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Effect of Varying Lopping Schedules and Stump Heights on Growth, Fodder Yield and Quality of Dual-purpose Barley (*Hordeum distichon* L.)

Sonia[1], Barkha[1], Kangujam Bokado[1], Heisnam Sobhana Devi[1]

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ABSTRACT

Background: The present study investigated the effect of lopping schedules and stump heights on the growth, fodder yield and quality of dual-purpose barley to optimise fodder production from existing cropping patterns in Punjab during winters.

Methods: An experiment was carried out during the *rabi* seasons of 2022-23 and 2023-24 at the agriculture farm of Lovely Professional University, Phagwara, Punjab with 10 treatments *viz*., T_1: No lopping, T_2: Lopping @ 30 DAS + 1-inch stump height, T_3: Lopping @ 30 DAS + 2 inches stump height, T_4: Lopping @ 30 DAS + 3 inches stump height, T_5: Lopping @ 45 DAS + 1 inch stump height, T_6: Lopping @ 45 DAS + 2 inches stump height, T_7: Lopping @ 45 DAS + 3 inches stump height, T_8: Lopping @6 0 DAS + 1-inch stump height, T_9: Lopping @ 60 DAS + 2 inches stump height, T_{10}: Lopping @ 60 DAS + 3 inches stump height, replicated four times in randomized block design. Growth parameters, fodder yield and quality parameters were recorded.

Result: Though, the higher green fodder yield (10.9 t/ha) was obtained under lopping at 60 DAS with a 1inch stump height, to maintain quality and further regeneration of crop, lopping done at 30 DAS with 3 inches stump height was found to be better with considerable green fodder yield (2.5 t/ha). Lopping in dual-purpose barley should be done at early vegetative stages to obtain a considerable amount of quality green fodder, as it provides sufficient time for the crop to regenerate further.

Key words: Dual-purpose barley, Green fodder yield, Lopping time, Stump height.

INTRODUCTION

Barley, the fourth most important cereal crop globally, is cultivated for its grains and green fodder. It's grown on over 50 million hectares of land globally, producing 150.9 million metric tonnes per hectare. India produced about 1.91 million metric tonnes of barley on an average of 27.3 quintals per hectare in 2023, over 617.5 thousand hectares, while Punjab produced around 21,100 tonnes over 5,500 hectares, resulting in a yield of 3.84 tonnes per hectare (DES, 2023; USDA, 2023).

In modern agriculture, dual-purpose barley has become popular as a versatile crop that offers both fodder and grains in adverse climatic conditions and possesses a good regeneration capacity. In the arid and semi-arid areas of India, small and marginal farmers use barley to address the scarcity of green fodder during the lean winter period without compromising grain production (Manju *et al.*, 2019). Lopping before the jointing stage for fodder production and optimal stump height influences regeneration, root systems, nutrient allocation and photosynthesis, all of which affect the plant's regeneration. Early lopping of barley resulted in higher-quality fodder than later lopping (Prasanna *et al.,* 2024). Additionally, delaying sowing negatively affected both fodder quality and grain production (Singh *et al.,* 2017).

Fodder quality is mainly assessed by its digestibility, with major quality parameters being crude protein (protein), which is generally required for tissue growth and milk production and crude fibre (fibre), which supports the effective digestion system and nutrient absorption. An adequate amount of ash content in fodder results in better bone health and metabolic processes. Lower amounts of ADF (indigestible fibre) in fodder allow the animals to extract more nutrients and energy, which results in boosting their productivity. Moderate levels of NDF (total fibre) maintain proper rumen function and prevent digestive disorders in animals (Van Soest *et al.,* 1991).

In most parts of Punjab, the dairy sector holds equal significance as crop production, but due to a significant imbalance between the availability and demand of feed, especially during winters, it is adversely affected (Dhillon and Ram, 2021). The availability of green fodder in the Punjab region is only 28.4kg/animal, falling short of the required 40.0 kg /animal (Dhillon *et al.,* 2018).

[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India.

Corresponding Author: Barkha, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India. Email: barkhasingh57@gmail.com
ORCID: https://orcid.org/0000-0002-0715-0285

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As many farmers in Punjab already grow barley for their grain, quality green fodder supply for their livestock can also be managed from the same without any need to grow a separate fodder crop. Thus, to mitigate the fodder shortage during the lean period in winter from the existing cropping pattern, this investigation was carried out to evaluate the effect of various lopping schedules and stump height on dual-purpose barley.

MATERIALS AND METHODS

A field experiment was carried out at Lovely Professional University in Phagwara, Punjab, during the *rabi* seasons of 2022-23 and 2023-24. The site is at an elevation of 254 m. The temperature ranged from 33.1°C to 7.1°C in 2022-23 and 33.8°C to 6.2°C in 2023-24, with rainfall totals of 116.6 mm and 142.2 mm. The soil was sandy loam and its chemical properties were assessed before the experiment shown in Table 1.

Preliminary information

The experiment was organised in a randomised block design with ten treatments and four replications. The treatments include- T_1: No lopping (Control), T_2: Lopping @ 30 DAS + 1-inch stump height, T_3: Lopping @ 30 DAS + 2 inches stump height, T_4: Lopping @ 30 DAS + 3 inches stump height, T_5: Lopping @ 45 DAS + 1-inch stump height, T_6: Lopping @45 DAS + 2 inches stump height, T_7: Lopping @ 45 DAS + 3 inches stump height, T_8: Lopping @ 60 DAS + 1 -inch stump height, T_9: Lopping @ 60 DAS + 2 inches stump height, T_{10}: Lopping @ 60 DAS + 3 inches stump height.

DWRUB-52 was sown at 100 kg ha^{-1} on November 19, 2022 and November 18, 2023, using a single-row hand drill at a 5 cm depth and 22.5 cm row spacing. A total of 75:30:20 NPK kg ha^{-1} was applied, with nitrogen in three splits. The crop was irrigated three times: once before sowing and twice during critical stages. Broadleaf weeds were controlled with 2,4-D herbicide and one manual weeding.

Biometric observations

Five plants per plot were measured for height at 30, 60, 90, 120 days and maturity. Whole plant samples from borders were collected for dry matter assessment, using Radford's (1967) formulas for growth parameters.

The equations used for the computations are as follows:

$$\text{Crop growth rate (g/m}^2\text{/day)} = \frac{W2 - W1}{(t2 - t1)\,S}$$

$$\text{Relative growth rate (g/g/day)} = \frac{\ln W2 - \ln W1}{(t2 - t1)}$$

$$\text{Absolute growth rate (g/day)} = \frac{W2 - W1}{(t2 - t1)}$$

Whereas,

W1 and W2 = weights of dry matter (g) at times t1 and t2.

S = area and lnW1 and lnW2 are their natural logs.

Green fodder yield and quality

Green fodder lopping was done manually in the net plot area, excluding T1-No cutting. The other treatments were lopped as specified and allowed to regenerate. Green fodder was measured per hectare and stump regrowth was monitored. Plant samples were collected, dried at 60°C, ground and analysed for quality using standard procedures in Table 2.

Statistical analysis

Statistical analysis was performed using microsoft excel with ANOVA based on a randomised block design. Nine treatments were assessed for green fodder yield, regeneration

Table 1: Chemical properties of the soil (2022-23 and 2023-24).

Soil parameters	2022-23	2023-24	Procedure
Available N (kg ha^{-1})	223	231	Kjeldahl's method (Jackson, 1973)
Available P_2O_5 (kg ha^{-1})	29.3	32.5	Olsen's method (Olsen, 1954)
Available K_2O (kg ha-^{1})	160	184	Flame photometry (Jackson, 1973)
EC	0.41	0.44	Potentiometry (Jackson, 1973)
Soil pH	7.6	7.9	Potentiometry (Jackson, 1973)

Table 2: Formula used for green fodder quality parameters.

Parameter	Formulae	Reference
Crude protein (%)	= Vol. of 0.01*N* H_2SO_4* Vol. made (ml) *0.0014*6.25/Aliquot taken* wt. of sample on DW basis*100	AOAC (2001)
Crude fibre (%)	= Wt. of the crucible with dry residue - Wt. of the crucible with ash/ Wt. of the sample*100	AOAC, (2000)
Acid detergent fibre (%)	= (Wt. of crucible + fibre) - Empty Wt. of crucible/ Wt. of dry sample* 100	Goering and Van Soest (1970)
Neutral detergent fibre (%)	= wt. of crucible + Ash- wt. of crucible/wt. of dry sample	Thiex *et al.* (2012)
Ash content (%)	= *100 After complete ashing, weight of crucible + ash - weight of empty crucible/weight of crucible + sample-weight of empty crucible *100	

days and quality, excluding treatment T1 due to no lopping. The least significant difference (LSD) and standard error of the mean (SEM) were calculated at the 5% significance level.

RESULTS AND DISCUSSION

Growth parameters

Data presented in Table 3 showing the periodical plant height (cm) of dual-purpose barley revealed that till 30 DAS, there was no significant influence on plant height since no treatment was given till that time. At 60 DAS, T_8 (51.6) showed a significantly higher plant height, which was statistically at par with T_1(51.4 cm) and T_9 (50.6). In later stages, *i.e.* 90, 120 days and at harvest, T_1(86.1, 102.9 and 104.1) showed maximum plant height, followed by T_4(82.8, 99.0 and 99.6). Treatment shows significant results later due to lopping time, stump height and an extra 15-30 days for vegetative growth in plants at 45 and 60 DAS. These results are supported by Lal and Saini, 2016; Dudi *et al.*, 2019; Neelam *et al.*, 2022.

Throughout the entire experiment in both years, dry matter accumulation (g/mrl) was recorded as maximum in T_1(193.2), followed by T_4, except during 60 DAS due to lopping. The early growth stage shows non-significant data in dry matter accumulation (DMA). At 60 DAS, significantly, the highest DMA was recorded in T1(193.2), which is statistically at par with T_8(192.2), T_{10} (188.9) and T_9(184.3). At 90, the significantly highest DMA was recorded in T_1(291.2), which is statistically at par with T_4 (280.4). Significantly higher values are recorded at 120 and harvest is recorded in T_1(296.4, 301.2).

Data in Table 4 shows the growth between 0-30 DAS was non-significant in both AGR and CGR. Between 30-60 DAS interval, highest AGR and CGR was recorded in T_9 (2.05 g/plant/day, 8.20 g m^{-1} row length day^{-1}) which is followed by T_{10}(1.99 g/plant/day, 7.99 g m^{-1} row length day^{-1}), T_8 (1.95 g/plant/day, 7.83 g m^{-1} row length day^{-1}) and T_1(1.92 g/plant/day, 7.71 g m^{-1} row length day^{-1}). Growth rate between 60-90 and 90-120 DAS shows significantly higher growth in both AGR and CGR in T_1 (1.93 g/plant/day, 3.96 and 7.42 g m^{-1} row length day^{-1}, 16.81 g m^{-1} row length day^{-1}). Growth between 120- harvest shows a significantly higher growth rate in T_4 (0.83 g/plant/day, 3.35 g m^{-1} row length day^{-1}), which is followed by T_1(0.82,3.29 g m^{-1} row length day^{-1}).

Relative growth rate shows non-significant results between 0-30 and 60-90 DAS (Table 4). However, between 30-60 DAS, the significantly highest growth was recorded at T_{10} (0.016 g g^{-1} day^{-1}), followed by T_8 and T_9 (0.016 g g^{-1} day^{-1}). In 90-120 DAS, T_8 (0.0096 g g^{-1} day^{-1}) shows the most comparable RGR, followed by T_9 and T_{10} (0.0093 g g^{-1} day^{-1}). From 120 DAS to harvest, T_1, T_3 and T_4 (0.0013 g g^{-1} day^{-1}) show higher results.

Taller stumps preserve nutrients, provide energy for the new shoots and absorb sunlight, while growth hormones such as auxins and cytokines boost cell division and elongation (Meena *et al.*, 2017; Nand *et al.*, 2019).

Table 3: Effect of lopping schedules and stump height on plant height and dry matter accumulation of dual-purpose barley (pooled data of 2022-23 and 2023-24).

Treatment	Plant height (cm)					Dry matter accumulation (g) / m row length				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1: Control (No lopping)	24.6	51.4	86.1	102.9	104.1	14.1	193.2	291.2	296.4	301.2
T_2: Lopping at 30 DAS + 1-inch stump height	24.7	23.0	76.9	95.1	95.8	13.4	96.5	263.0	266.9	269.6
T_3: Lopping at 30 DAS + 2 inches stump height	24.5	25.8	79.8	96.2	97.0	14.2	107.9	275.9	279.3	281.0
T_4: Lopping at 30 DAS + 3 inches stump height	25.0	28.6	82.8	99.0	99.6	13.3	119.7	280.4	284.2	287.1
T_5: Lopping at 45 DAS + 1-inch stump height	24.1	42.5	64.2	90.6	91.6	13.5	148.8	220.2	228.6	231.6
T_6: Lopping at 45 DAS + 2 inches stump height	24.1	45.2	69.9	92.9	93.7	13.4	155.8	230.8	238.0	241.3
T_7: Lopping at 45 DAS + 3 inches stump height	24.4	47.9	75.0	94.1	94.8	13.8	164.4	248.0	253.3	255.8
T_8: Lopping at 60 DAS + 1-inch stump height	24.3	51.6	41.2	79.7	80.4	13.9	192.2	182.1	194.9	203.4
T_9: Lopping at 60 DAS + 2 inches stump height	24.7	50.5	46.9	82.8	83.3	13.8	184.3	191.5	202.4	209.2
T_{10}: Lopping at 60 DAS + 3 inches stump height	23.4	50.3	55.4	84.7	85.2	13.7	188.9	198.8	210.7	214.9
SE(m)±	0.6	0.4	0.4	0.9	0.9	0.5	3.1	3.9	3.8	3.6
CD (P=0.05)	NS	1.1	1.1	3.0	3.1	NS	8.8	11.2	10.8	10.3

Table 4: Effect of lopping schedules and stump height on the absolute growth rate and crop growth rate of dual-purpose barley (pooled data of 2022-23 and 2023-24).

Treatment	Absolute growth rate (g/plant/day)					Crop growth rate (g m^{-1} row length day^{-1})				
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120- harvest	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120- harvest
T_1: Control (No lopping)	1.00	1.92	1.93	3.96	0.82	4.00	7.71	7.42	16.81	3.29
T_2: Lopping at 30 DAS + 1-inch stump height	1.08	1.08	1.41	3.50	0.74	4.34	4.34	6.68	14.83	2.99
T_3: Lopping at 30 DAS + 2 inches stump height	0.99	1.32	1.68	3.68	0.78	3.98	5.29	6.91	15.01	3.15
T_4: Lopping at 30 DAS + 3 inches stump height	1.05	1.33	1.69	3.83	0.83	4.22	5.35	7.28	15.42	3.35
T_5: Lopping at 45 DAS + 1-inch stump height	0.98	1.48	1.11	2.42	0.58	3.93	5.92	5.88	13.72	2.35
T_6: Lopping at 45 DAS + 2 inches stump height	0.99	1.63	1.30	2.74	0.62	3.95	6.55	6.09	14.00	2.48
T_7: Lopping at 45 DAS + 3 inches stump height	0.98	1.81	1.56	2.98	0.67	3.91	7.27	6.32	14.46	2.71
T_8: Lopping at 60 DAS + 1-inch stump height	0.98	1.95	0.85	1.73	0.50	3.93	7.83	5.36	12.80	2.02
T_9: Lopping at 60 DAS + 2 inches stump height	1.02	2.05	0.90	2.04	0.52	4.07	8.20	5.50	13.29	2.11
T_{10}: Lopping at 60 DAS + 3 inches stump height	0.99	1.99	1.20	2.24	0.55	3.95	7.99	5.74	13.49	2.21
SE(m)±	0.02	0.06	0.06	0.08	0.01	0.11	0.27	0.17	0.27	0.07
CD (P=0.05)	NS	0.21	0.18	0.28	0.05	NS	0.86	0.50	0.78	0.21

Table 5: Effect of lopping schedules and stump height on the relative growth rate, green fodder yield and regeneration of dual-purpose barley (pooled data of 2022-23 and 2023-24).

Treatment	Relative growth rate (g g^{-1} day^{-1})					Green fodder yield(t/ha)	Days taken for regeneration
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120- harvest		
T_1: Control (No lopping)	0.0690	0.015	0.0071	0.0090	0.0013	-	-
T_2: Lopping at 30 DAS + 1-inch stump height	0.0703	0.010	0.0064	0.0086	0.0012	2.9	10
T_3: Lopping at 30 DAS + 2 inches stump height	0.0690	0.012	0.0065	0.0083	0.0013	2.7	12
T_4: Lopping at 30 DAS + 3 inches stump height	0.0698	0.011	0.0069	0.0085	0.0013	2.5	13
T_5: Lopping at 45 DAS + 1-inch stump height	0.0689	0.013	0.0069	0.0090	0.0012	7.9	13
T_6: Lopping at 45 DAS + 2 inches stump height	0.0690	0.014	0.0065	0.0087	0.0013	5.9	15
T_7: Lopping at 45 DAS + 3 inches stump height	0.0687	0.015	0.0064	0.0087	0.0012	4.5	17
T_8: Lopping at 60 DAS + 1-inch stump height	0.0687	0.016	0.0069	0.0096	0.0008	10.9	15
T_9: Lopping at 60 DAS + 2 inches stump height	0.0693	0.016	0.0068	0.0093	0.0009	9.6	17
T_{10}: Lopping at 60 DAS + 3 inches stump height	0.0688	0.016	0.0067	0.0093	0.0010	8.6	19
SE(m)±	0.00041	0.0004	0.0002	0.0001	0.0001	0.2	0.3
CD (P=0.05)	NS	0.0012	NS	0.00051	0.0003	0.6	0.9

Green fodder yield

Data presented in Table 5 revealed that significantly higher green fodder yield (t ha^{-1}) was recorded in T_8 (10.9), followed by T_9 (9.6), which stayed at par. Lopping at 60 DAS yields more fodder than at 45 and 30 DAS due to higher later vegetative biomass. Similar results are reported by (Dhillon *et al.*, 2021). However, to get substantial fodder yield along with optimum grain yield in dual-purpose crops, it is important to decide on the right stage of harvesting (Singh *et al.*, 2017). So, lopping done at 30 DAS with stump heights of 1-inch (2.9), 2-inch (2.7) and 3-inch (2.5) is better as cutting plants at an early stage gives them sufficient time for regeneration and further growth.

Days taken for regeneration

The regeneration after lopping in barley is illustrated in Fig 1. Among all treatments, T_2(10 days) led to shorter regeneration times. Early lopping focuses energy on root and shoot growth, improving regeneration without affecting grain yield. However, cutting the crop at 60 DAS occurred under poor temperature conditions, delaying barley regeneration. The findings are further supported by Dhillon and Ram, 2021.

Quality parameters

For desirable fodder quality, it should have higher levels of crude protein (%) and crude fibre (%) along with lower levels of ash content (%), neutral detergent fibre (%) and acid detergent fibre (%). Pooled data in Table 6 revealed that the lopping done in T_4 (15.23) contained remarkably richer crude protein, which was statistically at par with T_3(15.10). It also resulted in significantly lower neutral detergent fibre (40.28) and acid detergent fibre (21.77), which is desirable for livestock. Significantly higher crude fibre content was recorded in T_8 (25.17). Significantly lower ash content in

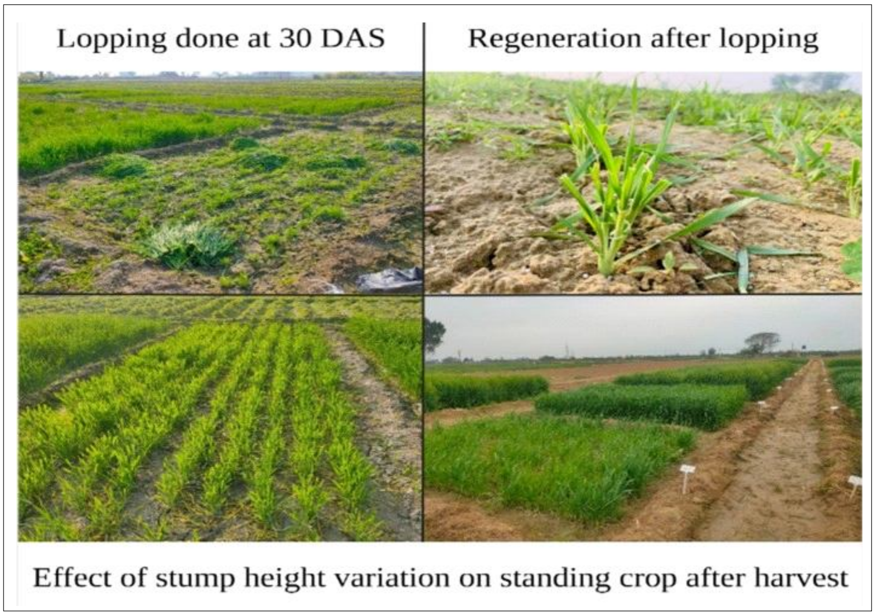

Fig 1: Impact of lopping time and stump height on regeneration of dual-purpose barley.

Table 6: Effect of lopping schedules and stump height on quality of green fodder barley (pooled data of 2022-23 and 2023-24).

Treatment	Crude protein%	Crude fibre%	Ash content%	Neutral detergent fibre %	Acid detergent fibre %
T_1: Control (No lopping)	-	-	-	-	-
T_2: Lopping at 30 DAS + 1-inch stump height	14.67	14.6	7.9	45.82	26.50
T_3: Lopping at 30 DAS + 2 inches stump height	15.10	14.5	8.4	41.77	22.99
T_4: Lopping at 30 DAS + 3 inches stump height	15.23	12.8	8.9	40.28	21.77
T_5: Lopping at 45 DAS + 1-inch stump height	13.44	19.98	10.20	53.49	32.66
T_6: Lopping at 45 DAS + 2 inches stump height	14.12	17.79	10.71	50.18	30.95
T_7: Lopping at 45 DAS + 3 inches stump height	14.47	15.38	11.50	48.34	29.24
T_8: Lopping at 60 DAS + 1-inch stump height	9.99	25.17	13.37	59.81	37.24
T_9: Lopping at 60 DAS + 2 inches stump height	10.85	24.42	14.62	56.63	35.81
T_{10}: Lopping at 60 DAS + 3 inches stump height	11.36	24.12	15.24	55.55	33.93
SE(m)±	0.2	0.1	0.1	0.3	0.2
CD (P=0.05)	0.8	0.4	0.4	0.9	0.8

fodder was recorded under T_2 (7.9). Good quality green fodder can be obtained until the flowering stage and lopping after this stage will impact quality and regeneration capacity (Singh *et al.*, 2017). Higher crude protein content results from enhanced photosynthetic activity, food allocation and metabolically active tissue, contributing to growth and energy generation (Balfany *et al.,* 2023; Sarkar *et al.*, 2020).

As the plants mature, they accumulate more structural carbohydrates for structural integrity and cell development and the feed concentration rises due to higher nutritional absorption (Lee, 2018; Hundal *et al.,* 2014; Meena *et al.,* 2016). Higher neutral detergent fibre and acid detergent fibre values are a result of structural carbohydrates like cellulose, hemicellulose and lignin accumulating in later stages; these components provide rigidity, nutrient redistribution and protection against environmental stress (Osho *et al.,* 2013). Similar results were also reported by Ishrath *et al.,* (2018).

CONCLUSION

Based on the results obtained, it can be concluded that lopping barley at 60 DAS will give a higher green fodder yield. However, as it is a dual-purpose crop and grains are to be harvested, lopping should be done at 30 DAS at 3-inch stump height to obtain a considerable amount of good-quality green fodder. Fodder quality deteriorates with advancing age and lopping at an earlier growth stage also results in quicker regeneration for further development to achieve optimum grain production.

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Conflict of interest

The authors declare that there is no conflict of interest.

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