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CHEMICAL CONTROL OF *PARTHENIUM HYSTEROPHORUS* L. AT DIFFERENT GROWTH STAGES IN NON-CROPPED AREA

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Abstract

Parthenium hysterophorus L., is a noxious annual weed rapidly spreading across the non-cropped areas of the Khyber Pakhtunkhwa (KP) province and elsewhere in Pakistan. Parthenium weed has attained the status of most frequently and densely occurring weed in Swabi, Mardan and Charsadda districts while it is present in Peshawar district in isolated infestations. Parthenium weed has become a major threat to grazing land, roadside, wasteland, wetland, as well as cultivated land in KP province. Field experiments were conducted to evaluate the efficacy of different herbicides against parthenium weed at different growth stages in non-cropped area of Charsadda District, KP-Pakistan during summer 2009 and 2010. The experiments were laid out in RCBD, replicated four times separately for each growth stage with ten treatments. Herbicides used in the experiments were Aatrax (atrazine) @ 1.0, Buctril Super 60 EC (bromoxynil+MCPA) @ 0.80, Round Up (glyphosate) @ 4.0, Dual Gold 960 EC (S-metolachlor) @ 1.92, 2,4-D @ 1.0, Sencor Extra (metribuzin) @ 2.0, Logran Extra 750 WG (triasulfuron+terbutryn) @ 0.30, Primextra Gold 720 SC (atrazine+s-metolachlor) @ 1.50 Stomp 330 EC (pendimethethalin) @ 1.50 kg a.i. ha^{-1} and a control. Statistical analysis of the data showed that different herbicidal treatments had significant effect on parthenium weed mortality. At rosette stage of parthenium weed herbicides treatments provided (32.5 to 89%) mortality at 2 weeks after treatment (WAT) and (42.5 to 96%) mortality at 4 WAT. Maximum parthenium weed mortality 96% and 87% were recorded in glyphosate and metribuzin treatments at 4 WAT at rosette stage. While 2,4-D, triasulfuron+terbutryn, bromoxynil+MCPA and atrazine+s-metolachlor gave 71-80% control of rosette parthenium weed at 4 WAT. The parthenium weed mortality of atrazine and s-metolachor were 56.5% and 57.5%. At bolting stage, herbicidal application gave 35-83.5% control at 2 WAT and 30-91% mortality at 4 WAT. The most effective treatments for parthenium weed control were glyphosate and metribuzin having 91% and 75% mortality at 4 WAT. While triasulfuron+terbutryn, bromoxynil+MCPA and atrazine+s-metolachlor gave 50- 61.5% control at 4 WAT. Weed mortality with atrazine, s-metolachlor and 2,4-D was 36.5, 41 and 43%, respectively. Pendimethalin was the least effective treatment for both growth stages. Overall, the efficacy of herbicides was promising on rosette parthenium plants than bolted plants.

Introduction

Biological invasions have almost in every type of native ecosystems and cause hundreds of biological extinctions throughout the world (Baillie *et al*., 2004; Anon., 2005). The current intensification and development of world trade system has strengthened a long-standing trend in the re-distribution of invasive alien species in general and parthenium weed in particular (McNeely *et al*., 2001; Perrings *et al*., 2005). The losses caused by weeds to agriculture worldwide have been estimated to be about $10^{10} annually. The losses estimated in Australia amount to about $3.3 billion per annum (Adkins & Navie, 2006). While in USA, the estimated losses due to invasive species amounts to more than US$ 138 billion annually (Pimentel *et al*., 2005) and approximately one-fourth of this is due to alien plant species. On an annual basis in the major crops alone, the losses caused by weeds in Pakistan exceed Rs.130 billion (Hassan & Marwat, 2001).

Parthenium hysterophorus L. an alien invasive weed is becoming a major weed of cropped and non-cropped areas in Pakistan (Adkins & Navie, 2006). Since the existing local weed flora is already a threat to the crop productivity, thus introduction of another alien species, like parthenium weed will further reduce the crop yield drastically and consequently increase the cost of production. Parthenium weed not only competes with desirable crops and pasture species but also causes farmers and stock animals to suffer an allergic skin condition while in contact with it (Chippendale & Panetta, 1994). Parts of parthenium weed plant are allelopathic, exhibiting strong competitive ability for soil moisture and nutrients while inhibiting the germination and growth of neighboring plant species (Adkins & Sowerby, 1996). In India, parthenium weed reduced yield up to 40% in several crops (Khosla & Sobti, 1981) and it was reported to reduce forage production by up to 90% (Nath, 1988). In India, parthenium weed is widely spread and infest about two million hectares of land (Dwivedi *et al.*, 2009). Parthanium is a serious problem in perennial grasslands in central Queensland (Adkins *et al*., 2001). Parthenium weed impedes pasture production by competing with beneficial forage plants; costing $109 million per year (Adamson, 1996). It is estimated to affect cropping systems to the tune of $10 million per year, given the $4 million impact to the sunflower crop. Parthenium weed is generally unpalatable, but cattle and sheep will eat it when feed is scarce. Consumption of large amounts will produce taints in mutton (Tudor *et al*., 1982).

Parthenium weed has infested almost all field crops, pastures, wastelands, yards, fencerows, and rights-of-ways and when left uncontrolled, it can reduce crop yields by 40 to 97% (Anon., 2004; Singh *et al*., 2004; Tamado & Milberg, 2004). Kohli *et al*., 2006 reported that it can badly impact agriculture, environment, human and animal health, and biodiversity and thus contribute to social and economic instability, placing constraints on sustainable development, economic growth, poverty alleviation and food security.

Similar estimates are not yet available for Pakistan, but enormous losses to crop and rangeland production have been observed. In addition farmers and livestock are known to suffer allergic skin and asthamatic reactions in

the parthenium weed infested areas. Parthenium weed now infests vast areas in the Punjab and Khyber Pakhtunkhwa and is likely to be in many other regions as it rapidly spreads by seed. This weed has been found in some of the most important rangelands (Swat & Pothohar valley) in the country as well as in fodder crops such as maize, sorghum, Persian clover and Egyptian clover (Hassan & Amin, 2009; Shabbir, 2006 and Shabbir & Bajwa, 2006a). Other reports also show parthenium weed to be threatening to infest other fodder and cereal crops, as well as vegetables like bitter gourd, gourd and melons as well as timber crops (Shabbir & Bajwa, 2006b). Parthenium weed is rapidly spreading in Pakistan and causing severe damage to the agriculture productivity of the country. Apart from these, allelopathic effects of parthenium are a major threat to the crop production in northwest Pakistan (Marwat *et al.,* 2008).

In non-cropped situations, various methods are being used to manage parthenium weed but manual removal is most prevalent in Pakistan. However, manual and mechanical methods for controlling parthenium weed are not effective (Muniappa *et al.,* 1980). Manual cutting results in rapid regeneration, which is quickly followed by flowering with abundant seed production (Dhawan & Dhawan, 1996). Besides this, manual control method is tedious, time consuming and expensive compared to chemical control. Successful control of *P. hysterophorus* has been achieved by several herbicides (Balyan *et al*., 1996). Control varies with herbicides, rates applied, and growth stage of weeds (Etheridge *et al*., 2001; Mueller & Womac, 1997). Tamado and Milberg (2004) reported in grain sorghum 2, 4-D provided variable control of *P. hysterophorus* and repeated applications were necessary. Parsons & Cuthbertson (1992) recommended the use of 2, 4-D in combination with atrazine. Singh *et al*., (2004) reported under a non-cropped situation 2,4-D, atrazine, atrazine plus 2, 4-D, metribuzin, metsulfuron, chlorimuron, and glufosinate failed to control *P. hysterophorus* while glyphosate at 2.7 and 5.4 kg ha^{-1} provided greater than 90% control when rated 18 weeks after treatment. New herbicide formulations need investigation for efficient and economic control of parthenium weed in non-cropped areas, fallow fields, pathways and along the water channels without posing any residual impact.

Due to recent introduction of parthenium; no field trials under non-cropped conditions were conducted to assess different herbicide against parthenium in Khyber Pakhtunkhwa province. The objectives of these experiments were to identify the most susceptible growth stage of parthenium weed to herbicides in non-cropped area and to screen out the most suitable herbicide for parthenium weed control in non-cropped areas.

Materials and Methods

Field experiments were conducted to assess the efficacy of different herbicides against parthenium weed (*Parthenium hysterophorus* L.) at different growth stages in non-cropped area of Charsadda District, Khyber Pakhtunkhwa, Pakistan during summer 2009 and 2010. The experiments were laid out in Randomized Complete Block (RCB) design, with a split plot arrangement, replicated 4 times. Herbicides used in the experiments were Aatrax (atrazine) @ 1.0, Buctril Super (bromoxynil+MCPA) @ 0.80, Round up (glyphosate) @ 4.0, Dual gold (s-metolachlor) @ 1.92, 2, 4-D @ 1.0, Sencor (metribuzin) @ 2.0, Logran Extra (triasulfuron+terbutryn) @ 0.30, Primextra Gold 720 SC (atrazine+S-metolachlor) @ 1.50, Stomp 330 E (pendimethethalin) @ 1.50kg. a.i. ha^{-1} and a no-herbicide control (Table 1).

Table 1. Details of herbicides treatments used in the experiments during 2009-10.

S. No.	Treatments	Common name	Rate (kg.a.i.ha^{-1})
1.	Aatrax	Atrazine	1.0
2.	Buctril Super 60 EC	bromoxynil+MCPA	0.80
3.	Round Up	Glyphosate	4.0
4.	Dual Gold 960 EC	S-metolachlor	1.92
5.	2,4-D	2,4-dichlorophenoxyacedic acid	1.0
6.	Sencor Extra	Metribuzin	2.0
7.	Logran Extra 750 WG	triasulfuron + terbutryn	0.30
8.	Primextra Gold 720 SC	atrazine + S-metolachlor	1.50
9.	Stomp 330 E	Pendimethethalin	1.50
10.	Control (Non-Treated)	----	------

Recommended doses of herbicides were applied on May 15, 2009 and May 20, 2010 at rosette growth stage and on June 5, 2009 and June 12, 2010 at bolted growth stage of parthenium weed (Table 2). The size of each experimental unit was 2x5m. A knapsack hand sprayer with 4 "T" jet nozzles fitted at a distance of 45cm between nozzles were used. Water at 200 L ha^{-1} was used as carrier at 40 Ibs psi after proper calibration. While, spraying the herbicides, all the precautionary measures were followed to avoid any uneven spray. Weedy check (untreated control) was also included for comparison. During the course of studies the data on parthenium weed mortality were recorded based on visual rating through reduction in plant population and plant vigor at 2 and 4 WAT (weeks after treatment). Scale of 1-5 was used for recording parthenium weeds mortality (%), where 1= 0-20, 2=20-40, 3=40-60, 4=60-80 and 5=80-100% parthenium weed mortality caused by the herbicidal application. Plants were monitored for six months after death to scrutinize regeneration of parthenium weed. Standard procedures were adopted for recording the data on the above parameters. Data was subjected to analysis of variance and means were separated using Fisher's protected LSD test at 5% level of significance (Anon., 2006).

Table 2. Parthenium weed density and size at the time of herbicide application at Charsadda District in 2009-2010.

Growth stage	Density (weeds m^{-2})	Plant diameter (cm)	Plant height (cm)	No. Leaves ($plants^{-1}$)	Flowering
Rosette	15-25	6-30	2-6	4-9	No
Bolted	12-20	25-70	56-96	23-28	Yes

Description and agro-ecological conditions of experimental site: The experimental site was an overgrazed native pasture that was destocked after it had been dominated by parthenium weed near to the Charsadda Sugar Mills, Charsadda, Khyber Pakhtunkhwa Province-Pakistan. This site is located at 71°45'44.56" east longitude and 34° 8'29.37" north latitude and at an elevation of 996 ft. Charsadda is 17 miles from Peshawar located in the west of the Khyber Pakhtunkhwa and is bounded by Malakand district on the north. Mardan district on the east, Nowshera and Peshawar district to the south and the Mohmand agency of the federally administrated tribal area on the west. This district has the most fertile lands in Khyber Pakhtunkhwa. The main crops of Charsadda are tobacco, sugarcane, sugar beet, wheat and maize. Vegetables include potato, tomato, cabbage, aubergens, okra and spinach. Among orchards, apricot, citrus, plum, strawberry and pears are noteworthy. The total area of the district is about 996 square kilometer (243753 acres). Average temperature during summer is 33-35ºC and averaged rainfall is usually 70cm. The experiments were conducted on a normal clay loam soil having pH 6.75, OM content 0.95%, $CaCO_3$ equivalent 0.60%, TSS 0.015%, N 0.047%, P 7.55 ppm and K 384 ppm (Anon., 2009)

Results and Discussion

Parthenium weed control at rosette stage: The statistical analysis of the data showed that different herbicidal treatments had significant effect on parthenium weed mortality in non-cropped conditions. The herbicidal treatments provided 32.5 to 89% mortality at 2 WAT and 42.5 to 96% mortality at 4 WAT (Fig. 1). The results exhibited that maximum weeds mortality (96%) at 4 WAT was recorded in glyphosate which was followed by metribuzin treated plots scoring 87% mortality. Parthenium sprayed with glyphosate started getting pale from the day after spraying and complete mortality achieved after one week. All the plants were observed for regeneration but there was no regeneration in glyphosate and metribuzin treatments. Our findings are in line with Balyan *et al*., (1998). Krishna *et al*., (2007) affirmed that at rosette stage, glyphosate provided greater than 93% control of parthenium weed at 3 WAT. Acifluorfen, bentazon, glyphosate, imazaquin, and metribuzin applied post emergence to plants less than 7.5 cm tall controlled greater than 80% parthenium weed (Tyson & Bryan, 1987).

While 2, 4-D, triasulfuron + terbutryn, bromoxynil + MCPA and atrazine + s-metolachlor give 71-80% control of parthenium weed at 4 weeks after treatment (WAT). In our study the control of rosette parthenium weed with bromoxynil+MCPA (57 to 79%) was similar to the control of parthenium weed in grain sorghum with bromoxynil to the extent of 47 to 82% (Rosales-Robles *et al.*, 2005). The parthenium weed mortality of atrazine and s-metolachor were statistically at par with each other. The respective values were 56.5% and 57.5%. Pendimethalin was the least effective treatment giving minimum (42.5%) mortality of parthenium weed at 4 WAT. The least efficacy may be due to the fact that pendimethalin is generally used as pre-emergence herbicides. The instant results suggest that glyphosate being cheaper, easily available in the market and comparatively safer for the environment is the best option for growers in the area under discussion. As infestation is on large scale therefore other methods of weed control seems to be uneconomical and difficult for the poor farmers. Although other option of parthanium management are feasible but those are of long term and needs proper execution. While the farmers in our country are poor, illiterate and of low economic status therefore chemical control seems to be the best option as *P. hysterophorus* is among major weed in Rawalpindi and Punjab and is spreading very fast (Qureshi *et al.*, 2011; Javaid *et al.*, 2010).

Parthenium weed control at bolted stage: In non-cropped conditions at bolted stage of parthenium, the herbicides treatments provided 35 to 83.5% mortality at 2 WAT and 30 to 91% mortality at 4 WAT (Fig. 2). The results revealed that the most effective treatments for parthenium weed control were glyphosate (91%) followed by metribuzin (75%) at 4 WAT. Krishna *et al*., (2007) stated that at bolted stage, glyphosate, glufosinate, and trifloxysulfuron controlled 86 to 95 % parthenium weed.

While, triasulfuron+terbutryn, bromoxynil+MCPA and atrazine+s-metolachlor gave (50 to 61.5%) control of parthenium weed at 4 WAT. The parthenium weed mortality of atrazine, s-metolachlor and 2, 4-D was statistically comparable with each other. The respective values were 36.5%, 41% and 43%. Mishra & Bhan (1995) and Muniappa *et al.*, (1980) claimed that atrazine up to 2.0 kg ha^{-1} failed to provide satisfactory control of mature parthenium weed. Whereas in our study, atrazine at 1.0kg. a. i. ha^{-1} controlled (36.5-56.5%) of parthenium weed, which are also not promising. Mishra & Bhan (1995) stated that 2,4-D ester at 1.5 kg ha^{-1} or glyphosate at 1.0kg ha^{-1} controlled 30cm tall parthenium weed 96 to 100% at 4 WAT. But in our findings, 2, 4-D at 1.0kg a.i. ha^{-1} only controlled 43% of tall parthenium weed. Pendimethalin was the least effective treatment and minimum 30% mortality of blotted parthenium weed was recorded at 4 WAT.

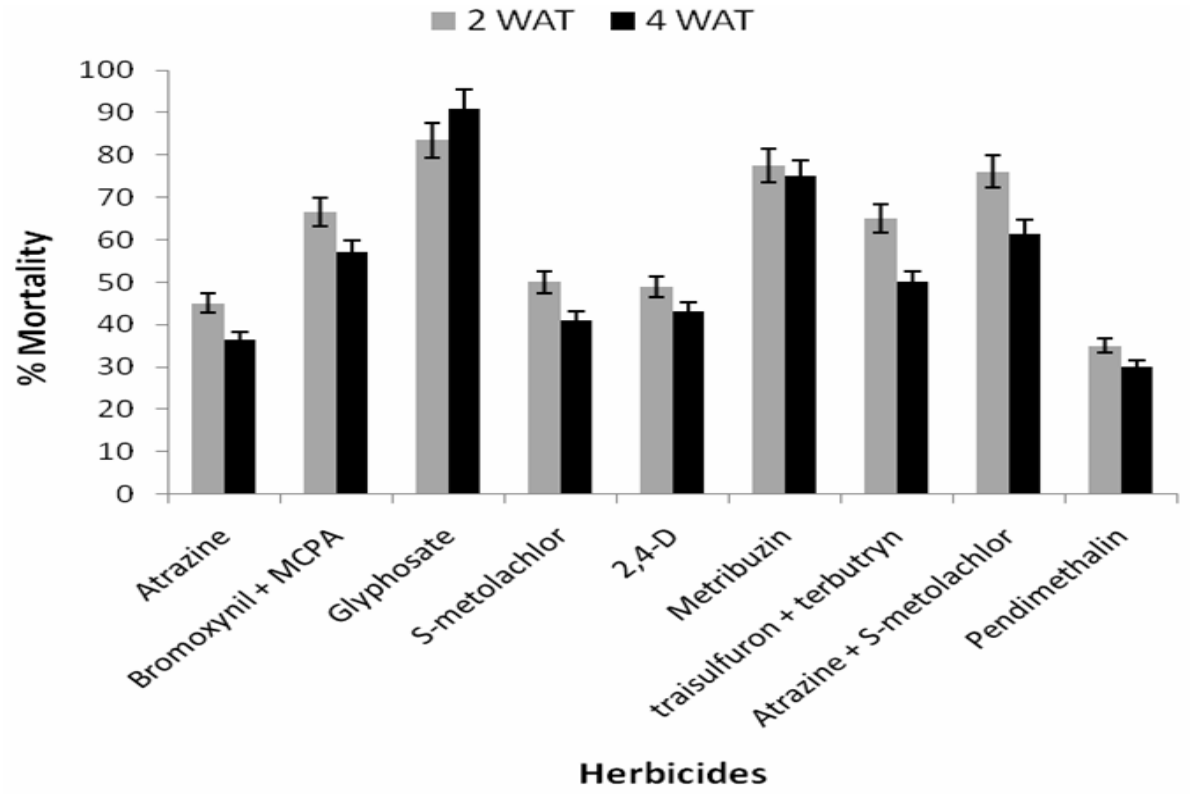

Fig. 1. Parthenium weed control at rosette stage with different herbicidal application at 2 and 4 WAT in non-cropped area of Charsadda District in 2009-2010.

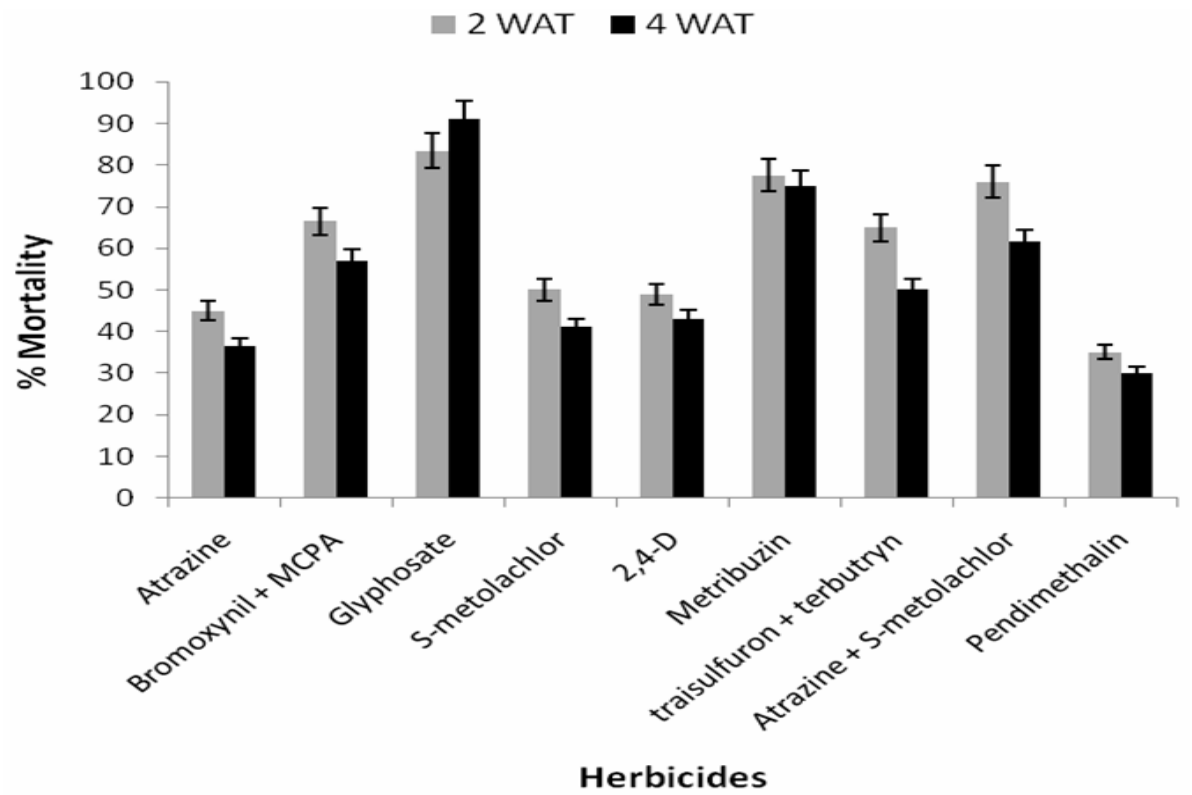

Fig. 2. Parthenium weed control at bolted stage with different herbicidal application at 2 and 4 WAT in non-cropped area of Charsadda District in 2009-2010.

The results indicated that well grown plants of parthenium weed can effectively be controlled with glyphosate. Other herbicides used in the study did not provide satisfactory control when applied to bolted stage, even high rates of herbicides failed to control. Our findings are supported by Singh *et al*., (2004) who reported that 2,4-D, atrazine, metribuzin, metsulfuron, chlorimuron, and glufosinate failed to control parthenium weed while glyphosate at 2.7 and 5.4 kg ha^{-1} provided greater than 95% control of bolted plants at 18 WAT. Walia *et al*., (2002) reported that other herbicides with the exception of glyphosate applied to well established parthenium weed plants did not provide satisfactory control. The parthenium weed mortality was due to phytotoxic effect of herbicides against parthenium weed. Some variation in parthenium weed control with herbicides treatments were recorded in 2009 compared to 2010. This may have been partly due to differences in weather conditions between the years.

Conclusion and Recommendation: In wasteland, non-cropped areas, along railway tracks, water channels and roadsides, the use of glyphosate and metribuzin has been shown promising results. The stage/time of parthenium weed for herbicidal control is important therefore parthenium weed should be treated at rosette stage. In light of the results the following conclusion and recommendations are suggested. Parthenium weed control at rosette stage was highest with glyphosate (96%) followed by metribuzin 87% at 4 weeks after treatment (WAT) and control was lowest with pendimethalin (42.5%) at 4 WAT. The results indicated that parthenium weed can effectively be controlled with glyphosate while other herbicides used in the study did not provide satisfactory control when applied at bolted stage. Parthenium weed is highly sensitive to amino acid synthesis and photosynthesis inhibitors compared to herbicides with other modes of action. In light of the instant studies, glyphosate and metribuzin are recommended for the control of parthenium weed in non-cropped area of Pakistan. It is recommended that spread of parthenium weed should be prevented to avoid its ill effects on the crop production, environment and human health.

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