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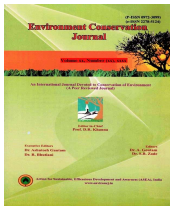

Growth, yield and economic analysis of eucalypts-barley based agroforestry system in semi-arid region of India

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ABSTRACT

The present investigation was carried out in the research area of Department of Forestry, CCS Haryana Agricultural University, Hisar during the year 2017-18 to evaluate the effect of 2.8 years old already established eucalypts plantation at 7×3 m on growth, yield attributes and yield of barley. The maximum growth increment in plant height (14.1 m) and diameter at breast height (10.3 cm) of eucalypts was recorded under agroforestry than sole eucalypts (without crop). The maximum plant height (98.5 cm), dry matter accumulation (1098.3 g/m^2), tillers/ m^2 (360.5), grain yield (3.28 t/ha), straw yield (4.32 t/ha) and biological yield (7.60 t/ha) were observed at harvesting of barley in control (devoid of eucalypts trees) than barley intercropped with eucalypts. However, maximum number of days taken for spike emergence (50 %) (97.4 days) and days to maturity (139.4 days) of barley were recorded under eucalypts plantation. The average per cent reduction of 11.33 % in effective tillers/ m^2, 15.15 % in spike length and 16.62 % in number of grains per spike in barley was recorded under eucalypts plantation over control. Maximum net return (Rs. 93347.1 ha^{-1}) was observed under eucalypts + barley cropping system than control. The overall B:C ratio was calculated higher in eucalypts based agroforestry system (1.73) over control (1.15).

Introduction

The country's total forest cover is 7,13,789 square kilometers, i.e., 21.71% of India's total geographical area (ISFR,2021). Haryana state with geographical area of 4.42 m ha is predominantly an agrarian state having 80 per cent of its area under intensive, technical and mechanical agriculture. According to ISFR (2021) report, Haryana's Forest and tree cover is 6.85 % of its total geographical area. Out of 6.85 %, the forest cover is 3.63 %, and the rest 3.22 % is the tree cover. In view of the prevailing socio-economic and agroclimatic conditions favorable for agriculture in the state, it is also not possible to divert the fertile agriculture to forest. The only option to increase area under tree

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cover is to integrate the tree species with agricultural crop on farm lands. Agroforestry system greatly contribute toward production of wood for industrial and other commercial purposes, besides maintaining ecological balance, uplifting of socio-economic status of the farmers and at the same time diversify the traditional rice-wheat crop rotation (Chauhan *et al.,* 2012). Woody perennial based production system has a great potential to combat the problem of sustainability. Historically, agroforestry in India involves two distinct pathways, *viz*; growing food crops in the forest and establishing tree crop production system on arable land (Kumar, 2006). Among mainly commercial tree species, eucalypts is considered as one of the most important agroforestry tree species in India. Brazil being the top which covers maximum area (41.17 %) of eucalypt spp. plantation followed by China (32.61 %), Chile (8.87 %), Sudan (6.54 %), Australia (6.47 %), India (2.86 %), Argentina (1.34 %) and least in Myanmar (0.09%) (Raj *et al.,* 2016). While it is considered as most water demanding due to its evergreen nature (Soare and Almeida, 2001) and also tends to show a great amount of allelopathic effect on nearby plants which causes an adverse effect on growth of nearby other plants. Eucalypts planting in India started taking shape through extension activities of the state forest departments in the late sixties and early seventies. Barley (*Hordeum vulgare*), is a nutrient rich cereal and occupies an area of 0.61 million hectare producing 1.82 million tonnes grain with productivity of 29.88 q/ha. It was cultivated on 19,400 hectares with a production of 74,000 tons in Haryana and ranked second in average productivity (38.03 q/ha) after Punjab (39.51 q/ha) during 2020-21 (ICAR-IIWBR, 2021). Eucalypts based agroforestry is also highly suitable for winter crops, such as barley, among farmers in Northern India, due to its low shading problem. Based on the tree-crop combinations, eucalypts-based agroforestry systems act as a sink and source for minerals. However, due to competition for nutrients and shading problem, generally the performance of crop grown in interspaces of eucalypts is found suppressed with lower yields (Chauhan, 2012). Hence, keeping in view the importance of agroforestry in present day context together with its importance in maintaining ecological balance and upliftment of the socio-economic status of the farmers greatly contributes toward production of wood for industries and other commercial purposes, the present investigation was planned to study the performance of barley under eucalypts based agroforestry system.

Material and Methods

The experimental site is located at 29° 10' N latitude and 75° 43' E longitude at an elevation of 215 m above mean sea–level in the semi-arid environment of North-Western India. The climate is subtropical-monsoonal, with an annual rainfall of 350-400 mm, 70% of which occurs between July to September. The summer months are very hot with mean maximum temperature ranging from 40 to 45°C in May and June whereas; December and January are the coldest months. The mean monthly values of weather parameters viz., temperature, evaporation and rainfall recorded at the meteorological observatory located at Research Farm, CCS Haryana Agricultural University, Hisar during the experimental period is shown in Figure 1.

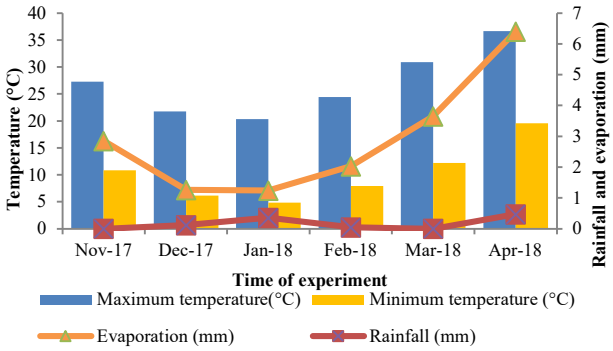

Figure 1: Monthly weather data (Temperature, Rainfall and Evaporation) of experimental site

Soil chemical properties were analyzed by following standard procedures for EC (Jackson, 1973), pH (Jackson, 1973), low organic carbon (Walkley and Black, 1934) and available nitrogen (Subbiah and Asija, 1956), medium in available P (Olsen *et al*., 1954) and available K (Jackson, 1973). The present study was conducted in 2.8 years old plantation of *Eucalyptus teriticornis* planted at a spacing of 7×3 m. During winter (*Rabi*) season, Barley (*Hordeum vulgare*) cv. BH-393 was sown under eucalypts plantation and also in control

(devoid of tree) in the first week of November keeping a row to row distance of 22 cm with a seed rate of 86.45 kg/ha. In the nearby field barley was sown as control (devoid of tree). The recommended dose of fertilizers (59.28 kg N, 29.64 kg P_2O_5 and 14.82 kg K_2O ha^{-1}) were applied as per package of practices of CCSHAU, Hisar. The half amount of N and whole amount of P and K was applied at the time of sowing. The remaining dose of N through urea was top dressed at 1st irrigation. Observations on growth of barley were recorded grown under eucalypts and control (sole barley). The plant population of barley was recorded 20 days after sowing (DAS) by counting number of plants with in a running meter row length. Plant height (cm), fresh and dry matter accumulation (g) of barley was observed at 30 days interval and at harvest. For dry matter, the samples were first sun dried and then oven dried at 70°C till constant weight was attained and weighed on a digital balance. The number of days taken to 50 % spike emergence, duration of maturity, number of effective tillers, length of spike, number of grains/spike were recorded by physical appearance of plants and counting under eucalypts based agroforestry system as well as from control. Sun dried bundles of each plot were then weighed before threshing to record the biological yield and then threshed with the help of mini-plot-thresher, the clean grains obtained were weighed to record grain yield. Straw yield was obtained by subtracting the grain weight from biological yield and converted to t/ha using appropriate conversion factor. A composite sample of grains was taken from the final produce and 1000 grains were counted and weighed to record test weight in gram (g). Harvest index (%) and attraction index (%) were determined using formula:

Harvest Index (%) = [Grain yield/Biological yield] × 100

Attraction index (%) = [Grain yield/Straw yield] × 100

The height (m), diameter at breast height (cm) and crown spread (m) of ten randomly selected eucalypts under study was recorded before (October) and after harvesting of barley (April). The B: C ratio of both systems (eucalypts-barley agroforestry system and sole barley) was calculated.

Results and Discussion

Soil: The soil of experimental site is non-saline EC (0.78 dS/m), pH (7.9), low organic carbon (0.42%) and available nitrogen (140 kg/ha), medium in available P (12 kg/ha) and available K (284 kg/ha).

Growth performance of eucalypts: The overall growth pattern of eucalypts planted at 7×3 m spacing followed increasing trend with the advancement of age. The maximum growth increment in plant height (14.1 m) and dbh (10.3 cm) was recorded under eucalypts based agroforestry system after 3 year plantation. Sole eucalypts (without crops) resulted in lesser plant height (13.9 m) and dbh (10.1 cm) than planting of eucalypts with crops. However, no variation for crown spread was observed between eucalypts planted with crops and sole eucalypts (without crops). Comparatively higher growth of eucalypts with intercropping may be attributed to timely and adequate application of fertilizer, irrigation and other cultural operations. According to Pinto *et al.* (2005) the main limiting factor in agroforestry systems is the availability of solar radiation, which together with the competition for water and nutrients limits sugarcane yields in plants near to the forest species in *Eucalyptus grandis* and Sharma *et al.* (2022) observed that maximum growth of forest trees was recorded in agroforestry due to proper availability of nutrients and moisture.

Number of plants (per meter row length) and plant height (cm) :

The maximum plant population (55) of barley was recorded in control (sole crop) as compared to eucalypts based agroforestry system (44) and a reduction of 20 per cent was recorded as compared to control (Table 2). Present results are in conformity with the findings of Kumar *et al.* (2013), Chauhan *et al.* (2015) and Gawali *et al.* (2015). The maximum plant height (98.5 cm) of barley was found at harvest which is statistically at par at 120 DAS (94.8 cm) in control (sole barley). The reduction in plant height was 2.40, 11.04, 12.88, 13.29 and 15.23% at 30, 60, 90, 120 DAS and at harvest, respectively at different stages of crop growth under eucalypts plantation over control (Fig 2). The low interception of radiation under eucalypts based agroforestry system reduced the photosynthetic efficiency of barley which resulted in poor growth performance.

Table 1: Growth performance of eucalypts under agroforestry and sole eucalypts

Time	Height (m)		DBH (cm)		Crown Spread (m)	
	Agroforestry	Sole eucalypts	Agroforestry	Sole eucalypts	Agroforestry	Sole eucalypts
October,2017	12.2	12.4	9.2	9.4	2.7	2.8
April, 2018	14.1	13.9	10.3	10.1	3.1	3.1

Table 2: Number of plants per meter row length in barley at 20 DAS under eucalypts plantation and control

Treatments	Number of plants per meter row length
Eucalypts + Barley	44
Control (Sole barley)	55
t-value	7.99*

Table 3: Phenology of barley under eucalypts plantation and control

Treatments	Number of days taken	
	Spike emergence (50%)	Maturity
Eucalypts + Barley	97.4	139.4
Control (Sole barley)	82.2	123.5
t-value	12.16*	12.98

Table 4: Yield attributes of barley under eucalypts plantation and control

Treatments	Yield attributes			
	Number of effective tillers/m^2	Length of spike (cm)	No of grains/spike	Test weight (1000 grain wt) (g)
Eucalypts + Barley	312.4	11.2	32.1	36.4
Control (Sole barley)	352.3	13.2	38.5	41.2
t-value	16.76*	1.63	4.96*	3.48*

* Significant at 0.05 per cent level of P

Table 5: Economics of eucalypts + barley based agroforestry system and control (sole barley)

Particulars	Agroforestry	Sole crop (barley)
Cost of cultivation (Rs./ha)	127097.3	46920.5
Gross return (Rs./ha)	220444.4	53994.2
Net return (Rs./ha)	93347.1	7073.7
Cost/benefit ratio	1.73	1.15

Bhardwaj *et al.,* (2017) observed that the growth of barley crop was poor near the tree line when it intercropped with eucalypts boundary plantation and it increase with the increases of distance from tree line. The present findings are in line with the findings of Kumar *et al.* (2013) and Bisht *et al*. (2022) who reported that plant height of wheat was significantly more in sole crop than the intercropping with trees.

Fresh and dry matter accumulation (g/m^2): The maximum dry matter accumulation of barley in eucalypts plantation was found at the time of crop harvest however, lowest dry matter accumulation was recorded at 30 DAS. Barley grown in interspaces of eucalypts plantation showed a maximum reduction in fresh weight (Fig 3) and dry weight (Fig 4) 29.76%, 57.99%, 13.59%, 15.8%, 11.36% and 27.42%, 21.32%, 12.98%, 15.25% and 10.01% at 30, 60, 90, 120 DAS and at harvest, respectively than in control (devoid of tree). The lower fresh and dry matter accumulation of barley under eucalypts based agroforestry system might be due to the low availability of sunlight and more competition between tree and crop for moisture and nutrients than in control (devoid of tree). Similar findings are in close agreement with Bisht *et al*. (2022) who reported that the dry matter accumulation by different wheat varieties also

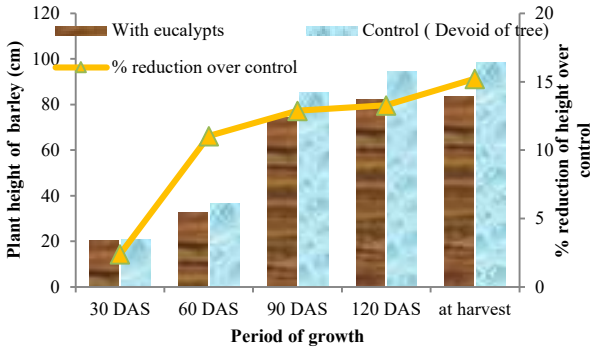

Figure 2: Plant height (cm) of barley at different time intervals under eucalypts plantation and control (sole barley)

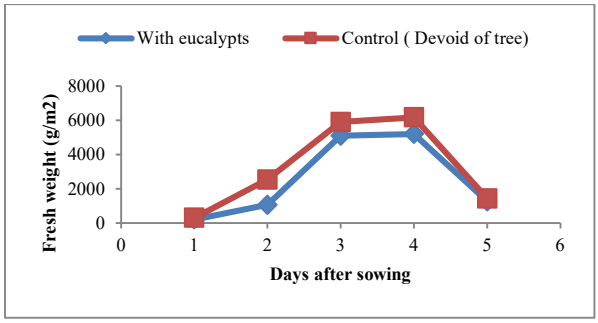

Figure 3: Fresh matter accumulation (g/m^2) at 30 days interval in barley under eucalypts plantation and control (sole barley).

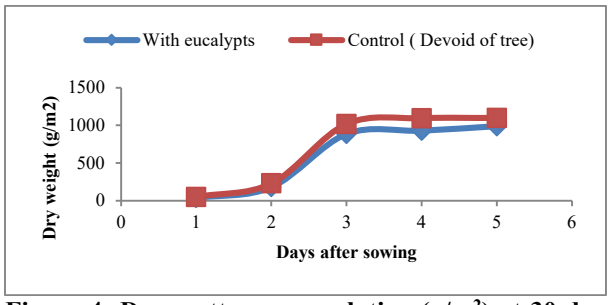

Figure 4: Dry matter accumulation (g/m^2) at 30 days interval in barley under eucalypts plantation and control (sole barley).

differed significantly among different spacings of eucalypts. Kumar and Rajput (2005) also reported that total dry matter accumulation differed significantly among wheat varieties under poplar based agroforestry system and under control. They further reported that variety UP 2338 recorded significantly more dry matter over all other varieties (WH 542, Raj 3077, PBW 154, HD 2285, HD 2329, UP 2113, UP 2003, PBW 226, UP 262 and PBW 343).

Number of tillers/m^2 : The maximum numbers of tillers were observed at 120 DAS and at harvest in both the systems (agroforestry and control). The average increase in the number of tillers between 60 to 90 DAS was higher as compared to increase between 90 to 120 DAS under eucalypts plantation as well as in control (Fig 5). However the numbers of tillers under eucalypts based cropping system reduced upto of 10.57 per cent over control (devoid of trees). Bijalwan and Dobriyal (2014) studied different varieties of wheat under *Grewia optiva* traditional agroforestry system. Results revealed that number of effective tillers was higher in control than agroforestry system. Kohali *et al.* (1997) reported that lesser number of tillers under poplar agroforestry system due to shading effect.

Phenological characters: The maximum number of days taken for spike emergence (50%) and days to maturity in barley were higher under eucalypts plantation in comparison to control (sole crop). In eucalypts based cropping system, both the phonological characters (spike emergence and maturity) of barley were delayed by about 15 days over control (sole crop) was possibly due to deprived photosynthetic ability of crop. Kumar *et al.* (2013) conducted a field experiment on wheat and mustard under eucalypts plantations. Results showed that spike length was significantly less under eucalypts than sole cropping. Daniel and Larkin (2017) also reported that grain per spike was more in control than agroforestry system.

Effective tillers/m^2, length of spike (cm),number of grains per spike and test weight (g): The reduction in effective tillers of barley under eucalypts was 11.33 per cent over control. The maximum spike length (13.2 cm) was observed in control (sole crop) as compared to eucalypts based agroforestry system (Table 4). Barley exhibited 15.15 per cent reduction in spike length under eucalypts plantation over control. These results are in line with the findings of Chauhan *et al.* (2011). They reported that the rate of decrease in spike length of wheat was 33.6% in 6 year old poplar plantation than control which ultimately reflected the grain yield. In sole barley maximum numbers of grains/spike were recorded whereas, minimum under eucalypts plantation. The reduction in the number of grains per spike was 16.62 per cent under eucalypts based agroforestry system over control (sole barley).

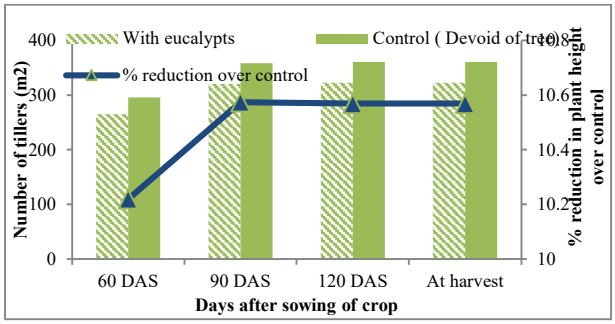

Figure 5: Number of tillers (m^2) in barley at 60, 90, 120 days after sowing and at harvest under eucalypts plantation and control (sole barley)

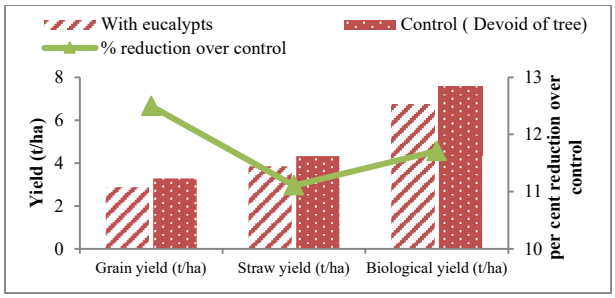

Figure 6: Grain, straw and biological yield (t/ha) of barley under eucalypts plantation and control (sole barley)

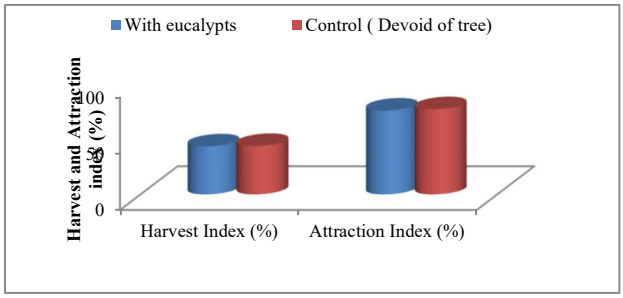

Figure 7: Harvest and attraction index (%) of barley under eucalypts plantation and control (sole barley)

Similar findings were also reported by Gandhi (2008) who found that the lower number of grains/spikes of wheat under poplar planted at 6×1.5 m, 6×3 m and 5×4 m spacing as comparison to control. Corroborative findings have also been reported earlier by Clemente *et al.* (2015) under *Eucalyptus teriticornis* based agroforestry system. In control, barley crop exhibited significantly higher test weight (41.2g) than under eucalypts based agroforestry system (36.4g). The reduction in test weight of barley was11.65 per cent under eucalypts plantation over control (devoid of tree). A significant decrease in 1000-garin weight of different agricultural crops under *Eucalyptus camaldulensis* based agroforestry system was reported by earlier Ahmed *et al.* (2008). Kumar *et al.* (2013) also reported the corroborative results which showing the reduction in test weight (26.7 g) of wheat under eucalypts based agroforestry system due to shade than in sole cropping system.

Grain, straw and biological yield (t/ha): The grain yield of barley was observed maximum (3.28 t/ha) in control (sole crop) than eucalypts. The per cent decrease in grain yield of barley under eucalypts was 12.50 % over control. The per cent reduction in straw yield of barley was 11.11% under eucalypts plantation over control (devoid of trees). However, the rate of decrease in straw yield was comparatively lower than grain yield of barley under eucalypts based agroforestry system. The maximum biological yield (7.60 t/ha) in barley was observed under control as compared to eucalypts based agroforestry system (Fig 6). Whereas, the biological yield of barley under eucalypts plantation reduced up to 11.71 % over control (sole barley). The reduction in the grain yield of barley under eucalypts based agroforestry system may be due to availability of low light and more competition for moisture and nutrients. Bhardwaj *et al.* (2017) reported that the grain yield of barley was significantly affected at different distances of eucalypts boundary plantation. Presents results are in agreement with the findings of Sharma *et al.,* (2007), Chauhan *et al.,* (2012) and Alebachew *et al.,* (2015) in different tree based agroforestry systems. Barley yield reduction under eucalypts based agroforestry system was also been recorded earlier by several research workers (Kohli and Saini (2003) and Kumar *et al.,* (2013).

Harvest and attraction index (%): The harvest and attraction index (%) of barley was significantly affected by eucalypts plantation (Fig 7). The results showed that sole barley (control) exhibited maximum harvest and attraction index (43.16 and 75.93%) than eucalypts based cropping system. The per cent reduction in harvest and attraction index of barley under eucalypts was 0.90 and 1.57 %, respectively over control. This deviation in harvest and attraction index might be due to the variation in total biomass production under agroforestry system. Bijalwan (2014) results revealed that harvest index varied from 16.42% (*Amaranthus caudatus*) to

45.01% (*Phaselolus vulgaris*) in summer season and 27.49 (*Brassica campestris*) to 47.15 (*Pisum sativum*) in winter season in northern aspect under agri-horticulture system. While the harvest index in the southern aspect varied from 26.44 (zea mays) to 47.05 (*Phaseolus vulgaris*) in summer and 24.94 (*Coriandrum sativum*) to 47.37 (*Pisum sativum*) winter season under agr-ihorticulture system. Gawali *et al.* (2015) observed that harvest index was reduced under closer spacing of poplar and highest straw yield under sole cropping.

Economic analysis of the eucalypts based agroforestry system:The maximum cost of cultivation (Rs. 127097.3/ha) and gross returns (Rs. 220444.4/ha) were found higher in barley under eucalypts based cropping system while the minimum in sole cropping. However, higher net return (Rs. 93347.1/ha) and benefit-to-cost ratio (B:C ratio) was recorded under eucalypts + barley system i.e. 1.73. The results are in line with Dhillon *et al.* (2018) who reported that higher gross return in eucalypts-barley agroforestry system over sole cropping of barley. Kaushik *et al.* (2017) also reported that horti-silvicultural systems showed maximum return in association with the field and vegetable crops. The loss in crop yield under eucalypts can be compensated by the income returns from the tree component at the end of the rotation. Satyawali *et al*, (2018) also reported that eucalypts based agroforestry system fetched higher net retruns as compared to melia.

Conclusion

In the present investigation of eucalypts-barley based cropping system, grain yield of barley was observed maximum (3.28 t/ha) in control (sole barley). However, the grain yield reduction in barley intercropped with eucalypts plantation (7x3 m) was 12.50 per cent over control**.** The maximum gross return (Rs. 220444.4/ha) as well as maximum net return (Rs. 93347.1/ha) were observed under eucalypts + barley-based agroforestry system as compared to sole cropping (control). Similarly, maximum B:C ratio (1.73) was also analyzed under eucalypts + barley cropping system. This study concludes that eucalypts-based agroforestry system will be more remunerative to the farmers than sole cropping.

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Conflict of interest

The authors declare that they have no conflict of interest.

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