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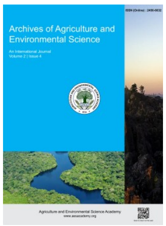

ORIGINAL RESEARCH ARTICLE

CrossMark

Response of nitrogen and phosphorus fertilizer rate for sorghum (*Sorghum bicolor* L. Moench) production in Wag-Lasta area of Ethiopia

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ABSTRACT

A field experiment was carried out at Lasta and Sekota woreda Eastern Amhara Ethiopia to assess the effects of application of different rates of N-P fertilizers on yield and yield components of sorghum (*Sorghum bicolor*). Four rates of N (0, 23, 46, 69, kg ha^{-1}) and three rates of P_2O_5 (0, 23, 46, kg P_2O_5 ha^{-1}) were arranged in randomized complete block design (RCBD) with three replications in a factorial arrangement. Nitrogen and phosphorus showed significant effects on yield and yield components of sorghum. Application of nitrogen and phosphorus at a rate of 46 N and 23 kg ha^{-1} increases the yield of sorghum by about 60.37% at Aybra and 56.33% at Lalibela compared to with control. The highest and profitable yield 3822 kg ha^{-1} and 2663.28 kg ha^{-1} was obtained from application of nitrogen and phosphorus at the rate 23 and 23 kg ha^{-1} and 23 and 46 kg ha^{-1} at Lalibella and Aybra, respectively. Therefore, application of 46 kg P_2O_5 and 23 N ha^{-1} could be appropriate for sorghum production Sekota (Aybra) sorghum growing areas. However, application of 23 N kg ha^{-1} and 23 P_2O_5/ha could be appropriate for Lalibella (Shumsha) areas. The current study confirmed that application of fertilizer is very important to boost the production and productivity of sorghum (*S. bicolor*) in these areas of Ethiopia.

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INTRODUCTION

Globally, sorghum (*Sorghum bicolor* L. Moench) is the fifth most vital rice, wheat, barley and cereal crop after maize (FAOSTAT, 2014; El-Mageed *et al*., 2018). It is an important crop staple food crop in the semi arid tropics of Africa, south Asia and Central America (Kumar and Chopra, 2013). In Ethiopia, sorghum is a major staple food crop, ranking second after maize in total production. It ranks third after wheat and maize in productivity per hectare, and after Tef and maize in area cultivated. It is grown in almost all regions, covering a total land area of 1.8 million ha (CSA, 2015). Sorghum grain is as nutritious as other cereal grains; contains about 11% water, 340 k/cal of energy, 11.6% protein, 73% carbohydrate and 3% fat by weight (Thimmaiah, 2002; Taylor *et al*., 2006; Yan *et al*., 2012).
Despite the large-scale production and various merits, Sorghum production and productivity have been far below the potential. Currently the average regional productivity is 2.1t ha^{-1} but, the study area productivity is below 1.3 t ha^{-1} which is very low as compared to other small grain cereals grown in Ethiopia (CSA, 2015). Low productivity of crops has been attributed to abiotic stress for drought and low soil fertility and biotic stress for the disease, insect and weeds (Olanite *et al*., 2010; Mbwika *et al*., 2011). And also Wortmann *et al*. (2006) reported that drought, low soil fertility (nutrient deficiencies), insect stem borers, insect shoot fly, quelea birds, Striga and weeds were recognized as major production constraints affecting sorghum in eastern Africa. To feed the ever increasing population and generate income, continuous cultivation of land became a common practice in major sorghum producing areas, which eventually led to soil fertility decline and subsequent reduction of crop yields (Farré and Faci, 2006; Marsalis *et al*., 2010; Saberi, 2013). Thus, as noted by Mwangi (1995) the use of inorganic fertilizer is critical to increase crop yield. Gruhn *et al*. (1995) suggested that, the

levels of the fertilizer being used are very low and this must be increased to meet the demand for food with population growth. Based on these facts the objective of this research was to determine the optimum rate of nitrogen and phosphorus fertilizer on yield and yield components of sorghum in Wag-Lasta areas of Ethiopia.

MATERIALS AND METHODS

Study area description

The study was conducted in the year 2014 and 2016 at Lalibella and Aybra found in Lasta Woreda and Sekota Woreda of Ethiopia, respectively Amhara regional state (Figure 1). The study sites were located at 11° 58' 50.15'' N latitude and 38° 59' 03.22'' Longitude and 12° 43' 52.82''N and 39° 01'22.01''E at altitude of 1966 m and 1915 meter above sea level (asl), respectively.

Experimental design and treatments

The experiment was conducted in Wag-Lasta areas of Amhara Region in 2014 and 2016 cropping season. The treatments consisted of four N levels (0, 23, 46 and 69 kg N ha^{-1}) and three P_2O_5 levels (0, 23 and 46 kg P_2O_5 ha^{-1}). The experiment was arranged in randomized complete block design (RCBD) with three replications in a factorial arrangement. The plot size was 14.25m^2 (3.75 m × 4 m) and consisted of 5 rows. A distance of 0.5 m and 1 m were left between plots and blocks, respectively. The spacing of 75 × 15 cm was used between rows and plants, respectively and there were 26 plants planted per row with a total of 133 plants per plot. Urea and Triple supper phosphate (TSP) were used as a source nitrogen and phosphorus fertilizer, respectively. Nitrogen fertilizer was applied by split; application method in the form of urea half at planting and the remaining 45 days after planting. Phosphorus was applied once in the form of TSP at the time of planting. Agronomic practices such as weeding, cultivation and tie-ridge were done uniformly for all treatments as per need. The tested variety was Misker (Figure 2).

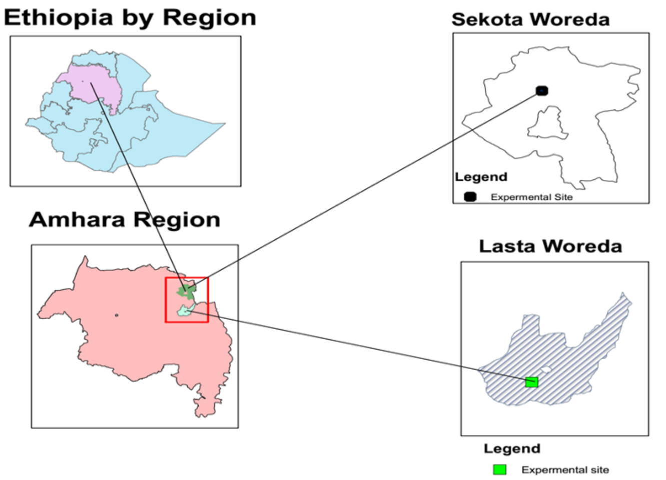

Figure 1. *Description of different study areas of Ethiopia.*

Figure 2. *View of researcher's and farmer's managed farm of sorghum.*

Data collection and analysis

The average plant height, Length of sorghum Head, average weight of sorghum head, gain yield and above ground biomass of sorghum were recorded from each plot. The data obtained were subjected to analysis of variance using SAS statistical software version 9.0 and treatment effects were compared using the Fisher's Least Significant Differences test at 5% level of significance.

Partial budget analysis

The partial budget analysis was done to see the economic feasibility. The costs include fertilizer cost and price of sorghum was collected from the study areas.

Soil analysis

The soil was air-dried and sieved through a 2 mm sieve. Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter. Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934) while percentage organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724. Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method.

RESULTS AND DISCUSSION

Characteristics of sorghum cultivated at Aybra

Soil characteristics

Soil analysis before sowing was analyzed and pH value of the surface soil at Lalibella and Aybra was 6.3 and 5.96, respectively (Table 1). Based on findings of Tadese (1991), soil pH rating, the value of surface soil of the study area was within moderately acid and slightly acid class at Lalibella and Aybra respectively. According to Tadese (1991) rating value organic matter and total N content in surface soil was Low.

Plant height

Nitrogen and phosphorus significantly ($P \le 0.001$) affected plant height of sorghum (Table 2). Mean plant height of sorghum (140.01cm and 140.08 cm) at 23 and 46 kg N and P_2O_5 $ha^{-1}$was significantly higher than the control, but were at par with each other all rates. The height was increase by 14.88 %, and 10.35 %, respectively compared with control. The current result is similar the finding of Legesse and Gobeze (2015) who report nitrogen and phosphorus at rate of 18 nitrogen and 46 phosphorus with tie-ridge had significant effect on plant growth in areas of southern Ethiopia. Similarly, Brhane (2012) has observed that nitrogen and phosphorus at rate of 18 and 46 kg ha-1 with in situ moisture conservation had higher plant height.

Grain yield

The grain yield was significantly affected by the application rates of Nitrogen and Phosphorus fertilizers at ($P<0.05$). The grain yield of sorghum as influenced by the different application rates of Nitrogen and Phosphorus fertilizers. Increasing the rates of N/P fertilizers from 0/0 to 23/46 kg ha^{-1} increased the yield of the crop from 1172 to 2959.2 kg ha^{-1}. Thus, compared to the control treatment, the highest rate of Nitrogen and Phosphorus (23/46 kg ha^{-1}) increased sorghum grain yield by 60.37%. Accordingly, the yield obtained from the control treatment was significantly lower ($P \leq 0.05$) than the yields obtained due to the application of all of the different rates of NP fertilizers (Table 4). This implies that without inputs like inorganic and organic fertilizer addition grain yield of sorghum was very low. The result of current study line with the finding of, (Legesse and Gobeze, 2015) and (Brhane, 2012) who reported that application of NP fertilizer at rate 18/46 $kgha^{-1}$ increases the grain yield of sorghum significantly. Similarly, research done by Gebrekidan (2003) observed that fertilizer application 46 P_2O_5 and 18 N with tie-ridge increases the grain yield of sorghum by 15-38% in the moisture stress areas of Eastern Ethiopia.

Biomass yield

The biomass yield of sorghum were affected significantly ($P< 0.05$) applying different rates of Nitrogen and Phosphorus fertilizers. Biomass yield was increased with applying NP fertilizers. The highest biomass yield (13731.5 kg ha^{-1}) was recorded at rate of 69 kg ha^{-1} N and 23 kg ha^{-1} Phosphorus fertilizer and the lowest biomass yield (5086.5 kg ha^{-1}) was record at control treatment (Table 5). The result indicates that NP fertilizer increases the biomass yield by 37.07% over control. Biomass yield is very important because the leaves and stems are used for cattle feed during the long dry season.

Partial budget analysis

Partial budget analysis (Table 6) shows that applying 46 kg N ha^{-1} and 23 kg P ha^{-1} had highest net benefit (16523.46 birr ha^{-1}) with MRR of 1349 % and followed by 23 kg N ha^{-1} and 23 kg P ha^{-1} with net benefit (13086.94 birr ha^{-1} and MMR of 714%.

Characteristics of sorghum cultivated at Lasta Woreda/ Shumsha Kebele

Plant height

Nitrogen and phosphorus significantly ($P \leq 0.001$) affected plant height of sorghum (Table 7). 69 kg ha^{-1}N and 46 kg ha^{-1} Phosphorus fertilizer had highest plant height compared with control. Height of sorghum was longer by 18.21 and 4.33 cm at 69 kg N and 46 P_2O_5 ha^{-1}compared with the control respectively (Table 8). The increment in plant height due to N application could be attributed to the effect of nitrogen on cell division and elongation which lead to growth and increased height of the stems and leaves (Rabinowitch and Kamenetsky, 2002). The result of this study is similar with the findings of Gebremariam and Aseefa (2015) who report nitrogen at rate of 69 kg ha^{-1} had significant effect on plant growth in northern Ethiopia. Similarly, Legesse and Gobeze (2015) also observed that 69 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5 has significant effect on plant height of sorghum.

Gain yield

The grain yield was significantly affected by the application rates of Nitrogen and Phosphorus fertilizers at ($P<0.05$). Highest grain yield (3888.3 kg ha^{-1}) was recorded at rate of 69/23 N -P_2O_5 kg $ha^{-1}$and lowest yield (1698.4 kg ha^{-1}) was recorded at control treatment (Table 9). Highest grain yield of sorghum 46/23 N -P_2O_5 kg $ha^{-1}$was significantly higher than the lower rate, but was at par with rate of 23/23, 46/23 69/23 kg ha-1 of N -P_2O_5 that responded linearly. Grain yield of sorghum was greater by 2190.4 kg $ha^{-1}$and 2148 kg ha^{-1}at 69/23 and 46/23 kg N and P_2O_5 ha^{-1} compared with the control. The yield was Increase by 56.33% and 55.88%. The result is in agreement with the findings of (Masebo and Menamo, 2016) who reported that application of NP fertilizer at increases the grain yield of sorghum. Similarly, Ashiono *et al.* (2005) reported that increasing rate of nitrogen and phosphorus had increase the grain yield of sorghum which study in Kenya.

Biomass yield of sorghum

The biomass yield of sorghum were affected significantly ($P< 0.05$) applying different rates of Nitrogen and Phosphorus fertilizers. The highest biomass yield (24924 kg ha^{-1}) was recorded with application of 69/23 N-P kg $ha^{-1}$and the lowest (8993 kg ha^{-1}) was recorded in control treatment (0N, 0P) (Table 10). Application of fertilizer increases the biomass yield of sorghum by 36.08%.

Partial budget analysis

Partial budget analysis (Table 11) shows that applying 23 kg N ha^{-1} and 23 kg P ha^{-1} had highest net benefit (23447.23 birr ha^{-1}) with marginal rate of return (MRR) of 1083% and followed by 23 kg N ha^{-1} with net benefit (16269.97 birr ha^{-1}) and MMR of 952%.

Table 1. Physico-chemical characteristics of the soil.

Site	PH	EC dec/m	OM %	TN%	Texture			
					Sand %	Silt%	Clay%	Textural class
Lalibella	6.23	1.3	1.06	0.07	39	27	34	Clay loam
Aybra	5.96	1.8	1.09	0.084	33	32	35	Clay loam

Table 2. Combined ANOVA for the effect of N and P fertilizers on the plant height, sorghum head length, head weight, grain yield and biomass.

Source of variation	DF	Mean square values				
		Plant height	Length sorghum head	Head weight	Grain yield	Biomass yield
N	3	1879.41***	3.96ns	922.14**	3463406.69**	246540773***
P	2	1460.56**	3.61ns	667.37***	2959677.33**	223566291**
N*P	6	186.92*	7.34*	310.57***	373721.83**	50981317**
Year	1	1305.00**	580.26**	9480.64**	509325.21*	13230964**
Rep	2	72.02ns	580.26ns	14.92ns	34422.65ns	10681603ns
Error	40	60.65	66.26	41.11	72891.91	10725818

Table 3. Effect of nitrogen and phosphorus on growth parameter of sorghum.

Treatment	Plant height (cm)			Length of sorghum head (cm)			Weight of sorghum head (g)		
N kg ha^{-1}	1st year	2nd year	combined	1st year	2nd year	Combined	1st year	2nd year	Combined
0	122.48^{b}	115.86^{b}	119.17^{b}	14.68^{b}	20.35^{ab}	17.94^{a}	13.84^{c}	20.83^{c}	17.33^{b}
23	130.56^{a}	149.46^{a}	140.01^{a}	15.53^{ab}	21.77^{ab}	18.23^{a}	17.12^{b}	46.33^{ab}	31.72^{a}
46	135.47^{a}	142.85^{a}	139.16^{a}	15.87^{ab}	20.82^{ab}	18.35^{a}	19.18^{a}	43.33^{b}	31.25^{a}
69	132.42^{a}	146.82^{a}	139.62^{a}	16.12^{a}	21.97^{a}	19.05^{a}	16.21^{b}	47.66^{a}	31.94^{a}
LSD $_{0.05}$	6.49	9.42	7.17	1.21	1.60	2.29	1.49	3.90	10.16
P_2O_5 kg ha^{-1}									
0	120.47^{b}	130.69^{b}	125.58^{b}	15.49^{ab}	21.05^{a}	18.27^{a}	15.47^{b}	32.25^{b}	23.86^{b}
23	137.59^{a}	142.56^{a}	140.08^{a}	16.34^{a}	21.31^{a}	18.82^{a}	17.21^{a}	50.75^{a}	33.98^{a}
46	132.65^{a}	143.00^{a}	137.82^{a}	14.83^{b}	21.33^{a}	18.08^{a}	17.08^{ab}	35.62^{b}	26.35^{ab}
LSD $_{0.05}$	5.62	8.16	6.21	1.05	1.38	1.98	1.29	3.38	8.79
CV	5.12	6.98	7.99	8.01	7.75	18.72	9.24	10.14	14.29

Table 4. Effect of nitrogen and phosphorus on grain yield (kg ha^{-1}) of sorghum at Aybra over year combined.

N level (kg ha^{-1})	P level (kg ha^{-1})		
	0	23	46
0	1172.5^{e}	1507.1^{de}	1559.0^{d}
23	2104.0^{c}	2293.8^{bc}	2959.2^{a}
46	1480.2^{de}	2404.9^{bc}	2111.3^{c}
69	1656.5^{d}	2546.2^{b}	2301.2^{bc}
LSD $_{5\%}$		348.99	
CV %		15.04	

Table 5. Effect of nitrogen and phosphorus on biomass yield (kg/ha) of sorghum at Aybra.

N level (kg ha^{-1})	P level (kg ha^{-1})		
	0	23	46
0	5086.3^{g}	7126.6^{f}	7433.2^{f}
23	9048.0^{e}	10810.9^{cd}	12018.8^{bcd}
46	10679.4^{d}	13407.4^{ab}	11382.2^{cd}
69	9058.6^{e}	13731.5^{a}	12151.0^{ab}
LSD $_{5\%}$		1410	
CV %		12.01	

Table 6. Partial budget analysis.

N	P_2O_5	Unadjusted yield	Adjusted	Gross benefit	Costs that varies	Net benefit	MRR%
0	0	1172.5	1055.25	7386.75		7386.75	
0	23	2104	1893.6	13255.2	608.5	9256.52	307
0	46	1480.2	1332.18	9325.26	1217	8108.26	D
0	69	1656.5	1490.85	10435.95	1825.5	8610.45	D
23	0	1507.1	1356.39	9494.73	755.5	8739.23	D
23	23	2293.8	2064.42	14450.94	1364	13086.94	714
23	46	2404.9	2164.41	15150.87	1972.5	13178.37	15
23	69	2546.2	2291.58	16041.06	2581	13460.06	46
46	0	1559	1403.1	9821.7	1511	8310.7	481
46	23	2959.2	2663.28	18642.96	2119.5	16523.46	1349
46	46	2111.3	1900.17	13301.19	2728	10573.19	D
46	69	2301.2	2071.08	14497.56	3336.5	11161.06	D

Table 7. Combined ANOVA for the effect of N and P fertilizers on the plant height, sorghum head length, head weight, grain yield and biomass.

Source of variation	DF	Mean square values				
		Plant Height	Length Sorghum Head	Head Weight	Grain Yield	Biomass Yield
N	3	1185.19**	10.99*	318.59***	10591267.03***	140261599.0**
P	2	152.80**	0.84^{ns}	115.75^{ns}	1267516.55**	1058796.5*
N*P	6	170.91**	2.46^{ns}	422.81***	1010479.64**	7253023.4**
Year	1	4402.58**	14.35**	375.63*	23109478.2**	483484.8*
Rep	2	25.98^{ns}	1.38^{ns}	5.59^{ns}	81695.80^{ns}	296755.9^{ns}
Error	40	660.77	48.18	2170.78	41557.58	458748.6

Table 8. Effect of nitrogen and phosphorus on grain yield (kg ha^{-1}) of sorghum at Lalibella.

Treatment	Plant height cm			Length of sorghum head cm			Weight of sorghum head gm		
N kg ha^{-1}	1st year	2nd year	Comb	1st year	2nd year	Comb	1st year	2nd year	Combined
0	140.80^{b}	156.69^{d}	149.17^{d}	19.11^{b}	18.63^{c}	18.87^{b}	40.12^{c}	44.60^{b}	40.96^{b}
23	146.78^{b}	161.73^{c}	156.50^{c}	19.51^{ab}	20.42^{b}	19.96^{a}	55.48^{a}	47.28^{b}	50.39^{a}
46	154.44^{a}	171.07^{b}	163.97^{b}	19.46^{ab}	21.11^{ab}	20.28^{a}	42.92^{bc}	54.60^{a}	47.84^{a}
69	154.46^{a}	179.26^{a}	167.38^{a}	19.95^{a}	21.44^{a}	20.70^{a}	44.13^{b}	56.37^{a}	49.11^{a}
$LSD_{0.05}$	6.48	3.43	2.73	0.83	0.93	0.73	2.94	4.04	4.96
P_2O_5 kg ha^{-1}									
0	146.86^{b}	165.88b	157.84b	19.35a	20.18^{a}	19.76a	45.74^{b}	47.49^{b}	46.28a
23	147.93^{ab}	168.94a	157.96b	19.66a	20.54^{a}	19.96a	49.27^{a}	53.71^{a}	49.56a
46	152.57^{a}	168.41a	162.17a	19.51a	20.76^{a}	20.14a	41.98^{c}	50.94^{ab}	45.39a
$LSD_{0.05}$	5.61	1.33	2.37	ns	ns	ns	2.54	3.5	ns
CV	4.46	8.91	5.23	4.41	5.19	5.49	6.61	8.19	15.64

Table 9. Effect of nitrogen and phosphorus on grain yield (kg ha^{-1}) of sorghum at Lalibella.

N level (kg ha^{-1})	P level (kg ha^{-1})		
	0	23	46
0	1698.4^{d}	2160.2^{dc}	1718.9^{d}
23	2607.7^{bc}	3822.6^{a}	3319.6^{ab}
46	2790.0^{bc}	3846.4^{a}	2887.6^{bc}
69	2454.4^{dc}	3888.3^{a}	3293.4^{ab}
$LSD_{0.05}$		800.16	
CV %		7.09	

Table 10. Effect of nitrogen and phosphorus on sorghum biomass yield (kg ha^{-1}).

N level (kg ha^{-1})	P level (kg ha^{-1})		
	0	23	46
0	8993^{d}	10387^{cd}	9786^{d}
23	12452^{bcd}	18253^{ab}	18156^{ab}
46	12493^{bcd}	17212^{bc}	18628^{ab}
69	12184^{bcd}	24924^{a}	17554^{b}
$LSD_{0.05}$		6983	
CV %		18.55	

Table 11. Partial budget analysis for sorghum cultivation.

P	N	Unadjusted yield kg ha^{-1}	Adjusted kg ha^{-1}	Gross benefit	Costs that varies	Net benefit	MRR%
0	0	1698.4	1528.56	10959.77		10959.77	
0	23	2607.7	2346.93	16827.4881	557.5	16269.97	952
0	46	2790	2511	18003.87	1115	16888.87	111
0	69	2454.4	2208.96	15838.24	1672.5	14165.74	D
23	0	2160.2	1944.18	13939.77	662.5	13277.27	D
23	23	3822.6	3440.34	24667.23	1220	23447.23	1083
23	46	3846.4	3461.76	24820.81	1777.5	23043.31	-72
23	69	3888.3	3499.47	25091.19	2335	22756.19	D
46	0	1718.9	1547.01	11092.06	1325	9767.06	D
46	23	3319.6	2987.64	21421.37	1882.5	19538.87	D
46	46	2887.6	2598.84	18633.68	2440	16193.68	D
46	69	3293.4	2964.06	21252.31	2997.5	18254.81	D

Conclusion

The result shows that Nitrogen and phosphorous fertilizer for sorghum production could make an important contribution to optimize profit through increasing production and productivity in the areas. Mean grain yield of sorghum significantly affected by treatment combination of NP fertilizer rate. However, N and P fertilizers are very important nutrients for plant growth, development and productivity of land and as well the production of the crops in the study area. Application of 23 kg P_2O_5 ha^{-1} and 46 kg N ha^{-1} is found to be the appropriate rate for optimum productivity of sorghum and recommended as first option and 23 kg P_2O_5 ha^{-1} with 23 kg N ha^{-1} as second option in Sekota (Aybra) and the same agro ecology area. Whereas Application of 23 kg N ha^{-1} and 23 kg P_2O_5/ha is found to be the appropriate rate for optimum productivity of sorghum and recommended in Lalibella (Shumsha) and the same agro ecology area.

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