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ISSN: 2320 – 7051
Int. J. Pure App. Biosci. SPI: **6 (1):** 56-62 (2018)
Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Root Zone Water Uptake of Irrigated Mustard and Lentil

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Received: 1.07.2018 | Revised: 30.07.2018 | Accepted: 11.08.2018

ABSTRACT

An experiment was carried out to know root zone water uptake of irrigated mustard and lentil crop grown in agro climatic condition of north Bihar. Water uptake from different soil layers was determined as difference of moisture content between two successive moisture measurement dates or within one irrigation cycle. The study indicated that water uptake pattern of both the crops was almost similar and they shown a declining trend of moisture use from upper to lower soil profiles of crop root zone. Maximum water uptake from the respective crops were observed as 55.2 and 77.4 percent from the top (0-30 cm) soil layer and from 30-60 cm root zone, 28.0 and 22.6 percent uptake was recorded. 60-90 cm soil depth of mustard crop exhibited 16.8 percent water uptake. Total water uptake of mustard and lentil were calculated as 104.5 mm and 84.2 mm, respectively and these crops yielded 1466.7 and 906.7 kg.ha^{-1} besides crop water use efficiency of 14.03 and 10.78 kg.ha^{-1}.mm^{-1}. On the basis of water uptake pattern, estimation of crop water requirement for the agro-climates having similar soil physical properties in different layers of the root zone of these crops can be determined.

Key words: *Root zone, Field capacity, Irrigation, Soil moisture content, Water uptake.*

INTRODUCTION

Water uptake from plant roots is process of transport of water in the soil–plant system and its pattern shows the relative amounts of moisture depletion from different soil depths within the crop root zone. It is generally employed to determine the amount of water use by irrigated crops grown in fairly uniform soils when depth to ground water does not affect the soil moisture fluctuation within the root zone. Study on profile wise water uptake provides very important information for optimum irrigation scheduling of crops thereby it promotes efficient use of available water resources. The rate of water uptake by the crops depend on various factors like profile water storage, type of crop, stage of crop growth, soil type, weather, rooting characteristics etc. Moisture uptake from the crop root zone is a function of depth from ground, moisture distribution and time. The movement of water from soil to plant roots has been studied for a wide variety of plant species across a range of dry and wet climate. Water use, water use efficiency and soil moisture extraction pattern of mustard was studied in relation to water stress and sowing methods[1]. Model of soil water extraction capacities of agro forestry crops was developed after study on root zone moisture distribution[2]. Besides that such studies were also conducted on pulse crops in which water use pattern and water requirement of lentil planted on different dates was evaluated[3].

Cite this article: Kumar, J., Singh, A.K.P. and Hasan, W., Root Zone Water Uptake of Irrigated Mustard and Lentil, *Int. J. Pure App. Biosci.* SPI: **6(1):** 56-62 (2018).

On the other hand, field study on consumptive use and water use efficiency of chickpea and yield prediction of green gram was as influenced by water use was carried out[4,5].

Mustard (*Brassica juncia* L.) and lentil (*Lens culinaris* L.) are major oilseed and pulse crops grown during Rabi season in North Bihar. Since, information on water uptake of these crops are scanty, the present study was conducted to find out pattern of water uptake from root zone of irrigated mustard and lentil along with moisture distribution pattern and crop water use efficiency in agro-climate of Pusa, Bihar (India).

MATERIAL AND METHODS

A field trial was conducted at Water Management Research Farm (25.98^o N Latitude, 85.67^o E longitude, 52 meter MSL) of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar formerly known as Rajendra Agricultural University, Pusa, Bihar to find out root zone water uptake of irrigated mustard (Brassica Juncia L.) and lentil (Lens Culinaris L.) crops. The soil of the study area has uniform topography, well drained, good tilth and it is easily workable. The climate of the area concerned is humid subtropical with average annual rainfall of 1270 mm out of which nearly 80.75 percent occurs in monsoon months. The mean minimum and maximum temperature of 11.83^o C and 30.12^o C and pan evaporation of 1.07 mmday^{-1} and 6.28 mmday^{-1}, respectively were observed during the study period whereas the mean minimum and maximum relative humidity were recorded as 48.4% and 76%, respectively.

The experiment was laid with five replications in a randomised block design (RBD) with plot size of 5 m X 3 m each and 1 m buffer space has been maintained between two adjacent plots. Mustard (Brassica Juncia L.) var. Varuna and lentil (Lens Culinaris L.) var. BR-26 were raised during the Rabi season with recommended agronomical practices. Measured quantity of irrigation water was applied in each plot time to time using a 7.5 cm parshall flume on the basis of available /deficit soil moisture status for maintaining the soil moisture level in the effective crop root zone to the field capacity.

In order to find out water uptake of mustard and lentil, profile wise soil moisture content in the effective root zone depth of the crops were worked out gravimetrically for different periods between two successive soil samplings. For this purpose, soil samples were collected on different dates prior to each irrigation from sowing to harvest with the help of tube auger from 0-30, 30-60, 60-90 and 90-120 cm depths from each plot of mustard whereas from lentil plots, samples were taken from 0-30 and 30-60 cm soil depths and average soil moisture was used as a basis to irrigate the crops. Intermittent soil samples were also collected. Soil moisture record and soil samples were collected from middle of each plot and the space between crop rows. Then, soil samples were dried in the oven at 105^0 C for 72 hours to find out the moisture content on gravimetric basis and volumetric moisture content was calculated by multiplying the respective bulk density with gravimetric moisture content. Daily records of rainfall data for the experimental periods were obtained from observatory located in the University. Due to low intensity of rainfall (4.0 and 3.5 mm) occurred in two rainy days, all amount were considered as effective and taken into account in calculations.

Bulk density of soil was determined by core cylinder method for which samples were collected from all the soil profiles upto 120 cm and 60 cm, respectively for mustard and lentil crops with 30 cm depth intervals. The effective root zone depth was calculated by using the model

$$RD = RD_m \left[0.5 + 0.5\sin\left(3.03\, t_r - 1.47\right)\right]$$

in which rooting depth followed a sigmoid pattern with time irrespective of plant species, soil type and water regime[6] where RD is rooting depth on day t (cm), RD_m is maximum expected rooting depth (cm) i.e. 120 cm for mustard, 60 cm for lentil, t_r is relative time (t/t_m) and t_m is time to attain physiological maturity (days after sowing) i.e. 100 for mustard as well as lentil. This model was selected because it estimated rooting depth as a function of time.

Weekly record of fluctuations in the ground water table in a well located near the experimental site was taken to find out the contribution of ground water in the effective root zone of the crop.

In calculating layer wise water uptake from different soil profiles during different growth period of crops, the moisture data of various dates for each 30 cm interval was used. Soil moisture depletion or water uptake (cm) from each soil layer of effective root zone depth for any time period between two successive soil moisture measurement dates were determined as product of difference between initial and final soil moisture content (%) of the soil profile within that period, bulk density (gcm^{-3}) and depth of the soil profile (m) then converted into mm. Soil moisture depletion for the period of different irrigation cycle was computed as difference of field capacity moisture content and the final soil moisture content at the end of that irrigation cycle. Further, total water uptake from crop root zone for successive sampling periods or within one irrigation cycle (cm) was determined by summing up moisture depletions from all the profiles whereas seasonal water uptake from crop was determined by summing up the soil moisture depletion from all the periods.

Water uptake rate ($mm.day^{-1}$) was calculated as water uptake by crop (mm) divided by duration (days) of two successive soil samplings[7]. Crop water use efficiency (CWUE) indicates how effectively irrigation water was utilized by the crop and it was computed as ratio of crop yield ($Kg.ha^{-1}$) and quantum of total water depleted (mm) by the crops in the process of evapotranspiration i.e. water uptake by the crops[8].

RESULTS AND DISCUSSION

In order to know the water uptake pattern of mustard and lentil, soil physical properties of the study area were evaluated for calculation of layer wise soil moisture depletion. Bulk density and field capacity of different layers of soil was determined at university laboratory using core sampler whereas textural class was found out by analysing the soil samples by “master sizer” at ICAR-RCER, Patna and results pointed out that bulk densities of 0-30, 30-60, 60-90 and 90-120 cm soil profile were 1.45, 1.47, 1.53 and 1.58 $Mg.m^{-3}$ whereas field capacities were calculated as 0.349, 0.386, 0.422 and 0.390 $cm3.cm^{-3}$ and textural class of the respective soil layers were sandy loam, loam, silt loam and loam. Trends of weekly water table depth variation at the experimental site throughout the crop period was also observed which indicated that ground water level were much below the crop root zone i.e. (below 4.0 meter), thus it is assumed that ground water contribution has no effect on root zone water uptake of mustard and lentil.

The effective root zone depth for different periods was evaluated by modelling technique and accordingly, simulated rooting depth of mustard and lentil have been given in Fig.1 which was used in calculations of water uptake from effective root zone of crops.

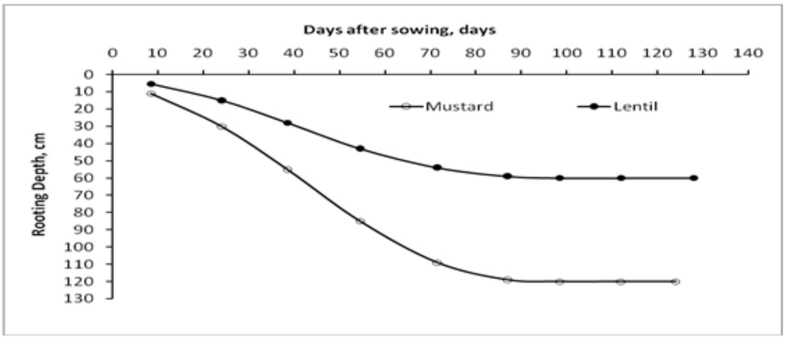

Fig. 1: Simulated rooting depth of mustard and lentil

Soil Moisture Distribution Analysis

Profile wise variation of soil moisture in the root zone of mustard and lentil crops have been presented in Fig.2 and Fig.3. These figures revealed that the soil moisture experienced variation in all the soil layers during crop growth periods, irrespective of the type of crops and the amplitude of variation was higher in upper layers than in lower layers. The root zone soil moisture storage in mustard (Fig.2) ranged from 28.17 to 32.87 percent or $m^3.m^{-3}$ in 0-30 cm soil depth, 36.07 to 37.29 percent in 30-60 cm, 38.97 to 39.99 percent in 60-90 cm and 40.95 to 41.36 percent volumetric moisture content (VMC) in 90-120 cm soil profile during different crop growth periods. However, only a slight decline in soil moisture was observed in 90-120 cm soil profile; the rate of decline was much lower as compared to 0-30, 30-60 and 60-90 cm soil profiles.

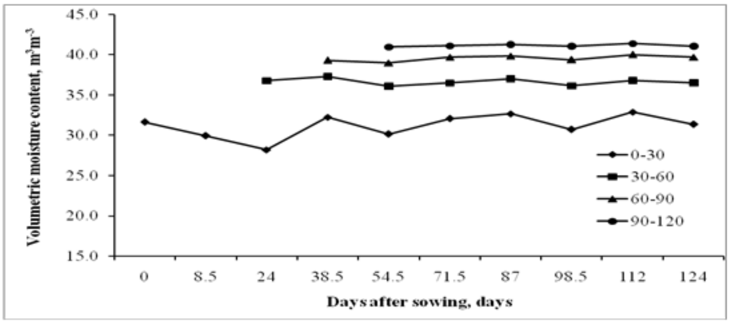

Fig. 2: Trend of variation of soil moisture in the root zone of mustard

Besides light shower of precipitation of 4.0 and 3.5 cm during the period of 47-63 days after sowing (DAS) and 64-80 DAS, required amount of irrigation water was applied at 46, 80, 94 and 121 DAS in mustard crop which caused increase in moisture level of soil profiles upto field capacity and after withdrawal of irrigations, a decline in soil moisture was observed. However, the decline rate from 90-120 cm soil profile was negligible and from 60-90 cm soil depth moisture uptake was lower than the upper layers.

It is inferred from Fig.3 that volumetric moisture content (VMC) in lentil ranged from 16.81 to 32.13 percent in 0-30 cm soil profile and 29.59 to 37.2 percent VMC in 30-60 cm soil profile which shown great variation in lower soil profile (30-60 cm) also. Besides light showers of precipitation of 4.0 and 3.5 cm during the period of 47-63 DAS and 64-80 DAS, required amount of irrigation water was supplied at 46 DAS which caused increase in moisture level of soil profile upto field capacity. When irrigation was withdrawn, a gradual decrease in soil moisture storage was noted after field capacity of soil from 0-30 and 30-60 cm soil layer which was due to change in soil water storage due to capillary rise and marked variation of root zone water storage was noticed from both the soil layers.

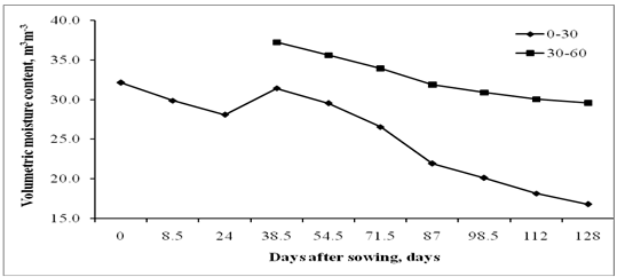

Fig. 3: Trend of variation of soil moisture in the root zone of lentil

A comparison of variation in soil moisture of mustard and lentil crop revealed that there was a rapid decline of soil moisture in 0-30 cm soil profile whereas the lower layers of 30-60 and 60-90 cm soil profiles in mustard as well as 30-60 cm soil profile in lentil exhibited a gradual decline in soil moisture during all the growth periods. The rate of decline was lower towards the lower layers. The 90-120 cm soil profile of mustard was not significantly affected by depletion and the rate of depletion was also not prominent in later growth periods. Intermittent rise in the moisture content of soil profiles above the field capacity were observed when irrigation or rainfall occurred. However, the rate of increase of profile soil water content was lower towards lower soil profiles. The soil profile below 30 cm remained unaffected due to light shower of precipitation of 4.0 and 3.5 cm during the period of 47-63 DAS and 64-80 DAS in both mustard and lentil. A continuous sharp decline of soil moisture in all soil profiles were observed in mustard as well as lentil after the period of irrigation or rainfall till next irrigation. High amplitude of variation of moisture depletion was noted in soil profiles below 30 cm of the root zone of mustard after recession of irrigation as compared to lentil.

Root Zone Water Uptake

The contribution of root zone water uptake for different growth periods of mustard and lentil have been presented respectively in Fig.4 and Fig.5. Figures inferred that the soil moisture was extracted from 0-90 cm layers in mustard and 0-60 cm root zone depth of lentil but initially water uptake was limited only from 0-30 cm soil depth upto 45 DAS and 62 DAS, respectively for mustard and lentil. As observed from Fig. 4, negligible amount of moisture was up taken from 90-120 cm soil profile of mustard as there was very less variation in soil moisture content. The magnitude of contribution from 30-60 and 60-90 cm soil profiles in mustard was low initially as compared to 0-30 soil profile. The depth variation of moisture within 60 cm soil profile was greatly influenced by the increased crop water uptake in later growth periods. The 60-90 cm soil profile contributed moisture upto the last irrigation event and plants extracted most of the soil moisture from 0-60 cm soil profiles in case of mustard whereas in case of lentil, major quantity of water uptake was observed from 0-30 cm soil depth (Fig.5).

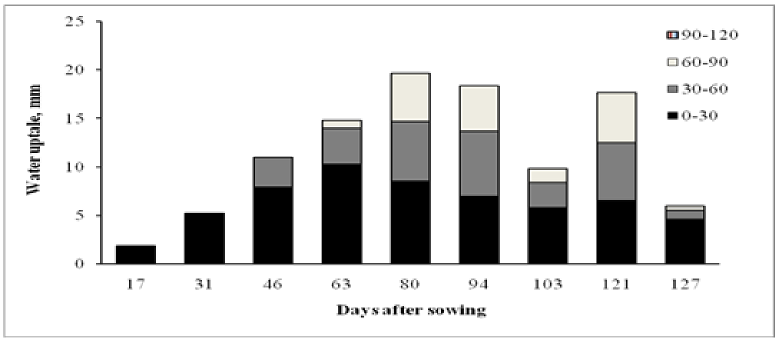

Fig. 4: Root zone water uptake of mustard crop

Figures indicated that all the soil profiles of mustard as well as lentil exhibited variation in moisture uptake with considerably low amplitudes in the lower layers as compared to those observed in upper soil layers throughout the crop growth period. Since, the plant roots were developed gradually after sowing and penetrated deeper in search of water when there was not adequate moisture in the upper soil layers, the soil moisture was extracted from 30-60 cm (46 DAS) and 60-90 cm soil profiles (63 DAS) in case of mustard and 30-60 cm soil depth (63 DAS) in case of lentil crop. Soil moisture depletion by both the crops exhibited a trend of increased water uptake from deeper soil layers as the crop season progressed after irrigation[9].

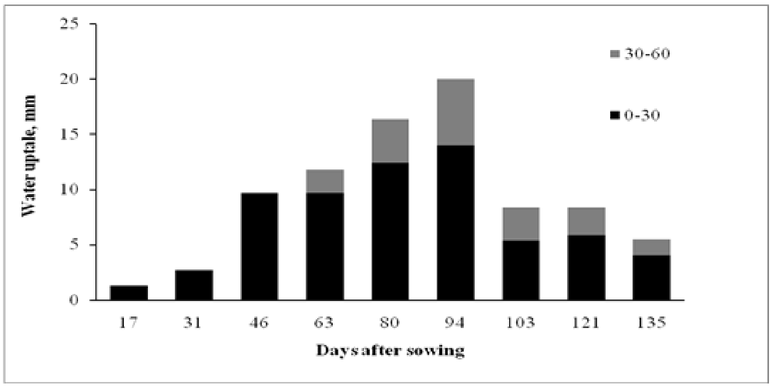

Fig. 5: Root zone water uptake of lentil crop

Therefore, it is inferred that 0-60 cm of soil profile should be considered for planning irrigation for mustard and 0-30 cm layer for lentil crop grown in sandy loam soil in the sub-tropical regions.

Water Uptake Pattern

Profile wise water uptake pattern from soil layers 0-120 cm of mustard and 0- 60 cm of lentil have been presented in Fig.6 and Fig. 7.

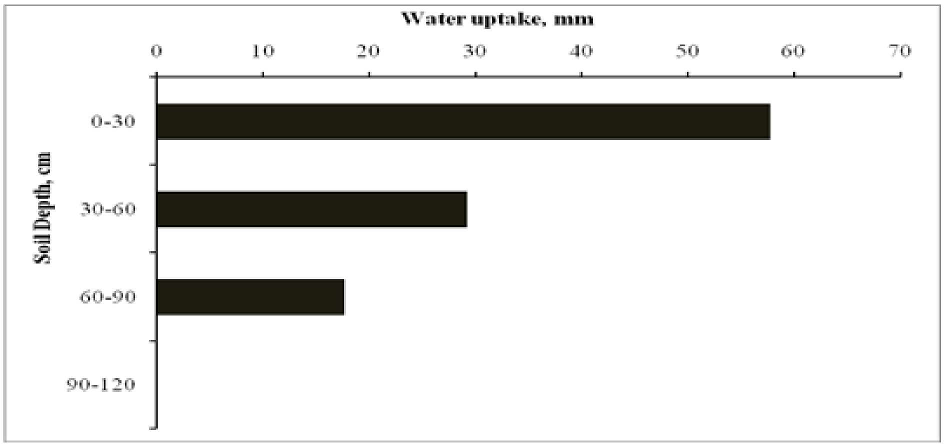

Fig. 6: Profile wise water uptake pattern of mustard

It is obvious from Fig. 6 that out of total profile water use of 104.5 mm, maximum water uptake occurred from 0-30 cm soil depth of mustard which amounted to be 57.7 mm (55.2 percent) then after amount of water uptake decreased as the soil depth increased. Likewise, from 30-60 cm soil depth, contribution of water uptake was 29.2 mm (28.0 percent) whereas 17.6 mm (16.8 percent) uptake was observed from 60-90 soil profile and uptake from 90-120 cm soil depth was almost negligible. The amplitude of the variation was more in upper soil profile mainly due to the evaporation from the soil surface. Reports of earlier studies confirmed that 40, 30, 20 and 10 percent moisture depletion occurred from each quarter (25 percent) of crop root zone depth from upper to lower soil profiles[9]. The upper 0-30 cm soil layer of mustard exhibited maximum moisture extraction[10]. Fig. 7 depicted that, lentil crop exhibited similar trend of profile water uptake as that of mustard and it is clear that again 0-30 soil profile contributed maximum soil moisture depletion of 65.2 mm (77.4 percent) out of total profile water use of 84.2 mm whereas 30-60 cm soil profile shown reduced water uptake as only 19.0 mm (22.6 percent) [11].

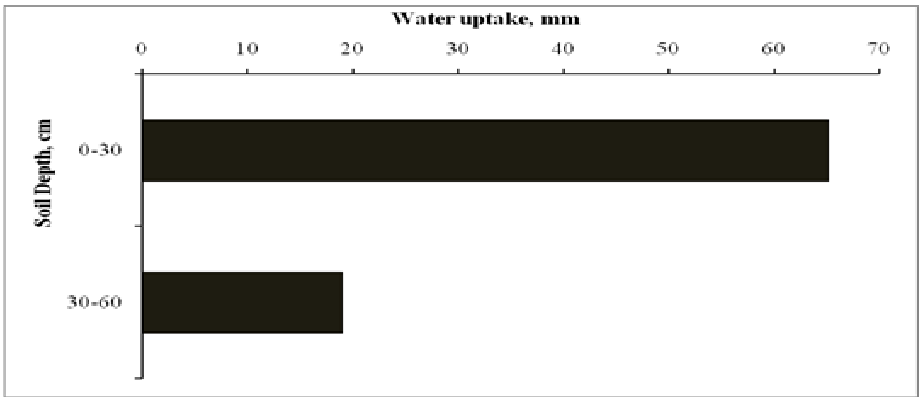

Fig. 7: Profile wise water uptake pattern of lentil

Water Uptake Rate and Crop Water Use Efficiency

Fig. 8 shows variation of water uptake rate of mustard and lentil in different periods which followed a increasing trend with the advancement of crop growth periods upto 94 DAS and attained its maximum value as 1.32 and 1.43 mm day^{-1}, respectively. After that period, the value decreased continuously in later growth stages till maturity which was mainly because at later stages of growth, crop could not extract much water[12]. Figure depicted that moisture uptake rate was greater in case of mustard crop and average rate of water uptake for the respective crops were calculated as 0.85 and 0.65 mm day^{-1}.

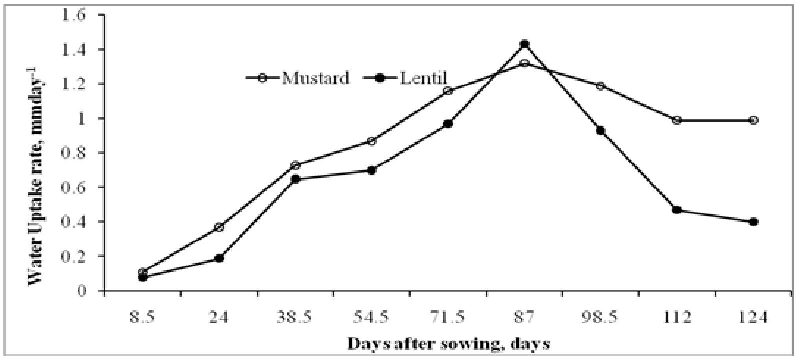

Fig. 8: Water uptake rate of mustard and lentil

Total water use of mustard and lentil was calculated as 104.5 mm and 84.2 mm, respectively with yield attribute as 1466.7 and 906.7 $kg.ha^{-1}$. Accordingly, mustard crop shown higher crop water use efficiency as 14.03 $kg.ha^{-1}$ mm^{-1} in comparison to lentil crop as 10.78 $kg.ha^{-1}$ mm^{-1}) which was due to combined effect of crop water use and yield.

CONCLUSION

Findings of the experiment indicated that under water stress condition, irrigation should be provided to mustard and lentil crops grown in sandy loam soils of sub-humid regions on the basis of water uptake pattern. Further, the results revealed that mustard and lentil crop grown in this region used most of the soil moisture from 0-60 cm and 0-30 cm soil profile, respectively. Thus, keeping in view water uptake pattern of stored soil water, irrigation should be maintained in specified soil profile of the crop root zone of those crops in water scarcity conditions.

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