T1974CULT07

EFFICIENCY OF HERBICIDES APPLIED ALONE OR COMBINED IN THE WEED CONTROL OF IRRIGATED OR NON-IRRIGATED SUNFLOWER CROPS

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Under the conditions of the Romanian agriculture, sunflower ranks second as a plant needing a great volume of weed control as compared to the commonly used hoeing method (manual weeding between rows). Due to the rapid industrialization of Romania the hand shortage is considerably felt in agriculture. This situation imposes a transition towards the application of a modern technology based on the use of herbicides in the weed control, with the purpose to avoid totally the manual weeding. This situation determined us to undertake a series of researches on the efficiency of numerous herbicides synthetized on a world scale, in the period 1960—1970. Among the herbicides belonging to different chemical groups, the best results were obtained with prometryn (Ulinici — 1968). Similar results were obtained in Bulgaria by Ljubenoff (1966), in USSR by Wojewodin (1966), and in France by Pierre et al. (1969).

Nevertheless, it is well known that prometryn, as well as other herbicides of the triazine group do not exert a physiological selectivity for sunflower plants. In practice, the use of these herbicides is based on the so-called mechanical „position" selectivity. In preemergence applications the herbicides are leached in superficial layer of the soil, killing monocotyledon as well as dicotyledon weeds. Under normal conditions the sunflower root system develops below the layer of soil containing prometryn. During years with abundant precipitations, after treatment application prometryn may become phytotoxic to sunflower plants (Şarpe et al., 1972, 1973). This phenomenon was also reported by Regnault et al. (1973) in France, where after a prometryn treatment the precipitation quantity was as high as 40 mm.

Due to the risks that may arise after the application of prometryn, beginning with 1971 we also studied other herbicides showing a physiological selectivity; on the other hand, we tried to obtain a wider

range of weed control and for this purpose we studied the possibilities of combining the different herbicides.

METHOD AND MATERIALS

The experiments were carried out according to a common research programme, at 8 agricultural experimental stations, located in different areas of Romania. This report presents the results of studies carried out in only 2 pedoclimatic zones, where large surfaces are under maize crops such as :

At the Research Institute for Cereals and Industrial Crops (I.C.C.P.T.) — Fundulea — on a medium leached chernozem soil, containing 3.5% humus and 36—38% clay.

At the Research Station for Irrigated Crops — Valu lui Traian — on a carbonated chernozen soil, containing 3.4% humus and 22—34% clay.

All the experiments were carried out according to the latin square method with 4 replications, on 25 sq.m. plots each.

The herbicides were applied with hand sprayers, using 600—1000 l water/ha.

The following herbicides were used during the experiments of 1965 to 1973 :

1) Prometryn [(2.4-bis-isopropylamino)-6-methylthio-s-triazine]
2) Ametryn (2-methylmercaptor-4-ethylamino-6-isopropylamino-1,3,5 triazine)
3) Terbutryn (2-tert. butylamino-4-ethylamino-6-methylthio-s-triazine)
4) Chlorbromuron [(N' - 3-chloro-4-bromo-4-bromo-phenyl) -N'-methoxy-N'-methylurea]
5) A-3623 (15% GS 13529 + 35% GS 14260)
6) Trifluralin (α,α,α trifluoro-2.6 dinitro-alpha N, N dipropyl-p-toluidine)
7) Butylate (N, N-diisobutyl-thiocarbonate of ethyl)
8) Nitralin [(N,N-di-N-propyl-2.6 dinitro-4-(methylsulphonyl)-aniline]
9) Nitroaniline (N-Cyclopropylmethyl-4-trifluoromethyl-2.6 dinitro N-n-propyl-aniline)
10) Trifluralin combi is an original combination containing trifluralin and metribuzin
11) Butylate combi is an original combination containing butylate and metribuzin
12) Nitralin combi is an original combination containing nitralin and metribuzin
13) Nitroaniline combi is an original combination containing nitroaniline and metribuzin.

The herbicide rates in kg/ha a.i. for each variant are given in Tables 1—5.

In all the experiments, the herbicides prometryn and terbutryn, as well as A-3623 were applied as pre-emergence treatments (immediately after sowing). The herbicides containing trifluralin, butylate, nitralin, nitroaniline (alone or combined with metribuzin) were applied before planting and incorporated in the soil at a depth of 7—8 cm by means of a moto-cutter.

During the vegetation period, observations were carried out on the phytotoxic effects, using both methods of counting of the emerged plants and the plants surviving up to harvesting, as well as the method of phytotoxicity evaluation by means of the EWRC scale (1 = no phytotoxic symptoms ; 9 = severe phytotoxic effects with 80—90% of the plants killed).

The herbicidal effect on the weeds was estimated by the EWRC scale (1 = = highly effective against weeds when these are killed in a proportion of 90—100%; 9 = no weed-killing effects, as well as by weighing the weed mass 10—15 days prior to sunflower harvesting).

After harvesting, the seed-yield of each plot was weighed.

RESULTS

The researches carried out with prometryn between 1965—1967 in different pedoclimatic areas, showed that the above-mentioned herbicide has the highest effectiveness in the control of monocotyledon weeds.

The herbicide prometryn introduced in bands (preemergent, at planting) yielded 26.7—28.1 q/ha, practically equal to the yield of the standard variant (27.7 q/ha). It should be mentioned that during the vegetation period, on the plots treated with prometryn (table 1) only

Table 1

Phytotoxic effect and yield of sunflower treated with prometryn — I.C.C.P.T. Fundulea — Chernozem with 3.5% humus

Amount of rainfalls in the 30 day period following prometryn application		
1965	1966	1967
Treated on 19.IV.	Treated on 6.IV.	Treated on 5.IV.
21.IV. ... 3.7 mm 22.IV. ... 2.8 mm 25.IV. ... 3.7 mm 27.IV. ... 4.8 mm 7. V. ... 4.1 mm 8. V. ... 6.3 mm 11. V. ...17.5 mm 12. V. ...31.5 mm 14. V. ...37.0 mm 15. V. ...13.1 mm	7.IV. ... 3.9 mm 11.IV. ... 1.8 mm 13.IV. ... 3.0 mm 17.IV. ...10.2 mm 18.IV. ... 3.5 mm 28.IV. ...19.6 mm 30.IV. ... 3.6 mm 1—6.V... 0.0	15.IV. ... 2.4 mm 17.IV. ... 0.7 mm 20.IV. ... 1.1 mm 22.IV. ... 4.1 mm 23.IV. ...10.8 mm 24.IV. ...21.8 mm 29.IV. ... 1.6 mm 5. V. ... 1.7 mm
124.2 mm	44.6 mm	44.2 mm

Treatment		Phytotoxic effect		Phytotoxic effect		Phytotoxic effect		Yield Average 1965—1967		
Herbicides	Dose kg/ha a.ai.	Emerged plants 1965		Emerged plants 1966		Emerged plants 1967				
		Nr/ha	%	Nr/ha	%	Nr/ha	%	q/ha	%	Dif.
Control	—	39,900	100	42,850	100	43,020	100	27.7	100	—
Prometryn	1.0	41,400	104	42,280	99	42,187	98	26.7	96	1.1
Prometryn	1.5	40,100	100	42,100	99	42,239	98	27.8	100	0.1
Prometryn	2.0	40,200	101	41,140	96	42,082	98	28.1	101	0.4
Prometryn	2.5	40,200	100	41,710	97	40,937	95	27.8	96	—0.3

3 mechanical hoeings between rows were made, while on the standard plot 3 manual weedings in the row + 3 mechanical hoeings between the rows.

During the years with normal precipitations — as it results from table 1 — no phytotoxic symptoms were observed : it shoud be also emphasized that during 1965 and 1970 no phytotoxic symptoms were observed at the state farms of our country — where prometryn was used in sunflower crops. However, in 1971 when abundant precipitations occurred early in May (above 80—100 mm), severe phytotoxic symptoms were observed at some of the state farms located in the south-eastern areas of Romania, on medium leached chernozem, brown carbonated chernozem and, especially, on alluvial soils with a humus content of below 2%.

Clear phytotoxic symptoms caused by prometryn were also recorded in 1971 in the experiments located on the brown chernozem soil of Valu lui Traian. In table 2 it can be seen that prometryn applied at the rate of 2.4—4.0 kg/ha considerably reduced the sunflower yields. From 2,920 kg/ha (check-variant 1) the yield diminished to 430 kg/ha in the variant treated with 4 kg prometryn/ha. In the variants treated with trifluralin, butylate and nitralin no phytotoxic symptoms

Table 2

Phytotoxic effect and yield of sunflower crops treated with different herbicides at the Research Station Valu lui Traian — during 1971 year with abundant precipitations during may month

Treatment		Phytotoxic effect EWRC scale	Weed control EWRC scale		Yield	
Herbicides*	Dose kg/ha a.i.		after 30 days	after 90 days	q/ha	%
Control I hoed 3 times	—	1	1	2	29.2	100
Control II not hoed	—	1	9	9	14.2	49
Prometryn	2.40	6	3	3	12.1	41
Prometryn	3.20	8	2	2	8.2	28
Prometryn	4.00	8	1	1	4.3	16
Trifluralin	1.00	1	5	6	17.7	61
Trifluralin combi	2.75	2	2	3	24.0	82
Butylate	6.20	1	5	6	19.1	65
Butylate combi	5.00	2	2	3	25.0	86
Nitralin	3.00	1	6	7	17.8	61
Nitralin combi	3.50	2	2	3	25.3	87

LSD 5% = 3.4; 1% = 4.6; 01% = 6.0 q/ha

* The plots treated with herbicides were not hoed

were recorded. Due to the heavy infestation with *Sinapis arvensis, Hibiscus ternatus,* and *Solanum nigrum* in the variants treated with trifluralin, butylate and nitralin, low sunflower yields were obtained. The sunflower yields increased sensibly (by more than 30%) in the plots treated with trifluralin combi, butylate combi and nitralin combi, as a consequence of the successful control of the resistant weed species *(Sinapis arvensis, Hibiscus ternatus* and partially *Solanum nigrum).* In these variants too, receiving combined herbicides, the perennial weed species *(Cirsium arvense)* were not killed, and this caused to some extent a diminution of the sunflower yields.

In order to provide a better explanation of the selectivity of some herbicides to sunflower crops, in 1971 and 1972 a special trial was organized at Fundulea. After a 10 days treatment with herbicides, the experimental plots were irrigated with up to 191 l water/sq.m., so as to reproduce the conditions created by the abundant precipitations during rainy years. The results are presented in table. 3. The phytotoxic effects of the triazine herbicides (prometryn, terbutryn, and A-3623) was very heavy and directly proportional to the doses used. In terms of the applied rate of the 3 herbicides (2.5—10.0 kg/ha), the sunflower plants were killed in a proportion of 4 to 95%. This phenomenon was caused by the very large quantities of water in the soil, leaching the active ingredient of the triazine herbicides up to the absorbtion level of root system, causing the death of the sunflower plants either before (at very high dosage rates) or 10—20 days after their emergence.

The results obtained in this same trial clearly show that butylate and trifluralin have a high physiological selectivity. No phytotoxic symptoms appeared even when twofold rates of butylate or trifluralin were applied. For this reason in the research programme carried out in the last 4 years, we accorded a special attention to the herbicides which have a physiological selectivity (trifluralin, butylate, nitralin, nitroaniline, etc.).

All these herbicides are, however, characterized by a limited range of weed control. With a view to extending the range of weed control, the effect of many associated herbicides (prior to the application) was studied in the laboratory and some of the results are given in tables 4 and 5.

On the medium leached chernozem soil, at Fundulea, where the principal weed species were prevalent i.e. (in descending order) : *Setaria sp., Sinapis arvensis, Echinochloa crus-galli, Amaranthus sp., Hibiscus ternatus, Chenopodium album, Thlaspi arvense, Polygonum convolvulus,* the most successful weed control was realized in the plots treated with trifluralin combi, butylate combi, nitralin combi and nitroaniline combi. The control of more than 80 to 90% of the annual mono- and dicotyledon weeds was achieved at Fundulea with these herbicides (table 4), this resulting in yields comparable to those obtained in the check variant I, hoed 3 times during the vegetation period. In the variants receiving only herbicides containing trifluralin, butylate, nitralin

Table 3

The phytotoxic effect of different herbicides upon the sunflower plants under conditions of excessive humidity on a medium levigated chernozem soil with 3.5% humus, Research Institute for Cereals and Industrial Crops Fundulea, 1971—1972

Total amount of water from irrigation and precipitations		
Day I	after seeding	25 l/m²
Day II	after seeding	25 l/m²
Day III	after seeding	20 l/m²
Day IV	after seeding	10 l/m²
Day V	after seeding	10 l/m²
Day VI	after seeding	15 l/m²
Day VII	after seeding	20 l/m²
Day VIII	after seeding	40 l/m²
Day IX	after seeding	10 l/m²
Day X	after seeding	16 l/m²
T o t a l :		191 l/m²

Treatment		Percent rate of plants surviving after emergence			Phytotoxic effect EWRC scale	Yield %
		After				
Herbicides*	Rate kg a.i./ha	10 days	20 days	30 days		
Control, hoed 3 times	—	100	100	100	1.0	100
Prometryn	2.5	97	96	96	1.4	93
Prometryn	5.0	62	60	60	4.0	60
Prometryn	7.5	20	12	8	8.8	30
Prometryn	10.0	15	10	5	9.0	20
Terbutryn	2.5	73	70	64	4.5	70
Terbutryn	5.0	60	58	55	5.6	51
Terbutryn	7.5	18	17	12	7.7	23
Terbutryn	10.0	6	3	3	9.0	14
A—3623	2.5	88	79	79	3.0	80
A—3623	6.0	83	80	70	5.0	75
A—3623	7.5	30	20	20	8.0	35
A—3623	10.0	25	20	15	8.5	27
Butylate	6.25	100	100	100	1.0	100
Butylate	9.37	100	100	100	1.0	100
Butylate	12.50	100	100	100	1.0	100
Trifluralin	1.0	100	100	100	1.0	100
Trifluralin	1.5	100	100	100	1.0	100
Trifluralin	2.0	100	100	100	1.0	100

*) The plots treated with herbicides were hoed 3 times

Table 4

The action of herbicides applied alone and combined on the sunflower hybrid Romsun 52, sown on non-irrigated field, at the Research Institute for Cereals and Industrial Crops, Fundulea

Treatment		Phytotoxic effect EWRC scale	Weed control EWRC scale after:		Yield	
Herbicides*	Rate kg a.i./ha		30 days	90 days	q/ha	%
Trial no.1: Results 1971—1973						
Control I, hoed 3 times	—	1.0	1	3	26.9	100
Control II, not hoed	—	1.0	9	9	11.7	43
Prometryn	3.0	1.0	3	5	18.0	67
Prometryn	4.5	1.5	2	4	22.3	83
Trifluralin	1.0	1.0	5	8	12.5	46
Trifluralin	1.5	1.0	4	5	15.0	56
Trifluralin combi	1.5	1.0	1	2	26.5	98
Butylate	6.2	1.0	6	9	12.0	44
Butylate	7.8	1.0	5	6	13.5	50
Butylate combi	7.8	1.0	1	2	25.1	93
Nitraline	1.5	1.0	5	7	14.1	52
Nitraline	3.0	1.0	4	7	13.4	50
Nitraline combi	2.0	1.0	2	3	21.0	78
LSD 5% = 5.6; 1% = 7.5; 0.1% = 9.7 q/ha						
Trial no.2: Results 1973						
Control I hoed 3 times	—	1.0	1	2	26.2	100
Control II, not hoed	—	1.0	9	9	14.8	50
Prometryn	3.0	1.0	4	4	22.7	87
Nitroaniline	0.6	1.0	4	5	21.7	83
Nitroanaline	0.9	1.0	3	4	22.6	86
Nitroaniline	1.8	1.0	2	4	21.8	83
Nitroaniline + Prometryn	0.6+2.0	1.0	4	4	20.8	79
Nitroaniline + Terbutryn	0.6+2.0	1.0	4	5	19.0	73
Nitroaniline + Ametryn	0.6+2.0	1.0	4	5	19.9	76
Nitroaniline + Chlorbromuron	0.6+1.5	1.0	3	4	20.3	77
Nitroaniline combi	1.4	1.5	1	2	26.7	102
Butylate combi	7.8	1.5	1	2	27.0	103
LSD 5% = 5.6; 1% = 7.4; 0.1% = 9.5						

*) The plots treated with herbicides were not hoed

and nitroaniline applied alone, the sunflower yields were greatly diminished (by more than 20 to 50%) due to the presence of herbicide-resistant weed species *(Sinapis arvensis, Hibiscus ternatus,* and *Thlaspi arvense).*

By summarizing the data presented in table 5, it can be concluded that the results obtained on the brown carbonated soil at Valu lui Traian are similar to those obtained at Fundulea.

Table 5

The action of herbicides applied alone and combined on sunflower hybrid Romsun 52 sown on irrigated fields, Research Station Valu lui Traian

Treatment		Phytotoxic effect EWRC scale	Weed control EWRC scale		Yield	
Herbicides*	Rate kg/ha a.i.		after 30 days	after 90 days	q/ha	%
Control I hoed 3 times	—	1.0	1	2	32.0	100
Control II not hoed	—	1.0	9	9	12.7	40
Prometryn	1.5	1.0	4	6	19.4	61
Prometryn	2.0	1.0	3	5	22.6	71
Prometryn	2.5	1.0	3	4	25.6	80
A—3623	2.5	1.0	4	6	19.3	60
A—3623	3.2	1.0	3	5	21.9	68
Trifluralin	1.0	1.0	4	6	19.8	62
Butylate	6.2	1.0	4	6	19.6	62
Trifluralin + Prometryn	1.0 1.5	1.0	3	5	21.8	68
Butylate + Prometryn	6.2 1.5	1.0	3	5	23.3	73
Butylate combi	7.8	1.0	1	2	29.5	92

LSD 5% = 2.6; 1% = 3.4; 0.1% = 4.4 q/ha

*) The plots treated with herbicides were not hoed

The most successful weed control and the highest sunflower yields were realized in the variant receiving butylate combi. In the variants recieving only trifluralin or butylate, the sunflower yields decreased by 30%, due to the presence of resistant weed species, such as : *Raphanus raphanistrum, Hibiscus ternatus,* and *Solanum nigrum.* In the variants treated only with triazine herbicides at the low doses of 1.5—2.5 kg/ha a.i. (so as to avoid the phytotoxic effects) the control of gramineous weeds *(Echinochloa crus-galli* and *Digitaria sanguinalis)* was less successful. The presence of the surviving gramineous weeds and of some perennial weed species resulted in a decrease by 20 to 30% of the sunflower yields as compared to the yield of check plot I, hoed 3 times.

CONCLUSIONS

1. Under the pedoclimatic conditions of Romania, where the soils are infested by a mixed flora of mono- and dicotyledon weeds, a highly effective weed control in the sunflower crops was achieved by means of combined herbicides belonging to different chemical groups. Trifluralin combi, butylate combi, nitralin combi and nitroaniline combi, containing metribuzin at various proportions, showed the highest effectiveness.

2. The herbicides containing trifluralin, butylate, nitralin and nitroaniline, applied alone (in spite of their high physiological selectivity) are only able to solve partially the weed control problem. These herbicides cannot be applied alone in crops that are severely infested by resistant weed species such as : *Sinapis arvensis, Raphanus raphanistrum, Hibiscus ternatus, Solanum nigrum,* widely distributed in all the western, southern and easterm sunflower-growing areas of Romania.

3. Prometryn and the other triazine herbicides, even if highly effective in controlling the mono- and dicotyledon weeds, can be applied in the sunflower crops only at low dose rates, depending on the humus and clay content of the soil, with a view to avoiding the phytotoxic effects resulting from their leaching up to the absorbtion zone of the root system. The activity of these herbicides depends, to a large extent, on the quantity of precipitations recorded after treatment applicaion. For this reason, their effectiveness can be satisfactorily increased under irrigation conditions.

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