Original Research Article

Study of effect of Water Harvesting Techniques (Holes and Crescents) on growth of Sidr (*Ziziphus Spina-Christi*) In South Omdurman Area, Khartoum State, Sudan

Abstract

This study was conducted at south west Omdurman area, Khartoum state, Sudan, following a complete randomized block design. The objective of the present investigation is to study the effect of two water harvesting techniques (Holes- T_1 and Crescents- T_2) in comparison with the control (C) on the growth parameters of *Ziziphus spina-christi* and soil moisture content. The growth parameters of *Ziziphus spina-christi* were measured at three weeks interval, the soil moisture content was measured before and after rains through the rain season from June to October. The results indicated that the both water harvesting techniques have a positive influence on the plant (Sidr) growth parameters compared to the control (C). The T_1 showed better improvement on plant (Sidr) growth parameters compared to the T2 water harvesting technique wtich resulted in increase of 15.1% in soil moisture content, 3.3% in plant length, 9.1% in number of leaves per plant and 5.1% in plant stem diameter. Holes type of water harvesting technique were recorded higher values of moisture content, Ziziphus spina-christi tree species is highly recommended in the west Omdurman area.

Key Words: Water Harvesting Techniques, Holes and Crescents, Sidr, soil moisture content, porosity, field capacity, infiltration rate.

INTRODUCTION:

Water conservation is one of the main challenges of agriculture, especially in rainfed areas. In arid and semi- arid regions, the distribution of rainfall is wobbling throughout the rainy season in term of quantity and duration time which makes rain fed agriculture a very risky. According to the United nation (2003) water resources steadily decline because of population growth, pollution and expected climate change due to the problem of global warming.

"Water crisis is getting more attention among all countries specially the developing ones. Therefore, new strategies and techniques to deal with water problems are highly needed. Water harvesting (WH) and spreading techniques succeeded to providing a feasible solution for improving the living conditions of many millions of people facing serious water supply problems" Shaker (2019).

"The WH is being practiced wider areas across the Sudan both in the low rainfall and high rainfall Savanna regions in traditional agriculture, the human and animal use, as well as the forest production in places having rainfall starting from 75 mm per annum. WH practices are actually found in most of the states in Sudan. The effectiveness and efficiency of WH practices depend on factors such as soil type, rainfall, and crop" Dawelbeit (2008).

According to Gould, (1999), Stoh, (2001) and Fentar *et al*, (2002) they "defined WH as the collection and concentration of runoff for productive purposes as crop, fodder, pasture or trees production, livestock and domestic water supply in arid and semi-arid regions. For agricultural purpose, it is defined as a method for inducing, collecting, storing and conserving local surface runoff in arid and semi-arid regions".

Generally, water harvesting (WHT) "techniques classified into two groups: micro and macro techniques. Micro-catchment methods also may be called on-farm systems" (Oweis, 2001).

"Some of the most important purposes of using soil moisture conservation techniques, that it used as measures for achieving greater water use efficiency to enhance plant growth and produce more food with less water" (kumawat *et al*. 2020). WHT, is also used to increase the period of moisture content in plant root zone after WH (Kumari and Singh, 2016), conserve the soil from erosion, moisture deficit and loss of fertility (Saeed et al., 2019), to increase the survival rate of seedlings (Abedi-Koupai and Asadkazemi, 2006), and reduce water losses by runoff and evaporation while maximizing soil moisture storage for crop production (Gachene *et al*., 2019). "Many rainwater harvesting structures are used to conserve soil and water in degraded lands, research findings have shown variability in their electiveness for plant growth, biomass production, restoration of degraded lands", etc. (Siyum *et al* 2019; Derib, S.D 2009). Gebru, *et al*., (2019) "stated that the moisture harvesting structures shows great potential in increasing tree survival and growth performance due to helping to harvest rainwater and protecting them".
The present study was undertaken, to compare two different water harvesting techniques and the control on the basis of soil moisture content (SMC), promote the growth of an indigenous tree species (*Ziziphus spina-christi*) and to examine the viability to improv the physical condition of the soil.

MATERIALS AND METHODS

- **Site location:**

This study was conducted at Khartoum New International Airport (KNIA) in the south western direction of Omdurman, Khartoum State at 15˚ 13́ N Latitude and 32˚ 19́ E Longitude, at a distance of about 40 km South of Khartoum center and 25 km west of the White Nile River.

- **Rainfall:**

The rainy season normally falls between July and September each year and the annual average rainfall is about 150 mm. Rains usually commence with relatively light showers but the effective rainy season starts in late June, increases in July and reaches its peak in August.

- **Topography:**

The topography of the study area is generally fairly flat but few isolated ridges and sand dunes may be observed in the western part of the site and the ground surface slopes gently to the east. The generally flat area of the site is confined by two wadies (shallow and relatively wide water course valleys).

- **Vegetation:**

"Vegetation cover is dominated by poor desert and semi desert type with different distribution. Generally, the vegetation is dominated by some trees species of Acacias such as *Acasia tortilis* (sayal), *Acacia ehrenbergiana* (salm) and *Ziziphus spina-christi* (sidir), some bushes and some grasses included *Aristida plumosa* (Gabash), *Aristida mutabilis* (Gaw) and *Cassia senna* (sena kalib)" Sona (2016).

- **Climate:**

According to (Van der Kevie, 1973), "the climate of study area is semi-desert to dry it is hot, dry and rainy during summer and cold dry in winter. rainfall during July and August. The average annual rainfall is 150 mm/year and the dry season covers 8-9 months. the daily average maximum temperature $37.7^{O}C$ while the daily an average minimum temperature $21.6C^{O}$. The daily evaporation rate is 7.7mm and the highest rate take place in April with average of 9.3mm. The daily mean of relative humidity is 38 6 at am and 21 at 2pm, while the mean wind speed is about 9 miles/hr".

- **Soil:**

"The area is covered by a light brown and very thin gravely sand layer (about 10mm thick), and few angular to sub-angular, 20 to 60mm sized fragments of the ferruginous sandstone. The southern part of the site is covered by sandy gravel probably formed due to the weathering of Nubian Group rocks which are outcropping in some places in the area. Cracks developed when the soil dries up by the end of the rainy season. Early rains penetrated into the soil through these cracks before they close. Runoff usually occurs due to heavy rains" (Sona, 2016).

- **Experimental treatments:**

The experiment included two water harvesting techniques which were constructed before the onset of the rainy season; each treatment was represented by a block which included the plant species. Two types of water harvesting techniques were designed as follows

(a) Holes (Deep pits) technique (HT):

Each hole was 2.5 m in width, 4 m in length and 50 cm deep. The distance between holes in the row was 10 meters while the distance between rows was also 10 meters. The slope direction was made from the upper side to trap the sheet flow run-off after rain storms.

(b) Crescents or curved terraces technique (CT):

The diameter of crescent was 30 meters and 50 cm deep. The crescents are 15 m apart

(c) control

Seedlings:

The seedlings were raised in nursery to be about three months old when transplanted at the onset of the rainy season in July to give the seedlings the full benefit of the rainy season.

Planting:

The planting was performed by using holes sides and crescents. In holes the seedlings were placed at the side and the root zone was covered with fine soil. In crescents plot the seedlings were planted half way of the inner side of terrace as Shown in Plate 1 and 2.

Plant parameters measurements:

The following parameters were taken every three weeks starting from planting.

1. **Plant height (cm):**
   Three plants were chosen at random from each treatment. Plant height for each plant was taken from the base of the plant to the top by using a metering device. The mean height of the three plants was recorded.
2. **Number of leaves per plant:**
   Three plants were taken at random from each treatment so as to account the number of leaves per plant, and the mean number of the leaves of the three plants was recorded.
3. **Stem diameter:**
   Three plants chosen at random from each treatment. Stem diameter was measured using a Vernia. The mean stem diameter of the three plants was recorded.

- **Equipment:**

The following equipment were used in the experiments:

1- A Loader was used construct the rain water harvesting structures.
2- Metering tab.
3- A vernier.

- **Soil moisture content (%)**

Soil samples were taken from three depths, 0-30, 30-60, and 60-90 cm at three locations by using the auger. Sampling was collected every month during the experiment in two seasons. Soil samples were weighed fresh and reweighed after oven dried at 105Cº for 24 hours.

$$\text{Soil moisture content\%} = \frac{\text{Soil fresh mass (g) - soil oven dry mass (g)}}{\text{Oven dry mass (g)}}$$

Where: wt = the sample weight in gm.

3.11 Statistical analysis:

Data for each trial were analyzed by as adopting ANOVA for as Complete Randomized Block Design (C.R.B.D) through standard analysis of variance techniques. Mean significant ($p \leq 0.05$) treatments were separated using Duncan's Multiple Range Test procedure (Steel and Torrie, (1980).

Plate (1) Planting of seedlings in Holes	Plate (2) Planting of seedlings in crescents

RESULTS AND DISCUSSION:

1. plant height

The result of plant height of tree shown in Figure.1 and Table 1. Analysis of variance for plant height at different time intervals under the treatments indicated no significant difference ($p \geq 0.05$) for all the readings. The T_1 recorded the significantly best plant height in the 1^{st}, 2^{nd}, 3^{rd} on par with the 4^{th} readings while the treatment T_2 recorded significantly best height in the 5^{th}, to 9^{th} readings. This is probably due to the high evaporation rate from T_2 and soil moisture content in the T_1.

When the compare result of the two treatments along with the control there is significant difference ($p \geq 0.05$) for all readings between treatments and control

This result agrees with Muhsen (2021) and Sona (2016) how reported the effect of water harvesting techniques on plant growth result of shoot length for the three trees species, showed no significant difference. For all the readings the best height was given by *Acacia senegal* flowed by *Ziziphus spina christi* and *Acacia tortilis subsp. raddiana*.

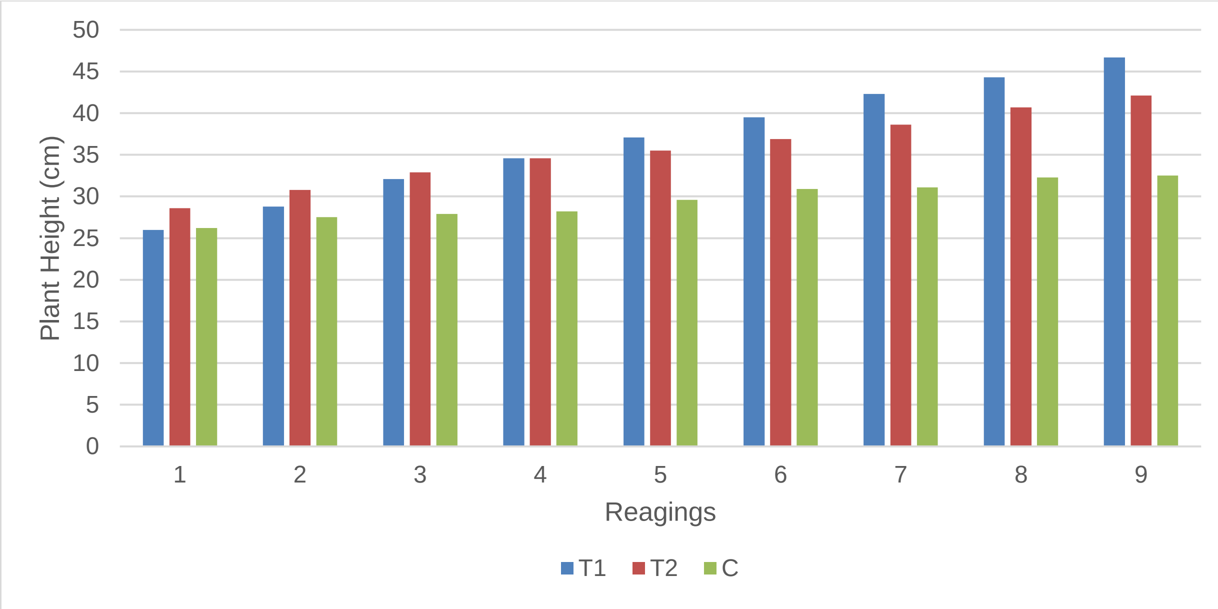

Fig.1: Plant height measurements

Table.1. Means of Plant height (cm)

Treatment / Readings	T_1	T_2	C
1	26	28.6	26.2
2	28.8	30.8	27.5
3	32.1	32.9	27.9
4	34.6	34.6	28.2
5	37.1	35.5	29.6
6	39.5	36.9	30.9
7	42.3	38.6	31.1
8	44.3	40.7	32.3
9	46.7	42.1	32.5

2. The effect of the experimental treatments on number of leaves per plant:

The on means data for number of leaves is shown in Fig. 2 and Table 2. For Analyses of variance for number of leaves for different time intervals.

The analysis of variance for number of leaves showed in Tables (2) for the two treatments. The results showed no significant difference ($p \geq 0.05$) for all readings. This result agreed with the results obtained by Natheer, et al, 2017 and Sona (2016)

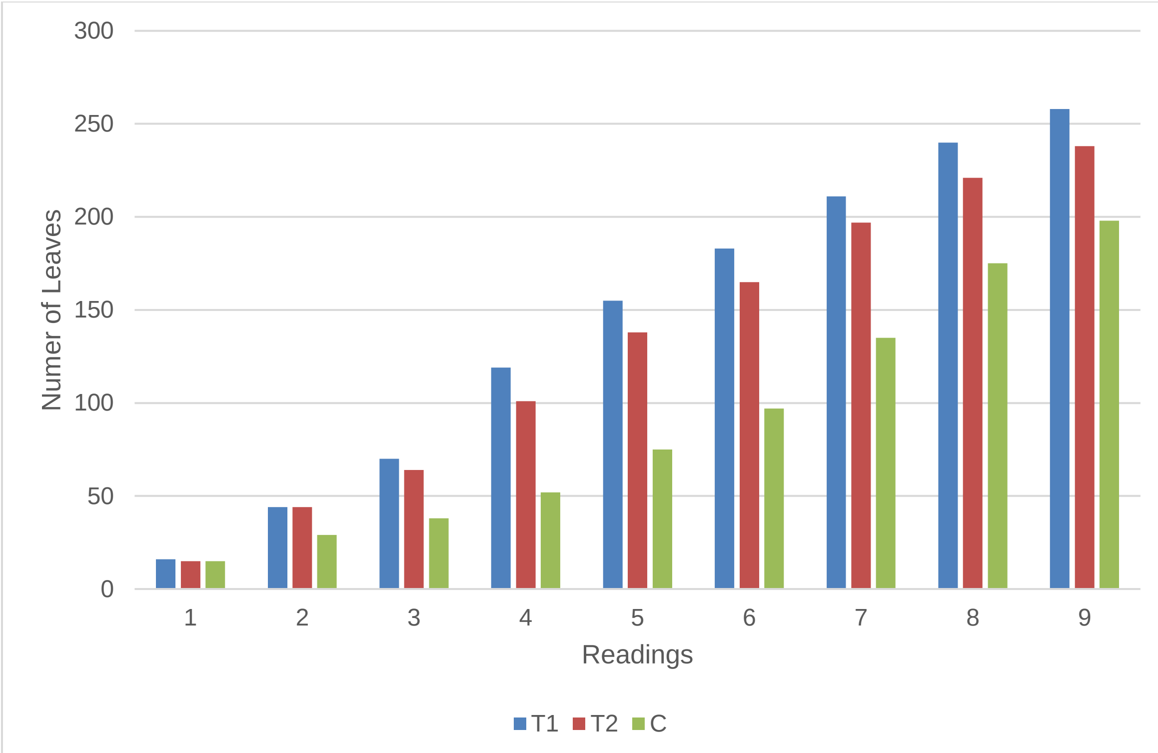

Fig.2: Number of leaves per plant measurements

Table.2. Mean on the Number of leaves per plant

Treatment / Readings	T_1	T_2	C
1	16	15	15
2	44	44	29
3	70	64	38
4	119	101	52
5	155	138	75
6	183	165	97
7	211	197	135
8	240	221	175
9	258	238	198

3. The effect of the experimental treatments on the stem diameter

one of the main important parameters that indicates the influence of the examined treatments on plants is stem diameter. The data of the stem diameter were shown in Fig. 3 and Table 3 Analysis of variance for stem diameter for different time intervals, The analysis of variance for stem diameter in the two treatments showed no significant difference ($p \geq 0.05$) for all readings. Generally, the results obtained for one location showed no significant difference among the treatments while Hamid (2004) recorded significant difference ($p \geq 0.05$) among treatments in three different locations.

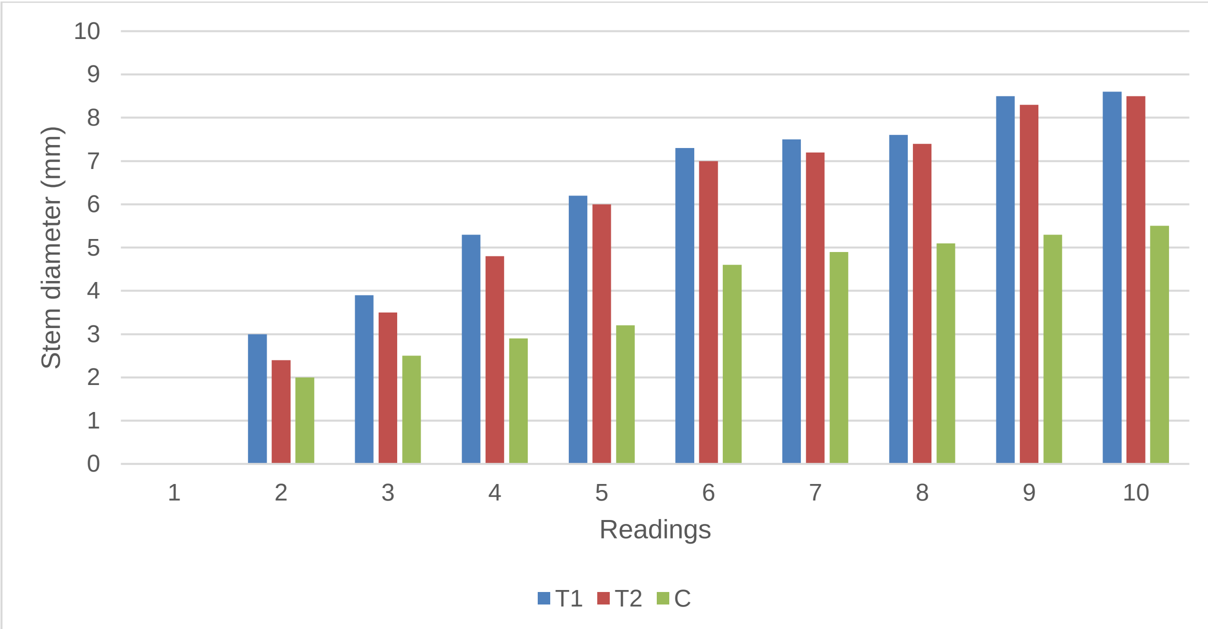

Fig.3: Stem diameter measurements

Table.3. Means of stem diameter (mm)

Treatment / Readings	T_1	T_2	C
1	3	2.4	2
2	3.9	3.5	2.5
3	5.3	4.8	2.9
4	6.2	6	3.2
5	7.3	7	4.6
6	7.5	7.2	4.9
7	7.6	7.4	5.1
8	8.5	8.3	5.3
9	8.6	8.5	5.5

The effect of the experimental treatments on soil moisture content

The moisture contents of the soil before and after rain for different depths are shown in Fig 4 and Table 4. The analysis of variance for the soil moisture content for different depths and different time intervals for the two different treatments in the 1st reading before the rain showed a significant difference ($p \leq 0.05$) for depth (60-90), while the 2nd and 3rd reading for depth (0-30)cm and (60-90)cm, respectively after the rain showed a significant difference($p \leq 0.05$) existed among the treatments. There was no significant difference ($p \geq 0.05$) for 4th, 5th, 6th, 7th, 8th and 9th readings showed for all depths. This result agreed with the results obtained by Azmi, *et al* (2015) who reported that all water harvesting techniques increased soil moisture content significantly, Sahar (2013) and Shiferaw *et* al (2020) he was mentioned that the use of water harvesting structures within land degradation projects shows both rise of soil moisture as well as an increase in biomass production of set species

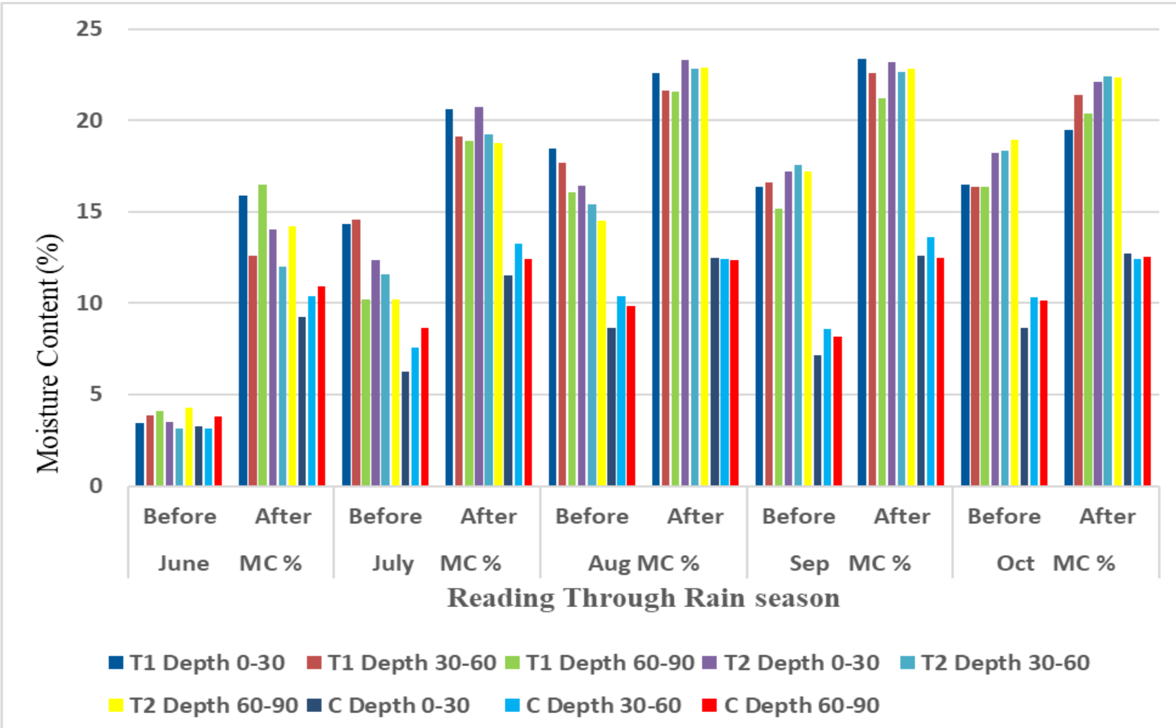

Fig.4: Soil moisture content (SMC) measurement (%)

Table 4 Soil moisture content (SMC) measurement (%)

Treatment	Depth/ cm	June MC %		July MC %		Aug MC %		Sep MC %		Oct MC %	
		1	2	1	2	1	2	1	2	1	2
T_1 Holes	0 - 30	3.45	15.89	14.36	20.6	18.46	22.6	16.4	23.4	16.5	19.5
	30 - 60	3.89	12.6	14.6	19.12	17.7	21.67	16.6	22.6	16.4	21.4
	60 - 90	4.12	16.52	10.2	18.86	16.1	21.56	15.2	21.2	16.4	20.4
T_2 Crescents	0 - 30	3.50	14.06	12.36	20.75	16.45	23.34	17.22	23.22	18.22	22.15
	30 - 60	3.14	12.00	11.6	19.25	15.4	22.83	17.60	22.69	18.38	22.40
	60 - 90	4.28	14.22	10.2	18.78	14.5	22.92	17.2	22.84	18.93	22.35
Control (C)	0 - 30	3.25	14.23	10.20	16.26	9.69	15.20	8.28	15.20	10.13	14.30
	30 - 60	3.50	13.32	10.25	18.30	9.20	15.30	8.25	16.36	10.42	13.48
	60 - 90	4.43	13.50	10.52	18.45	10.40	16.40	8.55	16.52	11.60	13.51

CONCLUSION

On the basis of the present experiment, there was no significant difference observed on the plant growth parameters (number of leaves per plant, plant length and stem diameter) in any location due to water harvesting technique. The holes and crescents water harvesting techniques improved soil moisture content significantly. Higher values of soil moisture content were recorded for the holes type of water harvesting technique as compared to the crescents type. The *Ziziphus spina-christi* tree species is highly recommended in the west Omdurman area. We recommend future studies to carry out research experiments on different water harvesting techniques in the area

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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