

## Effect of Plant Density on Morphological Characteristics, Yield and Chemical Composition of Napier Grass (*Pennisetum purpureum* (L.) Schumach)

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**Abstract:** An experiment to assess the effect of plant density on morphological characteristics, dry matter production and chemical composition of Napier grass (*Pennisetum purpureum* (L.) Schumach) was conducted in 2004 and 2005 at Haramaya University, eastern Ethiopia. There were a total of nine treatments with 1.5, 1 and 0.5m spacing between rows and 0.75, 0.5 and 0.25m spacing between plants, which consisted of 8,888.9, 13,333.3, 26,667.7, 13,333.3, 20,000, 40,000, 26,667.7, 40,000, and 80,000 plants per ha, arranged in a randomized complete block design with three replications. The plot size was 3m width x 6m length and the spacings between replications and plots were 1.5m and 1m respectively. There was no significant ( $P > 0.05$ ) effect in morphological characteristics of Napier grass due to plant density during the establishment year. However, the number of tillers, total leaves, internode number, internode length, basal circumference and leaf length per plant were significantly ( $P < 0.05$ ) affected by plant density in the second year. There was a significant ( $P < 0.05$ ) difference in dry matter (DM) yield due to plant density. A considerable variation in DM yield between the two years and number of harvests in each year was observed during the study and the DM yield in 2005 was much greater than the 2004 crop season. Higher DM yields were obtained from 80,000 (7.80 t/ha) and 40,000 (39.9 t/ha) plant density in 2004 and 2005 respectively. There was no significant ( $P > 0.05$ ) effect on the chemical composition of Napier grass due to plant density. However, the crude protein (CP) content of all the treatments was above 15%, which is the optimum required for animal growth or production. The fibre fractions were also below the threshold level (600 g/kg DM) at which DM intake of cattle is affected. Based on DM yield production and CP content, the production of Napier grass using 40,000 plants per hectare is recommended to livestock producers in eastern Ethiopia agro-ecologies of the country.

**Keywords:** Chemical Composition; Dry Matter Yield; Morphological Characteristics; Napier Grass; Plant Density

### 1. Introduction

The development of the livestock sub sector in Ethiopia is hindered by many constraints of which unavailability of both high quantity and quality feed is the major factor (Azage *et al.*, 1995). More than 90% of livestock feed is crop residues and natural pasture in Ethiopia (Alemayehu, 2004), both of which are low in quantity and quality for sustaining animal production (Seyoum *et al.*, 1998), resulting in slow growth rates, poor fertility and high rates of mortality (Osuji *et al.*, 1993). The shortage of feed can be solved through the introduction and utilization of adaptable and high-yielding cultivated forage crops with better nutritional values than the existing feed resources in the country (Seyoum *et al.*, 1998; Tessema and Halima, 1998).

Amongst the improved forage crops introduced in Ethiopia, Napier grass (*Pennisetum purpureum* (L.) Schumach) could play an important role in providing a significant amount of quality forage, both for the smallholder farmer as well as intensive livestock production systems with appropriate management practices (Alemayehu, 1997; Seyoum *et al.*, 1998; Tessema and Halima, 1998; Alemayehu, 2002; 2004). Because of the importance of Napier grass in small-scale livestock farming enterprises, it is one of the most widely-used fodder crops among the livestock producers in Kenya (Annido and Potter, 1994; Kariuki *et al.*, 1998), Pakistan (Butt *et al.*, 1993), USA (Robert *et al.*, 1995), Malaysia, Tanzania (Kidunda *et al.*, 1990). It also performs well in the low, mid and highland areas of Ethiopia (Alemayehu, 1997; Seyoum *et al.*, 1998; Tessema and Halima, 1998). It is superior to many other tropical grasses in terms of dry

season growth and forage quality (Bayer, 1990) and can support a large number of animal units (Sollenberger *et al.*, 1990) through the cut-and-carry system (Alemayehu, 1997; Kariuki *et al.*, 1998).

Napier grass has been introduced in soil conservation areas, around homesteads, road-sides and livestock exclusion areas by smallholder farmers due to land shortages in Ethiopia. With appropriate management practices, Napier grass can provide a continual supply of green forage throughout the year and best suits intensive small-scale farming systems (Orodho, 1990; Alemayehu, 1997). The present study was therefore designed to assess the effect of different plant densities on the morphological characteristics, dry matter production and chemical composition of Napier grass in semi-arid areas of eastern Ethiopia where information is lacking.

### 2. Material and Methods

#### 2.1. Location, Treatment and Experimental Design

The napier grass plant density experiment was conducted on alluvial-vertisols (Tamire, 1982) at Haramaya University Research Centre (9° 26' N, 42° 03' E; 2240 m a s l). The 0-40cm layer of the soil before fertiliser application had a pH of 6.34, total N of 0.16, available phosphorus level of 0.66 ppm, organic matter level of 2.28% and organic level carbon of 1.33%. The twenty years mean annual rainfall for the area is 625 mm and the average annual air temperature is 20.15°C. The monthly rainfall, number of rainy days, and the minimum and maximum air temperatures during the study are presented in Table 1.

Table 1. Monthly total rainfall (mm), number of rainy days, and minimum and maximum air temperature during 2004-2005 at Haramaya, Ethiopia.

Months	Rainfall (mm)		Temperature (°C)			
			Mean maximum		Mean minimum	
	2004	2005	2004	2005	2004	2005
January	38.2	0.5	24.15	21.43	9.3	9.65
February	0	2	23.95	24.26	5.85	6.25
March	25.4	39.9	25.65	24.45	8.85	8.76
April	163.5	119.5	23.9	25.7	14.2	13.5
May	39.5	198.3	26.45	23.7	11.7	12.5
June	25.5	19.2	24.75	25	14.1	14.4
July	71.32	68.1	24	23	13.3	13.2
August	116.4	126.2	24.5	24	13.6	13.5
September	126.7	156.4	24	23	12.1	12.5
October	43.8	17	25.04	23.1	6.45	11.2
November	38.6	33.6	24.7	23.7	5.5	7.9
December	4.5	0	21.43	22.4	4.0	6.1

The study was conducted in a randomised complete block design with three replications on a plot size of 3m (width) by 6 m (length). The spacings between replications and plots were 1.5m and 1 m, respectively. The treatments consisted of plant spacing of: 26,666.7 (1.5m row x 0.25m), 40,000 (1.0m row x 0.25m), 80, 000

(0.5m row x 0.25m), 13,333.3 (1.5m row x 0.5m), 20,000 (1.0m row x 0.5m), 40,000 (0.5m row x 0.5m), 8,888.9 (1.5m row x 0.75m), 13,333.3 (1.0m row x 0.75m) and 26,667.7 (0.5m row x 0.75m) plants per hectare. The treatment structure of the experiment is presented in Table 2.

Table 2. Row and plant spacing structures of the treatments during the experimental periods.

Row spacing (m)	Plant spacing (m)	Area/plant (m <sup>2</sup> )	Number of plants/ha
1.5	0.25	1.5m x 0.25m = 0.375	26,666.7
1	0.25	1.0m x 0.25m = 0.25	40,000
0.5	0.25	0.5m x 0.25m = 0.125	80,000
1.5	0.5	1.5m x 0.5m = 0.75	13,333.3
1	0.5	1.0m x 0.5m = 0.50	20,000
0.5	0.5	0.5m x 0.5m = 0.25	40,000
1.5	0.75	1.5m x 0.75m = 1.125	8,888.9
1	0.75	1.0m x 0.75m = 0.75	13,333.3
0.5	0.75	0.5m x 0.75m = 0.375	26,667.7

## 2.2. Establishment and Management of Napier Grass

High-yielding and adaptable Napier grass accession (ILRI No. 16791) was vegetatively propagated using uniform root splits on well-prepared soil under rainfed conditions in the last week of July 2004 when the soil was moist. Diammonium phosphate was applied at planting at 100 kg ha<sup>-1</sup> for establishment and urea at 50 kg ha<sup>-1</sup> was applied after establishment as recommended (IAR, 1988). In the second year, the same amount of urea was applied at the start of the main rainfall after uniform cutting of all the plots at the same time.

## 2.3. Data Collection and Analytical Procedures

Vigour was rated visually on the scale of 1 = poor to 5 = excellent. Three plants in each treatment were randomly selected to record number of tiller per plant (NTPP), basal circumference per plant (BCPP), total number of leaves per plant (TLPP), internode number per plant (INPP), leaf length per plant (LLPP) and leaf: stem ratio (LSR). Two tillers from each randomly-taken plant were used to determine the number of leaves per tiller (NLPT) (Butt *et al.*, 1993; Tessema, 2000; Tessema *et al.*, 2003).

Napier grass was harvested about 10-15 cm above the ground from all the treatments, excluding border rows, and all harvested samples from each plot were thoroughly mixed and 250 g was taken for dry matter (DM) yield determination by drying at 65°C for 72 h (constant weight). Harvests were made 2 and 3 times in 2004 and 2005 respectively when the plant height reached 1 m. Representative whole plants from each treatment were oven-dried, ground to pass through a 1 mm sieve and stored in airtight containers for different chemical analyses. Ash was determined by igniting at 550 °C overnight, total DM by drying at 105 °C and N by auto-analyser (Chemlab, 1984). Crude protein (CP) was calculated as N x 6.25. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Goering and Van Soest (1970). Hemicellulose and cellulose were calculated as NDF - ADF and ADF - ADL respectively. All the chemical analyses were done in duplicate (at the Haramaya University Animal Nutrition Laboratory.) to increase precision.

### 2.4. Statistical Analysis

Analysis of variance was carried out using the SAS (1998) General Linear Models' procedure and applied to randomized complete block design and mean separation was tested by least significant difference (LSD).

## 3. Results and Discussion

### 3.1. Morphological Characteristics

There was no significant ( $P > 0.05$ ) effect in morphological characteristics of Napier grass due to plant density during the establishment year (Table 3). However, NTPP, TLPP, INPP, ILPP, BCPP and LLPP were significantly ( $P < 0.05$ ) affected by different plant density in the second year (Table 4).

Table 3. Morphological characteristics of Napier grass as influenced by different plant populations during the establishment year.

Plant population	Morphological characteristics							
	Vigor	NTPP	NLPT	TLPP	INPP	BCPP	ILPP	LSR
26,666.7	5.00	22.27	11.00	244.64	6.00	70.67	7.67	1.24
40,000	5.00	25.53	11.73	264.76	5.67	65.00	6.33	0.98
80,000	5.00	20.67	12.33	252.77	6.00	64.33	8.23	1.07
13,333.3	4.00	18.93	11.33	216.03	4.67	58.67	6.17	1.08
20,000	4.67	24.20	10.80	257.04	4.33	48.33	5.60	1.08
40,000	5.00	20.80	11.53	239.21	4.67	51.67	5.40	1.41
8,888.9	4.33	24.13	10.00	236.21	4.67	61.00	4.97	0.93
13,333.3	3.33	18.80	11.27	206.21	4.67	54.67	7.03	1.30
26,667.7	5.00	20.40	11.27	229.33	5.00	64.00	7.80	1.11
Mean	4.59	21.75	11.25	238.50	5.07	59.82	6.58	1.13
s.e.	0.35	2.31	0.72	33.83	0.64	7.13	1.65	0.20
P level	*	NS	NS	NS	NS	NS	NS	NS

\* =  $P \leq 0.05$ ; NS = Non-significant; NTPP = number of tillers per plant; BCPP = basal circumference per plant (cm); TLPP = total number of leaves per plant; INPP = internode number per plant; LSR = leaf: stem ratio; NLPT = number of leaves per tiller

Table 4. Morphological characteristics of Napier grass as influenced by different plant populations during the second year of establishment.

Plant population	Morphological characteristics								
	NTPP	NLPT	TLPP	INPT	INPP	ILPT	BCPP	LL	LSR
26,666.7	62.3	15.3	955.5	10.3	637.0	14.3	198.7	116.7	1.02
40,000	35.0	15.0	525.0	9.7	372.0	15.7	153.3	120.7	0.94
80,000	36.0	14.7	528.1	10.3	381.3	17.3	167.7	127.0	1.00
13,333.3	38.3	13.3	510.9	8.0	297.7	17.3	160.7	121.0	0.95
20,000	29.7	14.0	415.5	10.0	297.0	15.7	125.3	125.7	1.09
40,000	22.7	14.0	317.4	8.3	176.3	16.0	126.7	126.7	1.12
8,888.9	59.3	15.0	890.0	10.0	596.7	19.0	191.3	121.7	0.95
13,333.3	32.0	14.0	448.0	9.0	289.3	16.0	141.7	121.3	0.90
26,667.7	24.3	14.0	340.6	8.3	200.3	17.7	125.0	128.3	1.01
Mean	37.74	14.47	547.9	9.33	360.9	16.6	154.6	123.2	1.00
s.e.	6.97	1.02	114.0	1.36	102.1	0.98	17.7	2.51	0.06
P level	**	NS	**	NS	*	*	*	*	NS

\*\* =  $P \leq 0.01$ ; \* =  $P \leq 0.05$ ; NS = Non-significant; NTPP = number of tillers per plant; BCPP = Basal circumference per plant (cm); TLPP = total leaves per plant; INPP = internode number per plant; LLPP = leaf length per plant; LSR = leaf: stem ratio; NLPT = number of leaves per tiller

The highest NTPP (62.3), INPT (10.3), TLPP (955.5) and BCPP (198.6 cm) were obtained from 26,666.7 plants per hectare. High morphological characteristic values of Napier grass were observed from medium and lower plant density compared to higher plant density per hectare during the study. This might be due to the fact that plants with wider spacing produced many fine-stemmed tillers and showed with vigorous growth and development and leafy structures because of reduced

competition for space, moisture and nutrients during the growing period as reported by Wilson *et al.* (1989).

The general trend of LSR increased as the spacing between plants and rows increased in Bana grass (Berihun, 2005). Napier grass planted at 50 cm × 50 cm spacing produced 1.49 leaf to stem ratio (Taye, 2004) compared to plant spacing of 100 cm × 50 cm with 1.91 LSR (Tessema, 2000; Tessema *et al.*, 2003). Narrow spacing resulted in a higher number and longer internodes than wider spacing (Singh and Singh, 1971) and the

tillering capacity increased with their relative increase in plant spacing. The maximum tillers in Mott Napier grass were recorded in spacing of 120 cm × 120 cm followed by 105 cm × 105 cm against the minimum tillers count in a spacing of 45 cm × 45 cm (Yasin *et al.*, 2003). Khan and Manghatt (1965) on pearl millet (*Pennisetum typhoides*) reported that the number of tillers increased consistently with an increase in plant spacing. Leaves' expansions from narrow spacing were smaller in length compared to those from wider spacing (Begna *et al.*, 2000).

### 3.2. Dry Matter Production

There was a significant ( $P < 0.05$ ) difference in DM yield among the different plant densities in Napier grass (Table 5). Higher total DM yields were obtained from 80,000 (7.80 t/ha) and 40,000 (39.9 t/ha) in 2004 and 2005 crop seasons respectively. There was also a considerable variation in DM yield between the two years and number of harvests in each year (Tables 5, 6).

Table 5. Dry matter production of Napier grass as influenced by different plant populations.

Plant population	Dry matter yield (t/ha)											Mean
	2004/05 harvest					2005/06 harvests						
	1 <sup>st</sup>	2 <sup>nd</sup>	Total	LDM	SDM	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	Total	LDM	SDM	
26,666.7	4.1	2.0	6.1	3.4	2.8	20.2	17.9	0.8	38.9	19.8	19.1	22.5
40,000	4.27	1.7	5.9	2.9	3.0	22.0	15.8	0.9	38.7	19.0	19.7	22.3
80,000	5.9	1.9	7.8	4.0	3.5	17.6	14.5	1.0	33.16	16.4	16.7	20.4
13,333.3	3.2	1.3	4.6	2.4	2.2	14.9	15.6	0.6	31.0	15.3	15.7	17.8
20,000	3.1	1.3	4.4	2.2	2.2	17.3	16.9	0.9	34.9	18.4	16.5	19.7
40,000	4.2	1.9	6.1	3.5	2.6	24.0	15.1	0.9	39.9	21.1	18.8	23.0
8,888.9	3.0	1.7	4.5	2.1	2.7	12.6	22.9	0.7	36.2	18.2	16.1	20.5
13,333.3	2.3	1.6	3.9	2.1	1.9	20.5	18.8	0.8	40.0	19.2	20.8	22.0
26,667.7	3.6	1.6	5.2	2.7	2.3	18.2	18.6	0.9	37.7	18.7	19.0	21.5
Mean	3.8	1.7	5.4	2.8	2.6	18.6	17.4	0.9	36.7	18.5	18.36	21.2
s.e.	0.67	0.23	0.82	0.43	0.50	1.54	2.56	0.104	2.86	1.53	1.33	1.98
P level	*	NS	*	*	NS	**	*	NS	*	**	**	NS

\*\* =  $P \leq 0.01$ ; \* =  $P \leq 0.05$ ; NS = Non-significant; 1<sup>st</sup> = First harvest; 2<sup>nd</sup> = second harvest; Total = Total dry matter yield (the sum of all harvests in each season); LDM = Leaf dry matter yield; SDM = Stem dry matter yield;

Table 6. The combined analysis of variance (ANOVA) for Napier grass plant density experiments over the years (2004-2005).

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F calculated	Probability
Replication	2	419.208	209.602	8.8740	0.0008
Year	1	13215.926	13215.926	559.5214	0.0000
Treatment	8	129.686	16.211	0.6863	
Treatment x Year	8	143.214	17.902	0.7579	
Error	34	803.082	23.620		
Total	53	14711.116			

The DM yield in 2005 was much greater than in the 2004 crop season. This might be due to the perennial nature of Napier grass, which produces more tillers and high vegetative growth as the pasture period increases, as reported by Tessema (2005) and Ndikumana (1996) from tests on different Napier grass accessions in the north western parts of Ethiopia and many African countries. In addition, the number of harvests taken in the 2005 crop season was three but only two harvests were taken in 2004 since it was the year of Napier grass establishment. The DM yield of the first harvest was higher than the second or third harvests in each year because of the fact that the first harvest was taken during the rainy season where rainfall was sufficient for growth, while the second and third harvests were taken in the early and late dry seasons respectively which might have resulted in reduced DM yield production.

The present findings are similar to those of Berihun (2005) who reported that there was a significant ( $P < 0.05$ ) effect on DM yield of Bana grass due to plant density in semiarid areas of north-western Ethiopia. However, the same author reported a non-significant ( $P > 0.05$ ) effect on the combined DM yield of Napier grass due to plant density. The effect of plant density in Napier grass was enhanced in the year of establishment and in the dry seasons, contrary to the subsequent years and in rainy seasons and, consequently, the overall effect of plant density on long-term average annual yields was negligible (Boonman, 1993). In addition, most trials with plant density varying from 3333 (300 cm x 100 cm) to 20,000 plants (100 cm x 50 cm) gave almost identical herbage yields when totalled over wet and dry seasons for a number of years in Kenya, as indicated by Boonman (1993). Low plant density or wider spacing made an

enormous difference to the rate of plant growth and yield performances, clumps expansion and filling for continuous growth within the rows compared to narrow spacing (Boonman, 1993). Dry matter yield increased as plant density increased. However, narrower row spacing may facilitate stand establishment and increase forage production in the early life of the pasture sward. Saeed *et al.*, (1996) on Mott Napier grass reported that close spacing produced higher productivity than wider plant spacing after establishment.

### 3.3. Chemical Composition

There was no significant ( $P > 0.05$ ) effect on the chemical composition of Napier grass due to plant density during the study (Table 7). However, Berihun (2005) reported that the combination of row and plant spacing affected the CP, NDF, ADF, ADL, Ca, P and IVDMD values of Bana grass in semiarid areas of north western Ethiopia but a significant effect was not reported on cellulose and hemicellulose contents due to plant density (Berihun, 2005). This might be due to the fact that all the plant materials used in the study were from the same genetic accession and all the treatments were harvested at the same growth stage. Many research reports revealed that plant height at cutting (Tessema, 2000; Tessema *et al.*,

2002a; 2002b; 2003), stage of growth (McDonald *et al.*, 1988; Seyoum *et al.*, 1998; Tessema *et al.*, 2002a; Tessema and Baars 2003; Taye 2004; Berihun, 2005) and varietal difference (Ndikumana, 1996; Seyoum *et al.*, 1998 and Tessema, 2005) are the major factors that affect the chemical composition and digestibility of Napier grass.

Plant density did not show any significant effect on the chemical composition of Napier grass in the study; however, the CP content of all the treatments was above the minimum CP level of 75 g/kg required for adequate rumen function in ruminants (van Soest, 1984). The minimum CP content required for lactation and growth of cattle is 150 g/kg (Norton, 1982), suggesting that all the treatments were above the recommendation (range 158.3-171.8g/kg) and would satisfy the production requirement of ruminants. The threshold level of NDF in tropical grass beyond which DM intake of cattle is affected is 600 g/kg (Meissner *et al.*, 1991), suggesting that all the treatments have a lower value than this (range 533.4-554.5g/kg). In the study, the cellulose (range 256.7–271.7 g/kg) and hemicellulose (range 237.4-253.0 g/kg) contents of the treatments were lower than those of most tropical grasses, 319 and 354 g/kg respectively (Moore and Hatfield, 1994).

Table 7. Chemical composition of Napier grass as influenced by different plant populations.

Plant Population	Chemical compositions (% DM basis)									
	DM	CP	NDF	TA	ADF	ADL	Cellul	Hemi cel	SS	BS
26,666.7	96.63	15.83	54.49	15.04	29.44	3.60	25.86	25.06	2.24	1.88
40,000	96.27	16.12	54.93	14.68	29.64	3.33	26.31	25.30	2.06	1.81
80,000	95.57	15.46	55.45	14.64	31.09	3.91	27.17	24.36	1.66	2.05
13,333.3	96.07	16.62	54.68	15.56	29.54	3.74	25.80	25.14	2.62	1.93
20,000	95.10	17.18	53.98	14.63	29.39	3.57	25.81	24.60	2.47	1.73
40,000	95.90	16.39	54.97	15.23	29.79	4.12	25.67	25.18	2.44	2.09
8,888.9	96.13	16.21	54.56	14.72	26.62	3.06	26.55	24.94	1.99	1.92
13,333.3	96.67	17.06	53.61	14.85	29.87	3.50	26.37	23.74	2.49	1.73
26,667.7	96.13	16.74	53.34	15.07	29.91	3.58	26.33	23.43	2.33	2.20
Mean	96.05	16.40	54.45	14.94	29.81	3.60	26.21	24.64	2.26	1.93
s.e.	0.52	0.54	0.83	0.56	0.59	0.33	0.50	0.62	0.29	0.40
P level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS =  $P > 0.05$ ; ADF = Acid detergent fiber; BS = Biogenic silica; Cellul = cellulose; CP = Crude protein; DM = dry matter; Hemicel = Hemicellulose; SS = Sand silica; TA = Total ash

## 4. Conclusions

In conclusion, there was no significant effect on the morphological characteristics of Napier grass due to plant density during the establishment year. However, NTPP, TLPP, INPP, ILPP, BCPP and LLPP were significantly affected by plant density in the second year. There was a significant difference in DM yield among different plant densities in Napier grass over the two seasons' study period. Higher DM yields were obtained from 80,000 and 46, 667 in the 2004 and 2005 crop seasons respectively. There was no significant effect on the chemical composition of Napier grass due to plant density during the study. However, the CP content of all the treatments was above the minimum CP level of 75 g/kg required for adequate rumen function in ruminants and the fibre fractions were below the threshold level at which DM

intake of cattle is affected. Based on DM yield production and CP content, the planting of Napier grass using 40, 000 plants per hectare on 0.25m<sup>2</sup> area/plant; i.e. 1m x 0.25m or 0.5m x 0.5m would be advantageous to the smallholder farmers (in the semiarid areas of Ethiopia and in similar agro-ecologies of the country.) instead of large areas per m<sup>2</sup>. Moreover, further studies on the economics of plant density are recommended as a means of achieving least-cost Napier grass pasture production in smallholder conditions in the semiarid areas of Ethiopia and other similar areas.

## 5. Acknowledgements

The author would like to acknowledge the Haramaya University (HU) Research and Extension Office and the Ethiopian Agricultural Research Institute (EARI), for

financing the research. All staff of the Animal Nutrition Laboratory of HU are gratefully acknowledged for their assistance during the chemical analysis.

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