

Poultry manure application time on pistachio (*Pistacia vera* L.) trees

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All relevant data are within the paper and its Supporting Information files.

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Abstract: The effectiveness of poultry manure application time was studied on pistachios (*Pistacia vera* L.) trees. The experiment consisted of seven different poultry manure application time, including poultry manure application as one time in 1) last week of October 2) last week of December 3) last week of January 4) mid-March and dividing into two parts and use in fall or in winter, dividing into four parts and use in dormant seasons (fall and winter). Based on the results, there were significant differences among treatments. The highest number of fruit per cluster (27.4) was found in poultry manure applied in last week of October. The highest nut splitting percent (84.3%) and the lowest nut blanking percent (8.6%) were obtained in poultry manure applied by dividing into four parts. Half kernel nuts followed a similar trend with blanking percent. Weight of 1000 nuts increased and responded positively and number of pistachios nut per ounce decreased by manure application when divided into two parts and used in the winter. Application of poultry manure in the mid-March enhanced the nut protein (19.63%).

1. Introduction

Production technologies of horticultural crops including pistachio tree have undergone vast changes recently, and led to the extension of innovative technologies about nutrient management. The critical factor of nutrient management of nut trees like pistachio is to elevate the net yield and improve the quality of nut fruits. Pistachio blanking and flower bud abscission can be directly related to nutrition management (Mahmoudi Meimand and Ghanbari Odivi, 2013). Nowadays, fertilizers play a key role in nutrition of fruit trees. Because of harmful side effects of chemical fertilizers, (Ljoyah and Sophie, 2009) the use of bio fertilizers are increasing recently. Organic fertilizers, such as animal manure, have a long history of use by men (BayBordi and Malakuoti, 2003). Different animal manures such as sheep, cow and poultry manures have been used as natural crop

fertilizers for centuries. Poultry manure, because of its high level of nitrogen which is absorbable for pistachio trees, has been recognized as one of the main favorable manures. It has been documented that poultry manures also supply other essential pistachio nutrients and act as soil amendament by raising organic matter content, which helps improve the moisture level of soil and nutrient maintenance. According to Alimoradi (2011) nearly 5.3 million tons of poultry manure is consumed in Rafsanjan and Kerman pistachio orchards every year. These bio fertilizers are known as main source of manure for Iranian pistachio growers. Nutrients provided by poultry manures have been indicated to establish effects on different crops, including fruit crops (Mitchell *et al.*, 1993; Miller, 1996). It has been reported that poultry manure is composed of essential elements for fruit crops containing about 3% of nitrogen NH_4^+ , 63.2% phosphorus P_2O_5 and 4.1% potassium K_2O (Reddy and Reddy, 1995). The main form of nitrogen in poultry manures is NH_4^+ , which elevate the availability of nitrate to the plants for a longer period (Burmester, 1993; Crawford and Chalk, 1993; Touchton and Boswell, 1980). On the other hand, organic manures application to decrease the use of chemical fertilizers in pistachio orchards and other fruit trees is an important goal in fruit production (Reganold *et al.*, 2001; Forge *et al.*, 2002). Organic manures increase the fertility of soil and the crop yield. Therefore, they can be helpful to achieve sustainable agriculture. It has been demonstrated earlier that poultry manure improved growth parameters, yield and quality in different crops (Ram and Rajput, 2002; Ingle *et al.*, 2003; Arancon *et al.*, 2003). Pimpini *et al.* (1992) revealed higher rate of extractable sucrose by using 4 t ha^{-1} of poultry manure in crops. Increased content of total carbohydrate, protein and ascorbic acid were reported by Abusaleha and Dutta (1988) when poultry manure was used. Improving photosynthesis, plant biomass and glycosides content of *Stevia* were also demonstrated before (Xiangyang *et al.*, 2010). Enhanced starch content, crude fiber, ash, crude protein, phosphorus, calcium and magnesium of *D. bulbifera* were reported by Ezeocha *et al.* (2014). Adekiya and Agbede (2017) showed that poultry application increased soil organic matter, leaf N, P, K, Ca, Mg contents, growth and yield in tomato. They also showed that the application of poultry manure at 3 weeks before transplanting had highest effects on leaf nutrient concentrations, growth and yield in tomato (Adekiya and Agbede, 2017). Now, pistachio

growers are frequently using poultry manure as a source of plant nutrient. To our knowledge, there are no reports available to recommend favorable time for poultry manure application in orchard of pistachio trees. The aim of this investigation is to study the effect of poultry manure application time on nut yield and quality in pistachios trees.

2. Materials and Methods

The experimental orchard selected for this study is located at Khatam, Yazd province, Iran. It is located at 39.33°N latitude and 54.40°E longitudes, at an elevation of 1605 m above sea level. The average temperature of the zone is 18.5°C, the annual total chilling hours ($\leq 7.2^\circ\text{C}$) is about 950; the average annual rainfall is 300 mm. The climate of this area is typically subtropical. Just before poultry manures application, soil sample of the experimental orchard were collected and chemically analyzed (Table 1). This research was conducted on 12 years old pistachio cv. Akbari grafted on 'Badamii Zarand' rootstock. Management factors such as irrigation regime, pruning practices, and weed control were followed according to local standards. Trees were trained with a modified central leader system and distance of trees was 2x6 m. To achieve better results, uniform trees were selected with uniform vigor and age and three uniform shoots were selected from different sides of the tree for data collection. Harvest index was considered when several nuts in the cluster were light colored and the hull was easily separated from shell. Characteristics of yield, percentage of splitting, weight of 1000 nuts, blanking, pistachio weight in

Table 1 - Soil fertility analysis report of the experimental orchard

Soil characteristics	Value
pH	7.6
EC ds m^{-1}	4
P ppm	28.1
K ppm	180
O.M. %	1.3
T.N.V. %	22.1
Sand %	52
Silt %	34
Clay %	14
Texture	Loam
ESP	17.9

ounce, dry weight and some other characteristics related to kernel and leaf were recorded. The experiment consisted of seven different poultry manure application time, with three replications based on the Randomized Complete Block Design (RCBD). The treatments were poultry manure application as one time in 1) last week of October 2) last December 3) last week of January 4) mid-March and dividing into two parts and use in fall or in winter, dividing into four parts and use in dormant seasons (fall and winter). These treatments were conducted beneath the tree canopy and mixed well with surface soil, 10 kg per tree. Data collecting was performed in next growth season. Statistical analysis was conducted using the SAS software (9.2) and means were compared by Duncan's Multiple Range test ($P \leq 0.05$).

3. Results and Discussion

Effect of poultry manure application time on yield parameters

Number of fruits per cluster. The study indicated that poultry manure application time had significant effects on number of fruits per cluster ($P \leq 0.05$) (Table 2). The highest number of fruit per cluster was found by poultry manure application in last week of October (27.4) followed by the last week of December (26.9) (Table 2). The minimum value (19.2) was observed in control treatment. The higher fruit per cluster with poultry manure application in last week of October (concurrently with tree deciduous) might be related with the positive role of nitrogen and other critical elements on cluster final development. Burmester (1993) Crawford and Chalk (1993) Touchton and Bosewell (1980) demonstrated the positive role and proportion ratio of elements on reproductive growth parameters.

Nut splitting percent. Also, our results demonstrated that poultry manure application time had significant effects on nut splitting percent (Table 2). Highest nut splitting percent (84.3%) was obtained in treatment of poultry manures divided into four parts and used in last weeks of October, December, January and mid-March followed by divided into two parts and used in fall (83.5%) and in winter (83.1%) (Table 2). The minimum value for nut splitting percent was reported in control treatment. Based on our results, the poultry manure application in four different times, thus involving a longer period of the year improved nut splitting percent. It has been demonstrated before that poultry manure was improved yield quality in different crops (Arancon *et al.*, 2003; Ingle *et al.*, 2003).

Number of pistachio nuts per ounce. Table (2) indicates that the use of poultry manure increased the pistachio ounce index or decreased number of inshell pistachio nuts per ounce significantly ($P \leq 0.01$). The results showed also that when a portion of poultry manure is allocated at the end of dormant season, increase fruit size is achieved. Previous findings showed that poultry manure improved yield component in different crops (Ram and Rajput, 2002; Arancon *et al.*, 2003).

Blanking percent. Based on the results, the lowest value (8.6%) for nut blanking was observed when treatment consisted in dividing poultry manures into four parts and using in last weeks of October, December, January and mid-March; this was followed by treatment divided into two parts and used in winter (11%) (Table 2). The maximum amount of blanking (%) was observed in control treatment (13.9%) with no significant difference with fall application. Therefore, poultry manure application at over the year in four different times decreased nut blanking percent. Yield component improving demonstrat-

Table 2 - Effect of poultry manure application time on yield parameters

Parameter\treatment	lwo	lwd	lwod	lwj	Mm	lwjm	lwodjm	control
Number of fruit	27.4 a	26.9 b	22.6 c	21.2 e	21.05 e	22.1d	26.9 b	19.2 f
Nut splitting %	77.3 b	76.4 b	83.5 a	70 c	69.8 c	83.1 a	84.3 a	64.8 d
Fruit ounce	22.6 a	22.6 a	22 ab	22.6 a	22.3 a	20.6 b	20.6 b	23 a
Blanking %	13.3 ab	13.5 ab	13.1 bc	12.5 bc	12.8 bc	11 d	8.6 e	13.9 a
Half seed fruit %	1.3 c	1.2 d	0.7 e	4.4 b	3.1 c	0.9 e	0.7 e	5.0 a
Weight of 1000 nuts	1249 b	1249 b	1288 b	1249 b	1267 b	1372.1 a	1370 a	1231 b

lwo= last week of October, lwd= the last week of December, lwj= the last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid. Means followed by the same letters are not significantly different (Duncan test, $P \leq 0.05$).

ed by Ram and Rajput (2002) and Arancon *et al.* (2003).

Half kernel fruit percent. Half kernel nuts followed a trend similar to blanking percent, it was decreased with dividing poultry manure into four parts (0.7%), followed by manure divided into two parts and used in fall (0.7%) or winter (0.9%) (Table 2). The highest half kernel nuts percent was obtained in control (Table 2).

Weight of 1000 nuts. Weight of 1000 nuts increased and positively and significantly ($P>0.05$) responded to the treatments. Highest weight of 1000 nuts (1372.1 g) were observed in poultry manure divided into two parts and applied in winter followed by treatment consisting in manure divided into four parts and used in last weeks of October, December, January and mid-March (1370 g). However, other treatments exhibited lowest weight of 1000 nuts (Table 2). Previous findings indicated that poultry manure improved yield component in different crops (Ram and Rajput, 2002; Arancon *et al.*, 2003).

Effect of poultry manure application time on nut quality parameters

Fruit stening. Fruit stening was influenced by application of poultry manure in different times (Table 3). Maximum amount for fruit stening (7.23%) was noted at mid-March application (7.23%) and control (7.16%) and the lowest value for this parameter was obtained with treatment divided into two parts and used in fall treatment (Table 3). It has been demonstrated earlier that poultry manure improved yield and quality in different crops (Ram and Rajput, 2002; Arancon *et al.*, 2003; Ingle *et al.*, 2003).

Nut protein. Nut proteins percent was also enhanced by the application of poultry manure in all treatment versus control (Table 3), but maximum value for nut protein percent was observed at mid-March (Mm) application (19.63%) followed by the last week of January (19.5%) and in poultry manures divided into four parts and used in last weeks of October, December, January and mid-March (19.2%)

with no significant differences (Table 3). The minimum value for nut protein percent was observed in control treatment (17.4%). Increasing amount of total carbohydrates, proteins and ascorbic acid content reported by Abusaleha and Dutta (1988) in a similar work that well described poultry manure application on increasing secondary metabolites. Enhancing crude protein in *D. bulbifera* was reported by Ezeocha *et al.* (2014). The results reported by Adekiya and Agbede (2017) showed that poultry application produced higher percent protein content, more growth and yield in tomato.

Effect of poultry manure application time on vegetative and reproductive parameters

Leaf fresh weight. According to obtained results, poultry manure application time had significant effects on leaf fresh weight ($P\leq 0.05$) (Fig. 1). The highest amount of leaf fresh weight was obtained at poultry application in mid-March (2.1 g), followed by

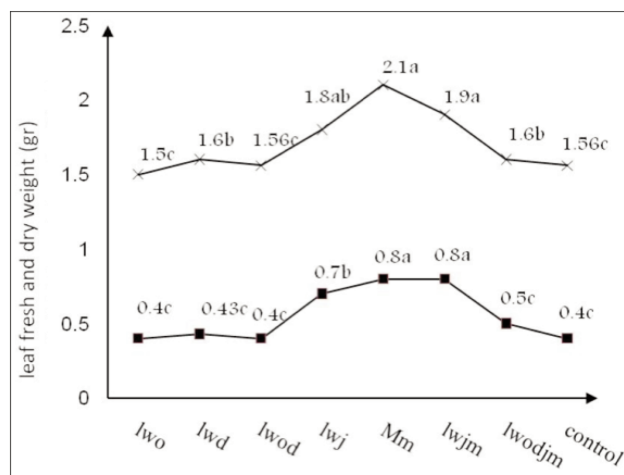


Fig. 1 - Changes of leaf fresh (x) and dry weight (■) (gr) of pistachio (*P. vera* cv. Akbari) grown in Khatam, Yazd, Iran. Duncan was calculated at $P\leq 0.05$. lwo= last week of October, lwd= last week of December, lwj= last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid.

Table 3 - Effect of poultry manure application time on nut quality parameters

Parameter\treatment	lwo	lwd	lwod	lwj	Mm	lwjm	lwodjm	control
Fruit stening (%)	5.6 d	6.56 b	4.2 f	6.8 b	7.23 a	5.9 c	4.96 e	7.16 a
Nut protein (%)	19.1 bc	19 c	18.9 c	19.5 ab	19.63 a	19.2 ab	19.2 ab	17.4 d

lwo= last week of October, lwd= the last week of December, lwj= the last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid. Means followed by the same letters are not significantly different (Duncan test, $P\leq 0.05$).

application divided into two parts and used in winter (1.9 g) (Fig. 1). The lowest rate of leaf fresh weight was occurred in control (1.5 g) and last week of October (1.5 g), respectively (Fig. 1). Based on our result, poultry manure application in mid-March at once increased leaf fresh weight. Increasing photosynthesis and plant biomass of *Stevia* was also demonstrated before (Xiangyang et al., 2010).

Leaf dry weight. Dry weight of leaves was significantly affected by different times of manure application ($P \leq 0.05$). Maximum leaf dry weight was found in poultry application in mid-March (0.8 g) and divided into two parts and used in winter (0.8 g), whereas the minimum was observed in control (0.4 g) and last week of October (0.4 g) (Fig. 1). This increase in leaf dry and fresh weights with application of poultry manures at the end of dormant season can be explained as following, this time of application cannot make the expected effect and causes to increase vegetative parameters, similar to reports published by Xiangyang et al. (2010).

Leaf nitrogen content. Results revealed that the leaf nitrogen content of pistachio trees fertilized with poultry manure in different times varied significantly ($P \leq 0.05$). Leaf nitrogen content was the highest (3.1%) at poultry application in mid-March once at any time compared to the treatments divided into two parts and applied in winter (3.03%) and in last week of January (2.9%) (Fig. 2). The higher leaf nitrogen content in mid-March application of poultry

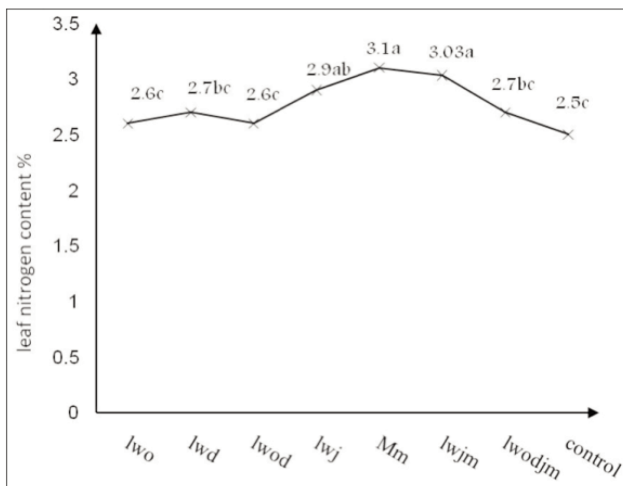


Fig. 2 - Changes of leaf nitrogen content of pistachio (*P. vera* cv. Akbari) grown in Khatam, Yazd, Iran. Duncan was calculated at $P \leq 0.05$. lwo= last week of October, lwd= last week of December, lwj= last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid.

manures could be in relation with releasing more nitrogen NH_4^+ form which is useful for vegetative parameters and causes nitrogen accumulation in the leaves. Previous findings emphasis on high level of NH_4^+ form in poultry manure. The application of poultry manure with high level of N, have influenced the growth and vegetative factors of tree and production of fruits (Reddy and Reddy, 1995). Adekiya and Agbede (2017) indicated that application of poultry manure increased percent of leaf N, P, K, Ca, Mg content, growth parameters and yield in tomato. Poultry manure usage at 3 weeks before transplanting caused higher leaf nutrients concentrations and more growth and yield in tomato (Adekiya and Agbede, 2017).

Shoot length. Based on our findings, shoot length was significantly affected by different application times of manure ($P \leq 0.05$). Maximum shoot length was obtained when manure was divided into two parts and used in winter (44 cm) and mid-March application (43.3 cm). Our results revealed that minimum value for this parameter was observed in control (26.6 cm) and in manure divided into two parts and used in fall (32.6 cm) (Fig. 3). Similar to the dry and fresh weights, application of poultry manures at the end of dormant season caused to increase shoot length. Our results demonstrated that application of poultry manures during fall stimulates a least vegetative growth with no significant differences between various times in fall (Fig. 3). Increasing vegetative growth and similar findings by using poultry manure

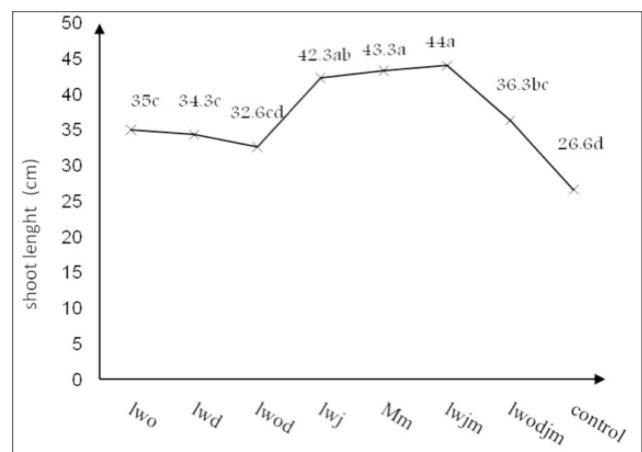


Fig. 3 - Changes of shoot length of pistachio (*P. vera* cv. Akbari) grown in Khatam, Yazd, Iran. Duncan was calculated at $P \leq 0.05$. lwo= last week of October, lwd= last week of December, lwj= last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid.

have been reported before (Xiangyang *et al.*, 2010).

Leafy bud number, floral bud number and leafy to flower bud ratio. Results indicated that leafy and floral buds and leafy to flower bud ratio of pistachio trees fertilized with poultry manure was positively affected by treatments ($P \leq 0.05$). Number of floral buds in the next growing season was the highest in last week of October and fall (in last weeks of October and December) (7.33) (Fig. 4). Minimum value for floral bud number was observed in control (Fig. 5). Results for leafy bud numbers showed that maximum value was obtained in treatment divided into two parts and applied in winter (5.6) and mid-March (5.3) (the letter two treatments have not any significant difference) (Fig. 4).

Floral bud abscission ratio. It was revealed that floral bud abscission during the grow season by poultry manure usage was significantly less than control, which it might be due to the role of poultry manure in decreasing floral bud abscission totally. Any treatment could not show significant effect on floral bud abscission, but minimum amount for this parameter was observed in treatment that was conducted in last week of December (0.32) (Fig. 5). Previous reports showed that poultry manure improves the yield component (Ram and Rajput, 2002; Arancon *et*

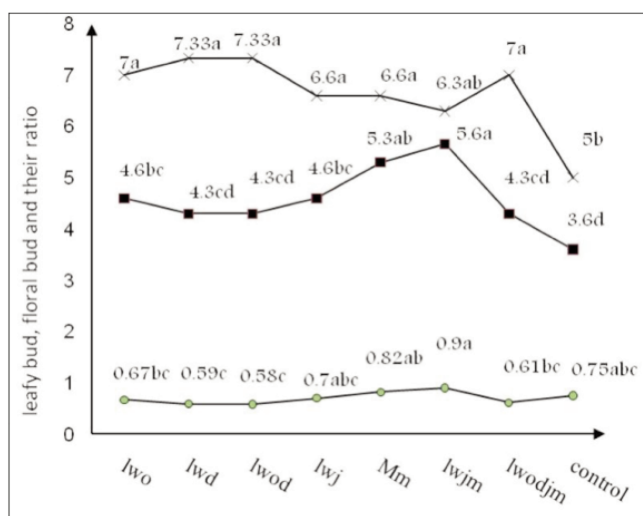


Fig. 4 - Changes of leafy bud number (■), floral bud number (×) and leafy to flower bud ratio (○) of pistachio (*P. vera* cv. Akbari) grown in Khatam, Yazd, Iran. Duncan was calculated at $P \leq 0.05$. lwo= last week of October, lwd= last week of December, lwj= last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid.

al., 2003), although there are no exact results about reproductive phase and parameters affected by poultry manure treatment, but flower bud abscission can be directly related to nutrition management (Mahmoudi Meimand and Ghanbari Odivi, 2013).

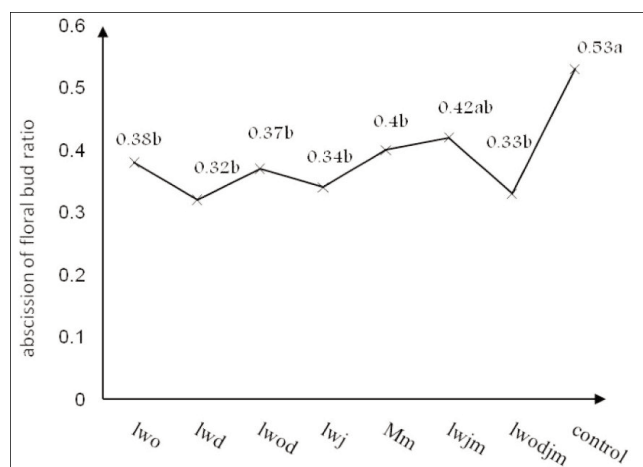


Fig. 5 - Changes of floral bud abscission ratio of pistachio (*P. vera* cv. Akbari) grown in Khatam, Yazd, Iran. Duncan was calculated at $P \leq 0.05$. lwo= last week of October, lwd= last week of December, lwj= last week of January, Mm= March mid, lwjm= divided into two parts and used in the winter, lwod= divided into two parts and used in the fall, lwodjm= poultry manures divided into four parts and used in the last week of October, the last week of December, the last week of January and March mid.

4. Conclusions

It is clear that application of organic fertilizers will improve the nut yield and quality, but application of poultry manure through dormant season can be effective on reproductive and vegetative parameters in pistachio. Based on our findings, dividing poultry manures into four parts and applying in last weeks of October, December, January and Mid-March, or using a single application in fall showed the best results for optimum nut yield, quality and floral bud emergence in pistachio.

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