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Response of Some Staple Crops (Maize and Wheat) to Irrigation Scheduling in Maiduguri

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Abstract: *This study investigated the response of maize and wheat crops to irrigation scheduling techniques in Maiduguri, a semi-arid region in northern Nigeria. The experiments were conducted at the Teaching and Research Farm of Ramat Polytechnic, using four irrigation scheduling techniques based on cumulative pan evaporation (CPE) at trigger levels of 20 mm, 30 mm, and 40 mm, and a fixed irrigation interval of four days. The treatments were applied to 2.0 m x 2.0 m plots in a Randomized Complete Block Design (RCBD) with three replications. Crop water use was calculated using the crop evapotranspiration (ETc) method, with irrigation depths determined by the crop's water requirement. Results showed significant effects of irrigation scheduling on crop growth parameters such as plant height, stem girth, and leaf length and width. The highest values for most growth parameters were observed in the control plot (FM1), followed by M1 and M2 treatments. The least values were recorded in the M3 treatment. Similarly, the yield and yield parameters, including cob length, cob weight, and 1000 seed weight, were significantly influenced by irrigation scheduling, with FM1 yielding the highest results. The experimental data were analyzed using Analysis of Variance (ANOVA), revealing significant differences among treatments in terms of evapotranspiration and crop performance. This study provides valuable insights into the optimal irrigation scheduling for enhancing crop growth and yield in semi-arid regions like Maiduguri.*

Keyword: *Irrigation Scheduling; Maize and Wheat; Crop Yield; and Evapotranspiration*

1.0 INTRODUCTION

1.1 Irrigation

Increasing pressure on water resources, coupled with degrading environmental conditions such as water quality issues, salinization, and waterlogging, presents significant challenges to improving irrigation efficiency for sustainable food production (Tal, 2016; Zhang et al., 2015). Globally, approximately 70%, 20%, and 10% of annual water withdrawals are allocated to agriculture, industries, and domestic sectors, respectively (Bekchanov et al., 2015; Food and Agricultural Organization [FAO], 2014). As the global population and standards of living continue to rise, the demand for water in the domestic and industrial sectors also increases, leading to a declining share of water allocated to agriculture (International Water Management Institute

[IWMI], 2015; Kumar et al., 2011). Relying solely on more intensive irrigation use would exacerbate water scarcity in many parts of the world (Springer & Duchin, 2014; et al., 2016). Consequently, the irrigation sector must adapt by producing more food with less water, improving the performance of existing irrigation systems (Zhang et al., 2015). Irrigation is an agricultural practice designed to supplement water from precipitation and groundwater, providing the necessary quantity of water at the right time to maintain optimal soil moisture levels for crop production (Zwart & Bastianssen, 2004; Nagy, 2008). Vaughan et al. (2007) define irrigation as the artificial application of water to crops, allowing farming in arid regions and mitigating drought effects in semi-arid areas, even where seasonal rainfall is sufficient. The irrigation water balance encompasses evaporation losses from both the soil and the crop (evapotranspiration), alongside losses from water distribution to the land (Fereres & Rabanales, 2007). The method of replenishing soil water deficits through irrigation is referred to as an irrigation method (Drastig et al., 2016), which can be broadly classified into surface (border, basin, furrow, and wild flooding), sprinkler, trickle, and sub-irrigation systems, each with different application efficiencies (Adeniji, 1992; Ali, 2011). The choice of irrigation method depends on factors such as crop type, soil properties, topography, and water availability and quality, with system efficiencies varying based on design, management, and operation (Holzapfel et al., 2009).

Irrigation is vital for avoiding water deficits that can reduce crop yields. It also plays a significant role in building resilience to climate variability and ensuring food security (Liang et al., 2016; Fereres & Rabanales, 2007). As a fundamental part of global food production, irrigation helps guarantee crop yields and provides economic stability to farmers and communities. Drastig et al. (2016) describe irrigation as one of the most effective means of securing farmers' income. Beyond its primary purpose, irrigation can also facilitate the application of fertilizers, pesticides, herbicides, and defoliants, as well as cooling crops, dissolving hard pans, and leaching salts from the root zone. Over the years, irrigation has significantly contributed to stabilizing food production and prices (Rosegrant et al., 2002). Efficiency in irrigation can be improved through strategic irrigation scheduling, ensuring water is applied when and where needed to minimize yield reduction from water shortages and excessive percolation (Evans et al., 1996). Irrigation scheduling involves determining the amount and timing of water application, influenced by factors such as crop water needs (evapotranspiration), water availability, and soil water holding capacity (Mohamed & Makki, 2005). For optimal irrigation scheduling, it is essential to understand soil water status, crop water requirements, and potential yield reductions under water stress to maximize profits and optimize water and energy use (Zegbe et al., 2003; Kang et al., 2002). Irrigation scheduling approaches range from simple calendars (Hill & Allen, 1996; Van der et al., 1996) to advanced computerized models (de Jager & Kennedy, 1996; Hoffman et al., 1990). Proper scheduling is critical for achieving optimal crop yields and ensuring efficient water use, potentially saving up to 20% of irrigation water (George et al., 2000; Mannini et al., 2013). Simulation approaches for irrigation scheduling allow for assessing crop water requirements, improving irrigation management practices, evaluating the impact of water stress on yields, and identifying water-saving, environmentally friendly practices (Popova & Kercheva, 2004; Geerts et al., 2010; Popova & Pereira, 2011). Improving irrigation scheduling is an essential management practice to enhance irrigation efficiency (Evans et al., 1996). Cereal crops, such as maize, are widely consumed and provide essential raw materials for feed mills and beverage industries. The sustainable production of maize promotes food security, job creation, increased income, and foreign exchange. Maize thrives in Northern Nigeria, where it is irrigated or rain-fed with annual rainfall between 600 and 900mm and a temperature range of 20°C to 25°C. It is the third most important cereal globally, after rice and wheat, and is used for human and animal consumption. In 2014, global maize production reached 823 million tons, with Africa contributing 53.4 million tons, and Nigeria producing 7.5 million tons (FAO, 2014). Despite a 5.46% annual growth in maize production in Nigeria, demand continues to outpace supply, indicating the need for increased production (Ado et al., 2007). Maize serves various purposes, including food, biofuel production, industrial raw materials, and forage (Babaji et al., 2007; Hussein et al., 2011; Mani et al., 1998, 2006a, 2006b; Shaib et al., 1997). The aim of this study is to determine the appropriate irrigation scheduling technique for optimizing maize production in Maiduguri, Nigeria

2.0 MATERIALS AND METHOD

2.1 Experiment Site

Field experiments was conducted at the Teaching and Research Farm, of Ramat Polytechnic, Maiduguri, in the semi-arid region of northern Nigeria. The site lies between latitude 11^05 N and longitude 13^009E (Kyari et al 2014). The area lies within Lake Chad Basin formation and about 335m above sea level. The climate of the area is semi-arid region or tropical grasslands vegetation which is known for its dryness. The area has a long dry season of 6 to 7 months spanning from November to March and a short wet season that last for about four months (July to October). The area has high temperatures which range from 20-43^{o}C with average annual precipitation 640mm. The hottest months are usually April and May, while the cold and the dry periods of haematin are from November to January. The texture of the soil is mostly sandy loam (Arku, 2011). The area is highly susceptible to drought with relative humidity of 13% and 65% in dry and rainy season respectively (Bashir 2014). Also the area is vulnerable to desertification (Dibal, 2002).

2.2 Treatment and experimental design

The experimental design for this study involves a single factor of irrigation scheduling techniques, with four levels of variation. These include cumulative pan evaporation (CPE)-based scheduling at trigger levels of 20 mm, 30 mm, and 40 mm, along with a fixed irrigation interval of four days. The research experiments with maize and wheat crops, with treatments randomly assigned to 2.0 m x 2.0 m plots (4.0 m²). A total of 12 experimental plots are used, arranged in a Randomized Complete Block Design (RCBD) with three replications. To separate each replication, two buffer ridges and buffer spaces are included between adjacent plots. The total research area is 96 m² (16 m x 6 m), divided into three replicates of 16 m² (4 m x 4 m) with 1.0 m buffer space between them and an additional 1 m discard surrounding the entire area.

2.3 Water application method

The amount of water required to meet the crop water need was applied using sprinkling irrigation system through watering can as suggested by (Howell 2001), based on the fixed irrigation interval and cumulative pan evaporation scheduled at varied trigger levels. The volume of water to be applied is determined by the formula suggested by (Fapohunda, 2011) in the equation below:

V=Area of plot x Depth of irrigation

Where: V= volume (m^3); A= area (m^2) and ; D= depth of irrigation (mm)

2.4 Irrigation water application

Irrigation was carried out in all the plots monitored by moisture meter under different irrigation scheduling techniques whenever the cumulative pan evaporation trigger level of 20 mm, 30 mm and 40 mm is reached, and fixed irrigation interval of four days. Irrigation depths (amount of water to be applied) was calculated through cumulative daily ETc values in a given period, and plots was replenished with an amount of water equal to cumulative ETc as per the treatment to be applied.

2.5 Crop water use

The daily crop water use which is the actual amount of water used by crop per day under different treatments was determined using the equation 3

$ETc = ET_o \times Kc$

Where: ETc= crop evapotranspiration (mm/day)

ET_o = reference evapotranspiration (mm/day)

Kc = crop coefficient

$ET_o = Kp \times Epan$.

Where:

Epan is the water lost from the evaporation pan and Kp is the pan coefficient

2.6 Depth of irrigation water

This was obtained from the formula suggested by Michael (2008), the soil moisture content was determined using soil moisture meter. However, other parameter was determined from laboratory and substituted in equation 2.

$$D = (FC - PWP)BD \times MAD \times DRZ$$

Where: D = Irrigation water depth (mm), FC= field capacity (%), PWP = permanent welting point (%), BD = Wet Bulk density (gcm^{-1}), MAD = Maximum Allowable depletion (%), and DRZ = depth root zone (m)

2.7 Irrigation schedule

The irrigation schedule is designed to be at cumulative pan evaporation (CPE) trigger value 20 mm, 30 mm, 40 mm, and fixed irrigation of three (3 days) for maize as recommended by (FAO. 2006).

2.8 Soil moisture measurement

Moisture content in soil was determined using a calibrated scientific speedy soil Moisture meter KS-D1 (4862) recommended by (Dalhat *et al*., 2015).

2.9 Soil Analysis

A composite soil sample was taken from the experimental field at incremental depth of 0-20cm from the surface down to 60cm of the soil profile. The samples were used to determine the Physiochemical properties of the soil. The properties include soil texture, bulk density, field capacity, permanent wilting point, organic matter content and soil pH.

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2.10 Cultural Practices

The agronomic practices for both maize and wheat research included obtaining improved maize and wheat seeds from the Lake Chad Research Institute, Maiduguri. Land preparation was performed manually to create favourable conditions for seed germination and control weeds, with fumigation applied to prevent pest attacks. Maize and wheat were planted at a depth of 7 cm, with inter and intra-row spacing's of 50 cm and 30 cm, respectively, at a density of three seeds per hole. Fertilizer application followed local recommendations, with the first dose applied one week after planting and a second dose four weeks later. Weeding was carried out manually at two and five weeks after planting. Pests and diseases were controlled using a knapsack sprayer as needed. Both maize and wheat crops were harvested manually when the kernels dried, between 80 and 90 days after planting, and were left to dry further in the field for safe storage.

2.11 Method of data collection

Data collection for the research began two weeks after planting, and various growth and yield parameters were recorded for both maize and wheat crops. These parameters included plant height, stem girth, number of leaves per plant, leaf area index, cob length, cob diameter, cob weight, 1000 seeds weight, total yield per hectare, number of cobs per plot, number of grains per plot, weight of grains per plot, number of grains per cob, and weight of 100 grains per plot.

For plant height, measurements were taken from three randomly selected plants per plot, using a graduated tape to measure from the ground level to the topmost leaf, with the average recorded. Stem girth was measured with a digital Vernier caliper on three randomly selected plants per plot, and the average girth was recorded. The number of leaves per plant was visually counted for three randomly selected plants in each plot, and the average number was recorded. Leaf area was calculated by measuring leaf length and width, using the equation $LA = W \times L \times 0.75$, where W is the maximum leaf width, L is the leaf length, and the shape factor was 0.75. The leaf area index (LAI) was determined by dividing the leaf area by the land area.

For the cob measurements, three cobs were randomly selected from each plot. Cob length was measured with a graduated ruler from the lower rachis to the tip of the cob, and the average length was recorded. Cob diameter was measured by determining the circumference of the cob at the center using a digital Vernier caliper. Cob weight was recorded by weighing three randomly selected cobs from each plot. Total yield was calculated by weighing the yield produced in each experimental plot. Additional parameters such as the number of cobs per plot, the number of grains per plot, and the weight of grains per plot were also recorded. The number of grains per cob was counted from randomly selected cobs, while the weight of 100 grains was determined by randomly selecting and weighing 100 seeds per plot. Statistical analysis of the collected data was conducted using Analysis of Variance (ANOVA), as outlined by Gomez and Gomez (1984), with mean differences between treatments separated using Duncan's Multiple Range Test (DMRT)

3.0 Results and Discussion

The experimental results on the response of irrigation scheduling techniques i.e (M1, M2, M3 and FM1 on the growth and yield of maize and wheat crop were presented at 2-10 Week after sowing (WAS) basis in the table below

Table 3.1 shows that both treatments used had significantly ($p \leq 0.05$) influenced the maize plant height. The highest plant height values at all weeks after sowing was observed in FM1 with corresponded plant height values of 15.4cm, 30.6 cm, 60.5cm, 80.93cm and 97.667cm, respectively. It was closely followed M2 same (WAS) with plant height values of 13.7cm, 28.6cm, 52.33 cm 73.20 cm and 83.533 cm respectively. Whereas, the least plant height was remarkably recorded between M2 and M3 respectively. which is in line with one reported in Mustapha. B (2012).

Table 3.1 The Response of Irrigation Scheduling Techniques on Maize Plant Height

Treatment	2WAS	4WAS	6WAS	8WAS	10WAS
M1	13.7^{b}	28.6^{b}	52.33^{b}	73.20^{d}	83.533^{b}
M2	11.53^{c}	26.4^{c}	47.0^{c}	69.57^{c}	76.567^{c}
M3	9.7^{d}	24.5^{d}	39.7^{d}	63.46^{d}	65.176^{d}
FM1(control)	15.4^{a}	30.6^{a}	60.5^{a}	80.93^{a}	97.667^{a}
SE±	0.68	0.2297	1.27087	1.1985	1.3485

Means within a column followed by similar letter(s) are not significantly different at 5% probability

As illustrated in Table 3.2. The response of irrigation scheduling techniques had significantly ($P > 0.05$) affected the stem girth of the maize crop. The highest SG values of 3.7 cm, 3.9 cm.3.7 cm and 4.1 cm at 2WAS, 4WAS, 6WAS and 8WAS was obtained from control plot (FM1), closely followed M1 at same WAS with corresponding SG values of 3.4667 cm, 8.4667 cm and 13.96 cm, 16.967 cm and 3.467 cm respectively. Whereas the least SG values were observed between M2 and M3 response respectively. which is in line with Abdeen (2002).

Table 3.2 The Response of Irrigation Scheduling Techniques on Maize Stem Girth

Treatments	2WAS	4WAS	6WAS	8WAS	10WAS
M1	3.4667[b]	8.4667[b]	13.96[b]	16.967[b]	3.467[b]
M2	3.3333[c]	7.633[c]	13.4[c]	16.4[c]	3.333[c]
M3	2.6[d]	6.6[d]	12.06[c]	14.7[c]	3.604[c]
FM1	4.733[a]	9.766[a]	15.733[a]	18.73[a]	4.733[a]
SE±	0.1727	0.1217	0.296	0.9181	0.4181

Means within a column followed by similar letter(s) are not significantly different at 5% probability

As regard to response of the irrigation scheduling techniques on the leaf length of maize as shown figure 3.1. The leaf length is increase gradually as the growing period increases, from the graph its clearly shows that the uppermost leaf length at all weeks after sowing was recorded from FM1, while least were observed from the other treatment experimented, which could be attributed to the fact that the leaf length gradually increases as the week increases as shown in 4WAS, 6WAS, 8WAS and 10WAS respectively.

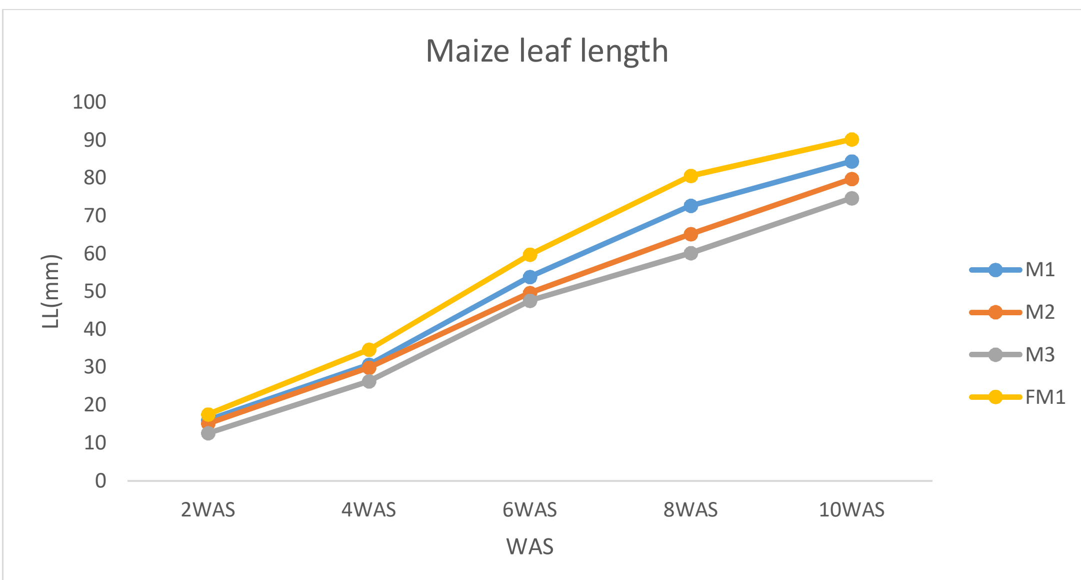

Fig: 3.1 The Response of Irrigation Scheduling Techniques on Maize Leaf length

As illustrated from figure 3.1 the response of the irrigation scheduling techniques affected the leaf width of the maize at all weeks after sowing during the experiment The longest leaf width at a 2WAS, 4WAS, 6WAS, 8WAS and 10WAS was observed FM1 plot, it was followed by M1 and M2. It was clearly indicating that, the length width gradually increases as the week increases as shown in 4WAS, 6WAS, 8WAS and 10WAS respectively

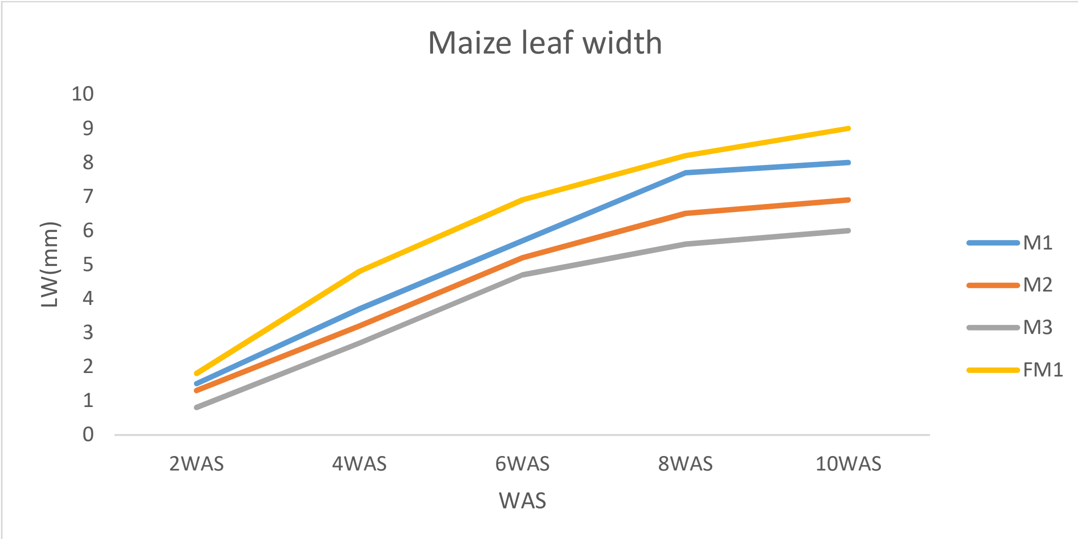

Fig 3.2 The Response of Irrigation Scheduling Techniques on Maize Leaf Width

Table 3.3 shows the yield and it attributes as affected by response of the irrigation scheduling techniques experimented in the study area. Treatments used significantly ($P<0.05$) affected the yield and its parameters for maize crop as shown in Table 4.3. The maximum CDPP, CHPP, NCPP, NCPPL NGPC, WCPPL, WGPP and 100 seed weight throughout the period of the experiment was recorded with FMI plot, it was closely followed MI and M2. While, the least was recorded in control plot. The findings tallied with Zhang *et al.* (2005).

Table 3.3: The Response of Irrigation Scheduling Techniques on Maize Yield and Yield Parameter

Treatments	CDPP	CHPP	NCPP	NCPPL	NGPC	WCPPL	WGPP	W100 SEED
M1	14.103^{b}	13.66^{b}	30^{b}	3.66^{b}	443.6^{b}	0.966^{b}	3.1395^{b}	0.023^{b}
M2	13.307^{c}	13.33^{c}	28^{c}	3.33^{c}	433.0^{c}	0.900^{c}	2.9325^{c}	0.023^{c}
M3	13.280^{d}	13.00^{d}	27^{d}	3.00^{d}	429.0^{d}	0.733^{d}	2.7945^{d}	0.220^{d}
FM1	14.547^{a}	14.66^{a}	31^{a}	4.00^{a}	451.6^{a}	1.066^{a}	3.2085^{a}	0.240^{a}
SE±	0.423	0.561	1.459	0.304	2.947	0.903	0.151	0.08

Table 3.4 shows the mean decades in days of the estimated evapotranspiration data for selecting of the irrigation scheduling in the study area. Table 4.5 shows the Analysis of variance (ANOVA) of the data, which revealed that there is significance difference among the mean evapotranspiration estimated on decades' basis in days in response

to the selection of scheduling of the maize crop experimented since the *f cal* is less than *f critical*.

Table 3.4 Mean days in decades of estimated crop evapotranspiration in response to the scheduling

Days	Kc	EPc(mm)	EP(mm)	ETo(mm)	ETc(mm)	ETc(m3/day)	ETc(L/day)
1-10	0.3	30.3	5.7	4.3	1.3	0.005	5.2
11-20	0.75	60.1	5.9	4.45	3.33	0.014	13.62
21-30	1.2	50.1	6.4	4.9	5.7	0.025	24.7
31-40	1.2	44.5	6.4	4.8	5.8	0.024	24.1
41-50	0.75	59.5	7.3	5.49	4.05	0.017	17.1
51-60	0.3	54.6	8.5	6.41	1.92	0.008	7.68
61-70	0.3	53.7	8.6	6.48	1.93	0.008	7.72
71-80	0.3	53.9	8.8	6.6	2.0	0.008	7.9
81-90	0.6	57.7	8.9	7.3	4.2	0.017	7.7

Table 3.5 Analysis of variance

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*Fcal*	*P-value*	*F critical*
Between Groups	257.066	8	32.13325	0.08282071	0.99952471	2.152133
Within Groups	17459.35	45	387.9856			
Total	17716.42	53				

3.2 CONCLUSION AND RECOMMENDATIONS

3.2.1 Conclusion

The research was carried out to determine the response of irrigation scheduling techniques on growth and yield of maize and wheat crop was conducted at the Agricultural Engineering Research and Teaching farm of Ramat Polytechnic Maiduguri during rainfed season in 2022. The result of the studies was analysed using statistic 8.0 as follows.

(i) The findings revealed that highest growth and yield parameter of maize at all weeks after sowing was observed with FM1

(ii) The findings revealed that M1 and M3 have significantly improved growth and yield of maize production in the study

(iii) Similarly, the analysis of variance revealed that there is significance difference among the evapotranspiration estimation while selecting the scheduling method

(iv)

3.2.2 Recommendations

(i) Since this experiment is seasonal under a single environment, further studies are required in order to develop reliable values.

(ii) Further research need to be carried out at different soil type, maize varieties and scheduling method.

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