design and treatments were replicated four times. Main plots received 2.2 kg/ha naptalam (2-[(1-naphthalenylamino)carbonyl]benzoic acid) plus 1.1 kg/ha dinoseb or no herbicide at the early postemergence stage of peanut growth. In 1987, 0.14 kg/ha paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was substituted for naptalam plus dinoseb because of the suspension of dinoseb registration by the Environmental Protection Agency. Subplots received preplant incorporated (PPI) applications of no herbicide, 1.7 kg/ha benefin ([N̲-butyl-N̲-ethyl-2,6-dinitro-4-(trifluoromethyl)benzenamine]) alone, benefin plus 2.2, 4.5, or 6.7 kg/ha metolachlor. The PPI herbicides were

[1]Research Agronomist, USDA-ARS, Coastal Plain Experiment Station, Tifton, GA 31793, and Professor, Extension Agronomy, Univ. of Georgia, Tifton, GA 31793.

applied in 140 L water/ha through nozzles mounted to a compressed gas unicycle sprayer. Herbicides were incorporated to a depth of 8 cm with a tractor-driven rotary tiller. All herbicides were applied and incorporated, peanuts planted, and the irrigation treatment applied within 8 hr. The early postemergence treatments were applied in 187 L water/ha with a unicycle sprayer 7 days after planting. Crop injury was visually rated (0 = no stunting, 100 = no growth) on May 28, 1985, August 27, 1985, June 27, 1986, and August 14, 1986. Peanuts were dug on September 17, 1985, October 8, 1986 and August 31, 1987 and yields expressed as field-dried harvest weights of in-shell peanuts.

Experiments at Tifton

The response of peanut growth and development to metolachlor applied PPI at 0, 2.2, 3.4, and 6.7 kg/ha was studied at Tifton. Treatments were arranged in a randomized complete block with eight replications in 1985 and four replications in 1986. Metolachlor was applied the day of planting in 234 L water/ha and incorporated immediately to a depth of 6 cm with a rotary tiller. Crop emergence was determined as the number of seedlings with at least one unfolded leaf. Emerged plants in four randomly chosen 1 m lengths of row were counted 10, 13, 15, and 18 days after planting (DAP) in each plot. Canopy height and width were measured at four random locations per plot at 20, 24, 28, 37, 45, 56, and 69 DAP. Two 0.5 m samples per row were taken at the R1, R2, and R3 stages of growth (1), corresponding to 30, 45, and 55 DAP, respectively. Leaves, stems, and reproductive parts were separated, counted, dried for 24 hr at 66 C, and weighed.

The leaf area of a 100 g subsample was measured with an automatic leaf area meter. The ratio of area to weight of the subsample was multiplied by the total leaf weight to calculate total leaf area. Pod maturity class distribution was determined from two 0.5 m samples per plot at the R7 growth stage (90 DAP). The hull-scrape method (6, 11) was used to determine optimum harvest date and to group pods into 25 stages of development. Peanuts were inverted and combined with conventional harvesting equipment and yield determined following cleaning and drying to 9% moisture. Pod samples (500 g/plot) were processed according to Federal-State Inspection Service specifications. Grade is reported as the percentage of sound mature kernels (SMK) plus sound splits.

Data were combined over years where there was no year x treatment interaction and subjected to analysis of variance. Visual ratings were transferred to $\sqrt{X}$ prior to analysis but actual values are reported. Orthogonal contrasts were used to determine linear and quadratic effects of herbicide rates; contrasts were used to compare treatment means with the control where linear and quadratic effects were not significant.

Results and Discussion

Where metolachlor injury occurred, peanut seedlings exhibited excessive swelling, curling, or corkscrew-like growth of the hypocotyl. Roots below the swollen hypocotyl were short and abnormally branched. Leaves of injured peanut seedlings were small and dark green, with a rough surface. Where injury was most severe the canopy appeared flat and stands were not uniform in growth.

Experiments at Sycamore

There were no differences in injury ratings or yields between the two early postemergence treatments and there was no interaction with PPI treatments (data not shown), therefore data were averaged over the early postemergence treatments. Irrigation immediately after metolachlor application reduced emergence rate and total emergence when compared with the control (Table 1). There were no differences (P>0.05) in injury or yield between untreated peanuts and peanuts receiving 1.7 kg/ha benefin (data not shown), therefore differences are assumed to be due to metolachlor. At the early observation date (approximately one month after planting) crop injury was a linear function of herbicide rate, except in non-irrigated peanuts in 1986. The level of injury was greater in 1985 than 1986, and ranged from 13% at 2.2 kg ha metolachlor in non-irrigated peanuts in 1985 to over 60% at 6.7 kg/ha metolachlor. By late season, however, the linear effect was no longer

Table 1. Injury and yield of irrigated[1] and non-irrigated GK-7 peanuts following preplant incorporated applications of 1.7 kg ai/ha benefin and three rates of metolachlor at Sycamore in 1985, 1986, and 1987[2].

		1985						1986						1987	
		Irrigated			Non-irrigated			Irrigated			Non-irrigated				
		Injury		Pod	Injury		Pod	Injury		Pod	Injury		Pod	Irrigated	Non-irrigated
No.	Metolachlor	5-28	8-27	yield	5-28	8-27	yield	6-27	8-14	yield	6-27	8-24	yield	pod yield	pod yield
	(kg ai/ha)	(%)		(kg/ha)	(%)		(kg/ha)	(%)		(kg/ha)	(%)		(kg/ha)	(kg/ha)	
1	0	0	0	5520	0	0	6150	0	0	4330	0	0	4690	5390	5200
2	2.2	28	0	5710	13	7	5790	16	6	4140	11	4	4270	5610	5460
3	4.5	44	1	5680	30	2	5970	33	9	4280	24	3	4490	5430	5850
4	6.7	62	9	4770	66	4	5500	45	12	4160	14	0	4560	4800	5610
Contrasts[3]															
L		**	NS	NS	*	NS	NS	**	**	NS	NS	NS	NS	NS	NS
Q		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1 vs 2			NS	NS		NS	NS			NS	NS	NS	NS	NS	NS
1 vs 3			NS	NS		NS	NS			NS	*	NS	NS	NS	NS
1 vs 4			*	*		NS	*			NS	*	NS	NS	NS	NS

[1]Irrigated and non-irrigated refers to an initial irrigation following herbicide application and planting as described in the text.

[2]Values are means of four replications and two early postemergence treatments.

[3]L and Q are linear and quadratic contrasts, respectively; 1 vs 2 etc., indicate orthogonal contrasts for comparison of treatments; * and ** indicate significant F-tests at the 0.05 and 0.01 levels, respectively.

significant except in irrigated peanuts in 1986. Only at the 6.7 kg/ha rate in irrigated peanuts in 1985 was injury detectable at the late season rating. Significant differences in pod yield occurred only in 1985 at the 6.7 kg/ha rate of metolachlor. There was not a clear herbicide rate response and neither linear nor quadratic effects were significant. In general, the suppression in early growth did not correspond to a reduction in final yield, although preemergence irrigation plus high rates of metolachlor resulted in the lowest yield two out of three years. Since growers apply metolachlor PPI at 2.2 to 3.4 kg/ha, data from this experiment do not indicate a need to alter current practices but demonstrate the potential for growth reduction, particularly where rainfall occurs soon after planting.

Experiments at Tifton

In both years of experiments at Tifton, planting was followed within two days by rainfall (1.8 cm in 1985 and 0.8 cm in 1986), although not in amounts comparable to the irrigation treatments at Sycamore. Since there was no year x treatment interaction the data were pooled over years. The rate of seedling emergence was significantly affected by all rates of metolachlor in the Tifton study (Figure 1). By 19 DAP there was no difference in number of emerged seedlings at the registered use rates (2.2 and 3.4 kg/ha). However, the data have implications for crop competitiveness since the first seedling occupying a space has a competitive advantage over later emerging species (3). A delay in seedling emergence due to metolachlor may increase competiton from uncontrolled weed species.

Canopy development was reduced by metolachlor as indicated by height and width measurements (Table 2). There was a linear effect of metolachlor rate on height and width at all observation dates except width at 56 and 69 days after planting. By 56 days after planting the canopy of adjacent rows had begun to overlap, making accurate width measurements difficult. The effect of

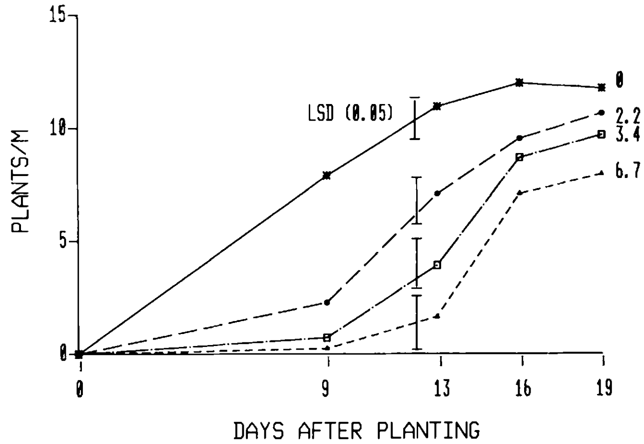

Fig. 1. Number of emerged Florunner peanut plants per m of row following PPI application of 0, 2.2, 3.4, and 6.7 kg/ha metolachlor at Tifton.

metolachlor was consistent over the season and peanuts did not "grow out" of the initial suppression as has been suggested for other herbicide injury symptoms (10). The reductions in canopy height and width would be expected to correspond to reduced light interception and crop competitiveness (3).

Peanuts sampled 30, 45, and 55 DAP were in the R-1, R-2 and R-3 stages of development, which represent beginning bloom, peg, and pod stages, respectively (1). Initial flower, peg and pod numbers were reduced in a linear fashion with increasing rates of metolachlor (Table 3). There was not a consistent rate response for shoot weight and leaf area at the R-1 and R-2 stages and differences only occurred between the control and the 6.8 kg/ha metolachlor treatment. However, at the R-3 stage there were clear rate responses for shoot weight, pods and nodes per plant. The herbicide rate responses for flowers, pegs, and pods were similar, indicating that the development of the most mature pods was delayed

Table 2. Height and width of Florunner peanut canopies on seven dates following application of 0, 2.2, 3.4 and 6.7 kg/ha metolachlor at Tifton.

		Days after planting													
		20	24	28	37	45	56	69	20	24	28	37	45	56	69
Treatment	Metolachlor	Height							Width						
	kg ai/ha	cm													
1	0	14	17	17	27	38	47	51	19	22	22	45	64	82	92
2	2.2	11	15	15	23	34	42	46	16	19	19	41	62	78	88
3	3.4	10	13	14	22	32	9	45	13	15	16	39	61	78	86
4	6.7	8	9	11	18	26	34	39	9	11	11	28	49	72	82
Contrasts[1]															
L		**	**	**	**	**	**	*	**	**	**	**	**	NS	NS
Q		*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1 vs 2														*	NS
1 vs 3														*	*
1 vs 4														*	*

[1]L and Q are linear and quadratic contasts, respectively; 1 vs 2 etc., indicate planned orthogonal contrasts for comparison of treatment means; * and ** indicate significant F-test at the 0.05 and 0.01 levels, respectively.

by the initital growth suppression. The influence of herbicides like metolachlor on early growth and reproductive development may complicate predictions made in simulation models (2, 12).

Table 3. Effect of preplant incorporated metolachlor on growth and yield of Florunner peanuts grown at Tifton in 1985 and 1986.

Treatment	Metolachlor	30 DAP shoot wt.	30 DAP leaf area	30 DAP flowers	45 DAP shoot wt.	45 DAP leaf area	45 DAP pegs	55 DAP shoot wt.	55 DAP pods	55 DAP nodes
	(kg/ha)	(g)	(dm^2)	(no.)	(g) (per m of row)	(dm^2)	(no.)	(g)	(no.)	per plant
1	0	22	39	4.1	91	158	21	190	12	9.9
2	2.2	23	41	2.7	105	201	17	160	9	8.9
3	3.4	17	31	2.6	96	163	15	120	6	8.5
4	6.7	13	21	1.7	72	131	7	80	6	7.2
Contrasts[1]										
L		NS	NS	*	NS	NS	*	*	*	*
Q		NS	NS	NS	NS	NS	NS		*	NS
1 vs 2		NS	NS		NS	NS				
1 vs 3		NS	NS		NS	NS				
1 vs 4		*	*		NS	NS				

[1] L and Q are linear and quadratic contrasts, respectively; 1 vs 2 etc., indicate orthogonal contrasts for comparison of treatment means; * indicates significant F-test at the 0.05 level.

Peanuts sampled at the R-7 stage of development and categorized by the hull-scrape method (6, 11) showed a linear decrease in number and weight of pods in categories 13 to 18 and an increase in number and weight of pods in the immature categories 1 and 2 with increasing rates of metolachlor (Table 4). This decrease in mature pods corresponds to the reduction in initial flower, peg and pod appearance (Table 3). There was no effect of metolachlor on pods in categories 3-12, which at maturity will contain a large proportion of the sound mature kernels. Delayed emergence due to metolachlor resulted in a 5 to 7 day delay in reproductive development and pod maturation. This slight delay in development did not have a consistent effect on yield (Table 4) and there were no differences in grade due to metolachlor (data not shown).

Table 4. The influence of metolachlor on number and weight of pods in various stages of development sampled 95 days after planting, and on pod yield at harvest for Florunner peanuts grown at Tifton in 1985 and 1986[1].

Treatment	Metolachlor	pod number 1-2	pod number 3-12	pod number 13-18	pod weight 1-2	pod weight 3-12	pod weight 13-18	Yield 1985	Yield 1986
	(kg/ha)	(percent in cagegory)						(kg/ha)	
1	0	27	65	9	1.5	75	24	4310	4590
2	2.2	27	66	7	1.7	77	21	4260	4340
3	3.4	32	62	6	2.0	80	18	4020	4390
4	6.7	38	59	3	3.2	84	12	3320	4050
Contrasts[2]									
L		NS	NS	*	*	NS	*	*	NS
Q		NS	NS	NS	NS	NS	NS	NS	NS
1 vs 2		NS	NS			NS			NS
1 vs 3		NS	NS			NS			NS
1 vs 4		*	NS			NS			*

[1] Values for pod number and weight are means of eight replications in 1985 and four replications in 1986.

[2] L and Q are linear and quadratic contrasts, respectively; 1 vs 2 etc., indicate orthogonal contrasts for comparison of treatment means; * indicates significant F-test at the 0.05 level.

The metolachlor injury observed in grower fields has been associated with rainfall or irrigation before seedling emergence and resembles the type of injury observed in these studies. In experiments at Sycamore and Tifton there was a suppression of early peanut growth linearly related to metolacholor rate. Differences in canopy height and width persisted to the middle of the season at Tifton and reproductive development was delayed in relation to the rate of metolachlor applied. However, later developing pods were not affected by metolachlor (Table 4) and over the long period of pod development the metolachlor effect on early developing pods was probably masked by the greater contribution of later developing pods to the final yield. As a result, yields were not suppressed except with 6.7 kg/ha metolachlor, which is well above the recommended use rate.

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