

RESEARCH ON THE SELECTIVITY AND EFFECTIVENESS OF THE HERBICIDE ISOXAFLUTOLE + CYPROSULFAMIDE IN THE CHICKPEA CROP IN THE PEDOCLIMATIC CONDITIONS OF MOARA DOMNEASCĂ

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Abstract: Chickpea is a small plant with a slow growth rate in its young growth phase, so it gives weeds the opportunity to take over its nutritional spectrum easily. In order to evaluate the effects of the herbicide isoxaflutole 240g/l + cyprosulfamide 240g/l (safener) on weed control in chickpea fields, the experiment was located at Moara Domnească in 2023 in randomised blocks in 4 replicates. The treatments included application of the herbicide in different doses and different times of crop vegetation in pre-emergence, early post-emergence (at 8-10 cm tall) and post-emergence (at 16-18 cm tall). The determination of weeds in the untreated version was done as percentage of soil coverage when the chickpea was around 8-10 cm tall. According to the results, the best yields were obtained when the herbicide was applied post-emergent at the rate of 0.18 l/ha when the crop was around 8-10 cm and pre-emergent at the rates of 0.3 and 0.2 for which yields between 1364 and 1325 kg/ha were obtained. The most severe forms of phytotoxicity that prevented the chickpea crop were present when the herbicide was applied at a rate of 0.18 and 0.36 l/ha when the chickpea was 16-18 cm tall and at the rate of 0.36 l/ha when the chickpea was 8-10 cm tall, with EWRS scores ranging from 2 to 5.

Keywords: chickpea, herbicide, selectivity, yield.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the important grain legumes in human nutrition and animal feeding with a high protein content. Depending on environmental conditions and cultivation technology, the chemical composition of chickpeas is strongly influenced, they contain on average between 12.6 - 31.2% protein, 4.03 - 8.2% fat, 42.5 - 71.2% carbohydrates; 2.4 - 12.2% cellulose and very few anti-nutritional factors around 2.4 - 5% (Borcean et al., 2006). In addition, according to the latest FAO (Food and Agriculture Organization) statistics from 2023, the import of chickpeas into Europe has almost doubled in the last 20 years, from

around 130 thousand tonnes in 2000-2002 to 230 thousand tonnes in 2020-2022, which indicates that there has been an increase in their use in recent years. Thereby, the areas cultivated with chickpeas in Europe in 2022 have increased 5 times (being 351 thousand ha) compared to the average cultivated areas in the years 2000-2010 (FAO, 2023).

Late sowing of the crop due to unfavorable weather conditions, inefficiency of uniform sowing, massive pest attack, inability to have a weed-free crop lead to significant reductions in grain yield. Besides the competition between weeds and the crop plant, weed infestation also leads to difficult and defective chickpea harvesting leading further to quality reductions (Şanlı et al., 2009). The chickpea plant is very poor in weed competition, this is due to slow growth in the early growing season and having limited leaf area formation. Yield losses due to weed competition depend very much on the weed species present and their density (Muharrem et al., 2018). Various studies focusing on this situation have reported yield losses ranging from 13 to 90% and in some situations reaching 98% due to weed competition (Bhan & Kukula, 1987; Solh & Pala, 1990; Mohammedi et al., 2005; Ashu & Sandeep, 2020).

Chickpea is known as one of the most drought and heat resistant grain legumes, besides, it is seen by some farmers as a crop with low labor consumption and in general its production requires less inputs compared to cereals crop (Cojocaru & Marin, 2022). It is a sustainable crop, can be grown on different soil types with residual moisture, but is sensitive to soils with a high alkaline pH. Chickpeas help to improve soil fertility by leaving after harvest a substantial quantity of residual nitrogen and adds an amount of organic matter being suitable in crop rotation (Cojocaru & Marin, 2021).

The use of herbicides in the chickpea crop is limited due to its sensitivity, especially for the application of post-emergence herbicides. In Romania there are very few herbicides approved for this crop, especially for the control of dicotyledonous weeds, which is one of the biggest problems faced by chickpea growers.

The purpose of the experiment was to determine the selectivity and effectiveness of the herbicide isoxaflutole 240g/l + cyprosulfamide 240g/l (safener) that can be used in weed control in the chickpea crop by establishing the limits of the dose and application period. We mention that in Romania, herbicides based on isoxaflutole + cyprosulfamides are not approved for the chickpea crop (MADR, 2023).

Isoxaflutole is a soil and post-emergence applied isoxazole herbicide that inhibits p-hydroxyphenyl pyruvate dioxygenase (HPPD), an important enzyme involved in the biosynthesis of carotene pigments in plants (Senseman, 2007). Isoxaflutole provides residual control of grass and broadleaf weeds such as wild proso millet (*Panicum miliaceum* L.), giant foxtail (*Setaria faberii* Herrm.), green foxtail [*Setaria viridis* (L.) Beauv.], yellow foxtail [*Setaria glauca* (L.) Beauv.], barnyard grass [*Echinochloa crus-galli* (L.) Beauv.], fall panicum (*Panicum dichotomiflorum* Michx.), common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), common ragweed (*Ambrosia artemisiifolia* L.), smartweed (*Polygonum* spp.), annual nightshades (*Solanum* spp.), and velvetleaf (*Abutilon theophrasti* Medic.) (Bhowmik et al., 1996, 1999; Luscombe et al., 1995; Taylor-Lovell & Wax, 2001; Vrabel et al., 1997, 1998). Safeners (cyprosulfamide) improve the tolerance of crops to herbicidal active ingredients (Mink et al. 2020).

MATERIALS AND METHODS

The research took place in 2023 at Experimental Didactic Field of University of Agriculture in Moara Domneasca village, Ilfov county, on the coordinates 44.5012061 latitude and 26.248937 longitude. The experimental plots was located on the reddish preluviosoil soil type, belonging to the luvisol class, with a moderate fertility for the 0-20 cm horizon of 2.2% humus, with a 32% clay content and an acid pH of 5.2% (Mihalache et al., 2010). The chickpea variety grown was Burnas, sown after wheat crop. The Burnas variety was developed at SCDA Teleorman in 2004 and approved in 2006 and is suitable for cultivation in arid areas of our country having high resistance to anthracnose (*Mycosphaerella rabiei* Kovatsch.).

The experiment was conducted according to the method of randomized block, in four repetitions, with a plot area of 21 m² (3,5 x 6). Research has shown the degree of selectivity and effectiveness of the herbicide isoxaflutole 240g/l + cyprosulfamide 240g/l (safener) in the control of dicotyledonous and monocotyledonous weeds. The treatments were applied in different rates and different times of crop vegetation and consisted of 3 variants applied pre-emergent at the time of seed imbibition (BBCH 01-03) with rates of 0.2; 0.3 and 0.4 l/ha; 2 variants applied early post-emergence when the crop was on average 8-10 cm tall (BBCH 14-16), at the rate of 0.18 l/ha and double-rated of 3.6 l/ha and 2 variants applied in post-emergence when the crop was on average 16-18 cm tall (BBCH 32-34) at the rate of 0.18 l/ha and double-rated of 3.6 l/ha as shown in Table 1. These variants were created in order to have a clearer frame of the efficacy differences.

Tabel 1. Investigated variants in chickpea crop, Moara Domneasca, 2023

No. var.	Experimental variants	Dose (l/ha)	Time of application	Chickpea growth stage
V1	Untreated	-	-	-
V2	Ut.2 - manually hoeing	-	-	-
V3	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.2	pre-emergence	seed imbibition
V4	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.3	pre-emergence	seed imbibition
V5	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.4	pre-emergence	seed imbibition
V6	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.18	early post-emergence	8-10 cm height
V7	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.36	early post-emergence	8-10 cm height
V8	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.18	post-emergence	16-18 cm height
V9	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.36	post-emergence	16-18 cm height

After the application of treatments, assessments were made on the degree of selectivity according to EWRS (European Weed Research Society) scale, where phytotoxicity was evaluated from 1 to 9, where 1 means no phytotoxic symptoms and 9 for crop totally destroyed,

at intervals of 7-14-28 days after treatments. The effectiveness of weed control (%) was realized by visual assessment estimated at the interval of 14-21-48 days from the moment of treatment for each individual variant. The results were calculated and interpreted based on the analysis of ARM software ($P=.05$, Student-Newman-Keuls).

Weeds density was evaluated as percentage of soil coverage and in couple of plants per square meter. Determinations of weeds flora was performed by visual estimation, on one square meter using a wooden frame (Chirilă, 1988). Weed mapping of the untreated was done when the weed was around 8-10 cm tall.

RESULTS AND DISCUSSIONS

Regarding rainfall during the growing season (february to august) in 2023 at Moara Domnească, chickpeas benefited of 242 mm, that was droughty compared to the multiannual average recorded in Romania. In the beginning part of the vegetation period, the rainfall ammount was very low în February and March with 2,5 respectively 14 mm, but in April was favourable with 72.5 mm, giving a convenient start to the crop (Figure 1). There was also good rainfall in July of 70 mm but very high temperatures reduced the moisture. A wave of scorching temperatures were recorded in July and August with a monthly average of 25.96 and 26.83°C respectively.

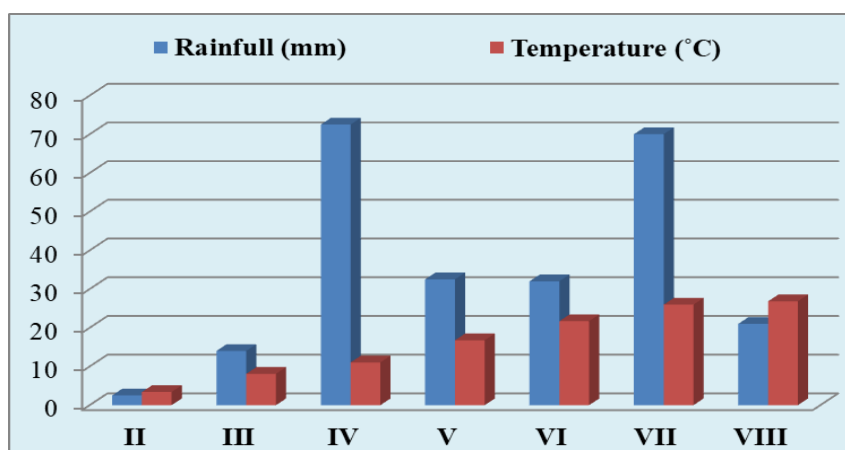


Figure 1. The evolution of precipitations and temperature at Moara Domnească, in 2023.

In general, the soil in the Didactic Field at Moara Domnească presents a huge reserve of weed seeds, in the chickpea experiment, annual dicotyledonous weeds such as *C. album*, *Polygonum aviculare* (L.), *A. retroflexus*, *Capsella bursa-pastoris* (L.) Medicus. and perennial dicotyledonous weeds *Convolvulus arvensis* (L.), *Cirsium arvense* (L.) Scop. were determined, which comprised a high percentage of soil coverage. Among the annual monocotyledonous weeds were found *Setaria* sp., *E. crus-galli* and *Digitaria sanguinalis* (L.) Scop. were present (Figure 2). Additional, were found other dicotyledonous weed species but in a very low density (aprox. 2 plants/m²), these were *Polygonum convolvulus* (L.) sin. *Fallopia convolvulus* (L.) A. Löve, *Solanum nigrum* (L.), *Galium aparine* (L.), *Portulaca oleracea* (L.), *Centaurea cyanus* (L.).

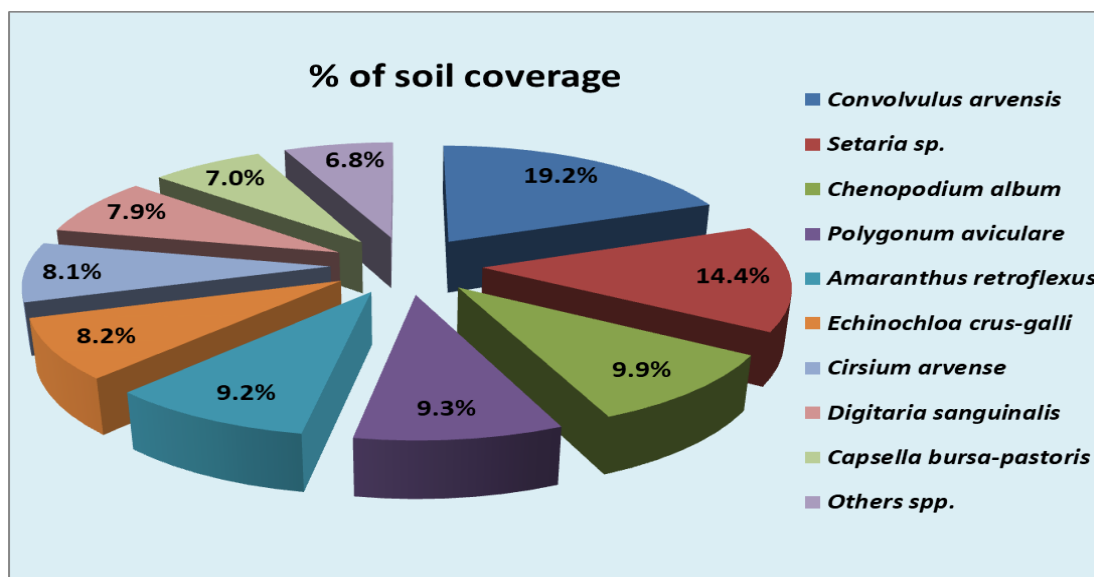


Figure 2. The degree of soil coverage of annual and perennial dicotyledonous weeds present in the untreated variant in the chickpea crop experience

Following the selectivity data of the herbicide isoxaflutole 240g/l + cyprosulfamide 240g/l (safener) in table 2 it is observed that the rate of 0.36 l/ha applied to the chickpea crop showed in the early post-emergent period, when the plants were 8-10 cm tall, phytotoxic phenomena shown by yellowing of leaves, bleaching and growth reduction, with negative influences on fruiting, the EWRS scores are at first 3 then 4 and 4. In V8, when the herbicide was applied post-emergence at 16-18 cm height and the rate of 0.18 l/ha the phytotoxic effect was slightly weaker, with EWRS scores of 2 at first and then 3 and 3. At V9 post-emergent herbicide application at the rate of 0.36 l/ha showed the highest phytotoxic phenomena with scores of 4 then 5 and 5. For V5 when the herbicide was applied at 0.4 pre-emergent, very small forms of phytotoxicity were observed at crop emergence, but the crop returned to normal, EWRS scores were 2, 2 and 1. Variants 7, V8 and V9 are not a treatment solution for chickpea cultivation. For V3, V4, V6 when the herbicide was applied pre-emergent and early postemergent when the chickpea was 8-10 cm tall at the rate of 0.18 l/ha no phytotoxicity was observed with a note of 1.

Table 2. Selectivity of isoxaflutole + cyprosulfamide herbicide applied to chickpea crop, Moara Domnească, 2023

No.	Experimental variants	Dose (l/ha)	Chickpea growth stage	Selectivity		
				7 days	14 days	28 days
V1	Untreated	-	-	-	-	-
V2	Ut.2 - manually hoeing	-	-	-	-	-
V3	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.2	seed imbibition	1	1	1
V4	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.3	seed imbibition	1	1	1
V5	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.4	seed imbibition	2	2	1
V6	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.18	8-10 cm height	1	1	1

V7	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.36	8-10 cm height	3	4	4
V8	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.18	16-18 cm height	2	3	3
V9	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.36	16-18 cm height	4	5	5

In Table 3 is shown the effectiveness of isoxaflutole 240g/l + cyprosulfamide 240g/l (safener) at 48 days after treatment, against weeds presents in experimental fields. The herbicide applied at the rate of 0.4 l/ha pre-emergent and at the rate of 0.36 l/ha post-emergent when the crop was 8-10 cm tall (V5 and V7) gave the best effectiveness results compared to the other variants for all weed species present in the experiment. For these doses the lowest results were for *C. arvensis*, *P. aviculare* and *C. arvensis* species between 12.39 and 50.01% and the best results were for *Setaria* sp., *C. album*, *A. retroflexus*, *E. crus-galli*, *D. sanguinalis* and *C. bursa-pastoris* between 92.70 and 100%. The weakest results were obtained when the herbicide was applied post-emergence when the chickpea was 16-18 cm tall at the rate of 0.18 and 0.36 respectively V8 and V9. These variants, in addition to not controlling weeds very well, also exhibited forms of phytotoxicity, which further hampered the crop. Regarding post-emergent herbicide application at the rate of 0.18 l/ha when the crop was 8-10 cm high and pre-emergent at the rates of 0.2 and 0.3 l/ha the results were acceptable for the control of *Setaria* sp., *C. album*, *A. retroflexus*, *E. crus-galli*, *D. sanguinalis* and *C. bursa-pastoris*, ranging from 82.87 to 97.43% and weaker for *C. arvensis*, *P. aviculare* and *C. arvensis* ranging from 0.32 to 38.74%.

Table 3. Effectiveness (%) of the herbicide isoxaflutole + cyprosulfamide at 48 days after treatment, Moara Domneasă, 2023

No. Var.	Doza l/ha	CONAR	SETSS	CHEAL	POLAV	AMAR E	ECHCG	CIRAR	DIGSA	CAPBP
V1	-	0.00 c	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.00 e
V2	-	-	-	-	-	-	-	-	-	-
V3	0.2	0.32 c	88.83 b	82.87 ab	29.94 b	90.30 ab	92.70 b	20.76 c	96.31 b	91.40 c
V4	0.3	1.86 c	97.43 b	90.60 a	34.96 b	95.57 ab	97.43 ab	34.96 ab	97.17 b	97.17 bc
V5	0.42	12.39 b	100.00 a	92.70 a	50.01 a	98.73 a	99.81 a	42.37 a	100.00 a	100.00 a
V6	0.18	17.13 b	92.70 b	85.18 ab	29.88 b	90.30 ab	95.35 ab	38.74 a	97.17 b	96.31 bc
V7	0.36	37.48 a	94.29 b	92.70 a	46.20 a	97.17 ab	99.68 a	41.13 a	100.00 a	99.68 ab
V8	0.18	11.17 b	70.06 c	66.31 c	14.82 c	67.82 c	77.55 c	14.54 c	88.10 c	80.32 d
V9	0.36	19.88 b	91.40 b	77.96 b	21.83 bc	85.99 b	88.83 bc	24.83 bc	93.90 bc	92.70 c
LSD P=.05		2.703 - 10.999	2.087 - 12.257	6.730 - 9.950	8.761 - 11.094	6.265 - 14.194	3.710 - 11.432	8.918 - 11.008	1.542 - 6.803	1.380 - 8.440
Standard Deviation		4.610t	5.649t	4.299t	4.359t	6.438t	6.050t	4.457t	4.850t	4.588t

Legend: CONAR = *C. arvensis*; SETSS = *Setaria* sp.; CHEAL = *C. album*; POLAV = *P. aviculare*; AMARE = *A. retroflexus*; ECHCG = *E. crus-galli*; CIRAR = *C. arvensis*; DIGSA = *D. sanguinalis*; CAPBP = *C. bursa-pastoris*.

The productions obtained in the chickpea crop according to the dose and the period of application of the herbicide are presented in Table 4, from which we can observe that the

production obtained in the untreated variant was 443 kg/ha and in the manually hoeing variant the production was 1615 kg/ha. But in conventional agriculture applying manually hoeing is not a suitable solution for chickpea growers. The herbicide variants yielded between 1364 kg/ha and 466 kg/ha. Among the herbicide variants, the best production was obtained at V6 of 1364 kg/ha when isoxaflutole 240g/l + cyprosulfamide 240g/l (safener) was applied in a dose of 0.18 l/ha when the crop was around 8- 10 cm, the next variants with high productions were V4 (1337 kg/ha) and V3 (1325 kg/ha) when the herbicide was applied pre-emergent in doses of 0.3 and 0.2 l/ha, respectively. The differences from the untreated variant reveal that all weed control variants gave statistically proven increases in yield. The differences from ut. 2 (manually hoeing) presents highly significant negative values. Variants 3, V4 and V5 gave practically equal, statistically undifferentiated yields. At V5 the yield was 1220 kg/ha, distinctly significantly negative compared to the manually hoeing variant. A dose of 0.4 l/ha may adversely affect yield. On land infested with annual dicotyledonous weeds and especially perennials such as *C. arvensis* and *C. arvensis*, we still have no solutions for a weed-free chickpea crop. Variants 7, V8 and V9 are not a solution because following the treatments the chickpea plants showed phytotoxic phenomena, the crop suffered and yields were low. With the herbicide isoxaflutole + cyprosulfamide we can obtain satisfactory yields for chickpea cultivation in Romania.

Table 4. Chickpea yields as a result of dose and time of application of isoxaflutole + cyprosulfamide herbicide, Moara Domnească, 2023

No.	Experimental variants	Dose (l/ha)	Production yields		Difference from the untreated (kg/ha)	
			kg/ha	%	kg/ha	
V1	Untreated	-	443	100	Ut.1	-1172 ^{ooo}
V2	Ut.2 - manually hoeing	-	1615	364.6	1172 ^{***}	Ut.2
V3	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.2	1325	299.1	882 ^{***}	-290 ^o
V4	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.3	1337	301.8	894 ^{***}	-278 ^o
V5	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.4	1220	275.4	777 ^{***}	-395 ^{oo}
V6	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.18	1364	307.9	921 ^{***}	-251 ^o
V7	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.36	642	144.9	199 [*]	-973 ^{ooo}
V8	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.18	854	192.8	411 ^{**}	-761 ^{ooo}
V9	240 g/l, isoxaflutole + 240 g/l, cyprosulfamide (safener)	0.36	466	105.2	23	-1149 ^{ooo}

DI 5 % = 149.5 kg/ha; DI 1 % = 306.3 kg/ha; DI 0,1% = 420.5 kg/ha

CONCLUSIONS

Isoxaflutole + cyprosulfamide herbicide can be successfully applied to chickpea crop on Moara Domnească soil pre-emergently at rates of 0.2 - 0.3 l/ha and in vegetation, early post-emergent when plants are 10 cm tall at a rate of 0.18 l/ha.

The highest yields in the treated variants were 1364 and 1337 kg/ha, highly significant compared to the untreated variant and significantly negative compared to the manually hoeing variant.

Application of the herbicide during the growing season, post-emergent at 16-18 cm shows phytotoxic phenomena, plants suffered and yield was only 854 kg/ha.

The variants in doses of 0.36 do not represent a solution since the chickpea plants showed major phytotoxic phenomena and yields were low at 642 and 466 kg/ha respectively.

The effectiveness of the herbicide applied at 0.4 l/ha pre-emergent and 0.36 l/ha post-emergent when the crop was 8-10 cm tall gave the best results compared to the other variants for all weed species present in the experiment. The lowest results were obtained at 0.18 and 0.36 l/ha when the herbicide was applied post-emergent when the chickpea was 16-18 cm tall.

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