Effect of Soil Applied Herbicides and Depth of Sowing on Common Cocklebur (*Xanthium strumarium* L.) and Maize (*Zea mays* L.) Emergence and Early Growth

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Abstract

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Greenhouse trials were conducted during 2005 to investigate the effect of six soil applied herbicides on common cocklebur (*Xanthium strumarium* L.) sowed at a depth of 4 cm and 7 cm, and determine the potential injury to maize by the herbicides and the influence of sowing depths. The efficacy of all herbicides was high, regardless of sowing depth and, generally, the coefficient of efficacy ranged from 86.3% to 100.0%. Most of the herbicides had no significant phytotoxic effect on maize plant density/container, height and fresh weight of maize. Exceptions were Atranex-90WDG and Cyatral-SCZ, which caused serious injury to maize (33% and 37%, respectively) if seeded at a depth of 7 cm, and significantly reduced height and fresh weight of the plants.

Keywords: *Xanthium strumarium* L.; *Zea mays* L.; herbicides

Common cocklebur (*Xanthium strumarium* L.) is a large, summer annual broad-leaved weed and one of the most competitive and worst weeds in maize, cotton, peanut and soybean fields (Miller 1970; Holm *et al.* 1977; Charudattan & Walker 1982). Its significance as a troublesome weed in these crops is increasing across the Balkan area, including Macedonia, probably due to difficulties in its chemical control. In soybean, full-season competition by common cocklebur at densities of 3300, 6600, 13 000 and 26 000 plants/ha reduced soybean seed yields by 10, 28, 43 and 52%, respectively (Barrentine 1974). Soybean seed yields were reduced 15–100% by common cocklebur densities of 2000–64 000 plants/ha under drought conditions (Waldrep & McLaughlin 1969 – cit. Barrentine 1974). High densities of common cocklebur (24 and 48 weeds per 7, 31 m of row, respectively) caused reductions in boll and seed weight and resulted in almost 90% yield reduction in cotton (Buchanan & Burns 1971). Similar results by Snipes *et al.* (1987) demonstrated that season-long competition from one common cocklebur plant/15 m of row reduced the hand-harvested seed cotton yields from 72 to 115 kg/ha. Rawson (1964) reported that peanut yields were reduced up to 16% if one plant of common cocklebur per 0.836 m^2 was allowed to grow to maturity in a peanut field.

Common cocklebur is less competitive in maize then in soybean, but can still cause significant yield losses (Weaver 2001). According to Nakova *et al.* (2004), common cocklebur density had a negative effect on growth parameters at the 4–5 leaf growth stages and on grain yield in maize. Compared with weed-free maize, its different densities (5, 15 and 25 plants/m) decreased maize height by 12.1, 23.4 and 59.6 cm, respectively, and significantly reduced maize production by 1917.5, 2970.0 and 3942.3 kg/ha. In addition to direct yield losses through competition, infestation by common cocklebur decreases seed quality through increased foreign matter and higher seed moisture content.

Considering all these facts, control of common cocklebur is a very important aspect of a profitable maize production system in Macedonia. There are many post-emergence herbicides (Weaver 2001) for its control, but the objective of this study was to determine whether soil applied herbicides can effectively control common cocklebur when it emerges from different depths.

MATERIAL AND METHODS

Trials were conducted during 2005 under greenhouse conditions at the Institute of Agriculture, Skopje. The trial was laid out in a randomised complete block with four replications. Plant growing containers of 17 × 25 × 11 cm were used, and each container was filled with alluvial soil with 2.0% o.m. and pH 6.7, which was taken from fields normally used for maize production. Into each container, 10 seeds of the maize hybrid ZP-677 (Institute for Maize "Zemun Polje", Belgrade, Serbia) and 30 seeds of common cocklebur were planted at one of two depths, 4 cm and 7 cm. The variants of the trial are given in Table 1.

The herbicides were applied to the top of the soil immediately after sowing with a CO_2 pressurised backpack sprayer at 550 l/ha water. The containers were irrigated and drained as under field conditions and non-target plants removed during the complete study period. Percent injury to maize plants was rated 21 day after planting (DAP) and on a scale from 0 (no visible injury) to 100 (dead plant). The injury was visually rated by determining the average percentage of deformation, plant stunting, chlorosis, necrosis, or all these factors occurring on treated maize plants as compared with untreated plants. Also, the density of maize plants/container, their height and fresh weight and, at the same time, herbicide efficacy were determined 21 DAP by counting maize and cocklebur plants. The coefficient of herbicide efficacy was calculated by the following equation:

$$C_E = \frac{C_{cp} - C_{tp}}{C_{cp}} \times 100$$

where:

C_E – coefficient of efficacy

C_{cp} – number of cocklebur plants in the untreated control containers

C_{tp} – number of cocklebur plants in the treated containers

Table 1. Trade names, depth of planting of maize and common cocklebur, active ingredients and rates of application of herbicides

Treatment	Depth (cm)	Active ingredient (%)	Name of active ingredient	Rate (kg/ha)
Untreated control	4	–	–	–
	7			
Atranex-90WDG	4	90	Atrazine	1.4
	7			
Inacor-T	4	34 + 16	Atrazine + Prometrin	3.0
	7			
Liron S-50	4	50	Linuron	3.0
	7			
Aspect 500-SC	4	30 + 20	Atrazine + Flufenacet	3.0
	7			
Racer 25-EC	4	25	Flurochloridone	1.5
	7			
Cyatral-SCZ	4	13.5 + 13.5 + 36	Cyanazine + Atrazine + Alachlor	7.0
	7			

Table 2. Effect of herbicide treatments on plant density in maize and visible injury of plants

Treatment	Maize plants per container (%)					
	4 cm			7 cm		
	total	healthy	injured	total	healthy	injured
Untreated control	9.5	100	0	9.5	100	0
Atranex-90WDG	9.5	95	5	9.0	67**	33**
Inacor-T	10	95	5	9.5	95	5
Liron S-50	9.0	95	5	10	100	0
Aspect 500-SC	9.5	95	5	10	100	0
Racer 25-EC	9.5	100	0	9.5	95	5
Cyatral-SCZ	10	95	5	9.5	63**	37**
$LSD_{0.05}$	*0.84 NS*	*8.37 NS*	*6.55 NS*	*1.07 NS*	*4.80*	*5.32*
$LSD_{0.01}$	*1.15*	*11.47*	*8.97*	*1.44*	*6.58*	*7.29*

*P < 0.05, **P < 0.01, NS – not significant

The data were finally subjected to statistical analysis, applying LSD-test (Steel & Torrie 1980).

RESULTS AND DISCUSSION

Visible maize injury. Several herbicides, mainly those which contained atrazine as active ingredient, caused injury to maize plants at both seeding depths of 4 cm and 7 cm (Table 2). Injury was expressed as leaf chlorosis, deformation and plant stunting. Injury caused by Inacor-T, Liron S-50, Aspect 500-SC, Cyatral-SCZ and Atranex-90WDG (depth 4 cm), and Inacor-T and Racer 25-EC (depth 7 cm), respectively, was often manifested as minor stunting of plants, but that later recovered (Sumich 1963). The most serious plant injuries, particularly expressed as deformation and stunting of the plant followed by chlorotic and necrotic tissue at the leaf edges, were recorded in the 7 cm depth variants treated with Atranex-90WDG (33%) and Cyatral-SCZ (37%). The high percentage of injured plants in these variants was probably due to a low content of organic matter in the soil (Johnson *et al.* 2003), and regular irrigation (Janjic 1985) that caused the herbicides

Table 3. Effect of herbicide treatments on plant height and fresh weight in maize

Treatment	Height (cm)		Fresh weight (g)	
	4 cm	7 cm	4 cm	7 cm
Untreated control	41.3	39.8	40.6	36.8
Atranex-90WDG	40.2	34.7**	38.0	29.4**
Inacor-T	40.8	40.3	41.5	39.1
Liron S-50	41.4	41.3	39.8	40.1
Aspect 500-SC	42.6	43.2	45.2	41.2
Racer 25-EC	43.4	40.0	43.5	40.7
Cyatral-SCZ	42.5	32.3**	41.6	24.5**
$LSD_{0.05}$	*2.44 NS*	*3.54*	*5.89 NS*	*5.45*
$LSD_{0.01}$	*3.34*	*4.85*	*8.19*	*7.46*

*P < 0.05, **P < 0.01, NS – not significant

Table 4. Efficacy of soil applied herbicide treatments to control common cocklebur in maize

Treatment	Common cocklebur density per container		Coefficient of efficacy (%)	
	4 cm	7 cm	4 cm	7 cm
Untreated control	14.5	11.0	–	–
Atranex-90WDG	0.0**	0.0**	100	100
Inacor-T	0.0**	0.0**	100	100
Liron S-50	0.0**	0.0**	100	100
Aspect 500-SC	0.0**	1.5**	100	86.3
Racer 25-EC	0.5**	1.5**	96.5	86.3
Cyatral-SCZ	0.0**	0.5**	100	95.4
$LSD_{0.05}$	*0.79*	*1.54*		
$LSD_{0.01}$	*1.09*	*2.11*		

*$P < 0.05$, **$P < 0.01$, NS – not significant

to leach and accumulate deeper in the soil. The injury caused by Atranex-90WDG and Cyatral-SCZ was directly reflected in significant reduction of height and fresh weight.

Maize density per container. Statistical analysis of the data (Table 2) revealed that density of maize plants, regardless of seeding depth, was not significantly affected by soil applied herbicides. Generally, the number of maize plants per growing container ranged between 9.0 (Liron S-50 at 4 cm and Atranex-90WDG at 7 cm) and 10 (Inacor-T and Cyatral-SCZ at 4 cm, and Liron S-50 and Aspect 500-SC at 7 cm). These results are in conformity with the findings of Sumich (1963, 1966) who reported that linuron did not cause a reduction in crop vigour and crop density. Similar results were reported by McPhail (1968) and Woon (1970) in respect to the effect of atrazine on maize plants.

Mean height of the maize plants. At the seeding depth of 4 cm the height of the maize plants was found not to differ statistically between treatments (Table 3). However, the tallest maize plants were in containers treated with Racer 25-EC (43.4 cm), followed by Aspect 500-SC (42.6 cm) and Cyatral-SCZ (42.5 cm), while the shortest (40.2 cm) were in containers treated with Atranex-90WDG. The height of the maize plants was significantly reduced by Atranex-90WDG and Cyatral-SCZ, but only at the seeding depth of 7 cm. At this depth, the tallest maize plants (43.2 cm) were in containers treated with Aspect 500-SC, while the shortest (32.3 cm and 34.7 cm, respectively) were in containers treated with Cyatral-SCZ and Atranex-90WDG, respectively.

Mean fresh weight of the maize plants. Fresh weight depended on the previous parameters: density and height of maize plants. No significant reduction in fresh weight of maize plants was caused by herbicide treatment of containers seeded at the depth of 4 cm. Maximum fresh weight (46.5 g) was measured in Racer 25-EC treated containers, followed by containers treated with Aspect 500-SC (45.2 g). The lowest fresh weight (38.0 g) was measured in Atranex treated containers. In containers seeded at 7 cm there was a significant reduction in fresh weight of plants when treated with Cyatral-SCZ and Atranex-90WDG (24.5 g and 29.4 g, respectively).

Herbicide efficacy. The criterion for herbicide efficacy was taken as the percentage of weed plants that are controlled by any particular treatment. The data regarding herbicide efficacy presented in Table 4, show that all investigated herbicides had a highly significant ($P < 0.01$) effect on *Xanthium strumarium* control, regardless the depth. Generally, the coefficient of efficacy ranged from 86.3% to 100.0% for all herbicides. McWhorter & Anderson (1976) found a preemergence treatment with metribuzin and a postemergence application of bentazon provided 92–99% control of common cocklebur in soybean. Similar results with control of common cocklebur in maize by preemergence herbicides were reported by Nolte and Young (2002) and Hendrix *et al.* (2004).

From the present results it is clear that common cocklebur is susceptible to all investigated soil applied herbicides and could easily and effectively be controlled. That raises the question why it is considered a problem weed in maize production. The answer can probably be found in the fact that its seeds remain viable for many years in the soil (Kozlowski 1972; Kostov 1994) and could germinate at any suitable time during crop cultivation, thus evading standard control measures.

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