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Effects of location, orchard type, laying period and nest position on the reproductive performance of Turtle Doves (*Streptopelia turtur*) on intensively cultivated farmland

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Abstract

Background: Until recently little was known about factors affecting reproductive parameters of the Turtle Dove (*Streptopelia turtur*) on intensively cultivated farmland in the Mediterranean area. In this study, the reproductive parameters of this game species were evaluated in relation to location, orchard type, laying period and nest position in central Morocco.

Methods: A total of 317 nests were found and analyzed across five breeding seasons (2004–2008) in the Haouz and Tadla regions, over two major agro-ecosystems made up of olive and orange orchards. Nest position, laying period, clutch size and the number of chicks hatched and fledged per nest were determined on 120 study plots. I used Generalized Linear Models (GLMs) with a Poisson distribution and a log link function, including the logarithm of the number of eggs in each clutch as an offset to model the number of chicks hatched and fledged per nest.

Results: Clutch-size was not affected by location, orchard type, laying period or nest position. The number of chicks hatched per nest differed between orchard types; they were greater in olive orchards (1.33 ± 0.06) than in orange ones (1.03 ± 0.08), whereas the number of chicks fledged per nest consistently differed with laying period and orchard type, which were higher in the early laying period (1.22 ± 0.07) than in the late period (0.93 ± 0.08) and higher in olive orchards (1.22 ± 0.06) than in orange orchards (0.90 ± 0.06). Neither location nor nest position were related to variation in the fledging success of the Turtle Dove.

Conclusions: Olive orchards and the early laying period confer better nesting conditions than orange orchards and the late laying period. Although nest position could be different in each orchard type, it did not affect the breeding success of the Turtle Dove, suggesting that factors other than tree characteristics are influential. Further studies are needed to improve our understanding of the effects of anthropogenic disturbance, especially agricultural activities and hunting, on the productivity of Turtle Dove nests.

Keywords: Agroecosystems, Breeding parameters, Columbid species, Gamebird species, Morocco

Background

The Mediterranean area is characterized by special climatic and environmental conditions which, *inter alia*, include structurally low water availability (Magnan et al. 2009). Mediterranean landscapes are experiencing accelerated changes due to increasing urbanization of coastal and inland areas, abandoned traditional farming activities and expansion of modern intensified agricultural methods (Belda et al. 2011; Sokos et al. 2012). In the late sixties, Morocco decided to make large hydraulic projects a pillar of agricultural development. It launched its aim of achieving an area of one million hectares of irrigated land before the year 2000. Nine major irrigated areas

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have been created so far. Irrigated agriculture occupies 15 % of the entire national area of cultivated land (MAPMFF 2015), contributes up to 45 % of the average added agricultural value and accounts for 75 % of agricultural exports (MAPMFF 2015).

Given the expansion of these new landscapes, it is important and necessary to understand the ways in which animals and plants respond to man-made environments in order to provide sound biodiversity management under global change scenarios (Pimm and Gittleman 1992; Benton et al. 2003; Rey 2011).

In many species of birds, reproductive success is heavily affected by nest-site choice (Martin and Roper 1988; Lomáscolo et al. 2010; Hanane and Besnard 2013). Placement and attributes of nest location can affect, for example, the risk of predation, access to food resources and the microclimate experienced by the developing embryos (Crabtree et al. 1989; Barea 2008). Other studies have also shown that breeding success is linked to availability of nesting habitat (Drobney et al. 1998; Browne et al. 2005) and season (Lepage et al. 2000; Herényi et al. 2014).

The Turtle Dove (*Streptopelia turtur*) is a sub-Saharan migratory bird that has an extensive breeding distribution range in the western Palearctic (Cramp 1985). In its European breeding areas, the species has undergone a moderate decline in range and abundance between the 1970s and 1980s (Heath et al. 2000; Boutin 2001), with a more serious decline starting during the 1980s (PECBMS 2010). The major threats to the Turtle Dove appear to be nesting habitat degradation (Browne et al. 2004), changes in food availability (Browne and Aebischer 2003) and agricultural land use in addition to hunting (Boutin and Lutz 2007). Other factors that may contribute to the decline of Turtle Doves in Europe are changes in wintering grounds and prevailing ecological conditions throughout the migration route (Browne and Aebischer 2001; Eraud et al. 2009).

In North Africa, the species is a common migratory breeding bird (Isenmann and Moali 2000; Thévenot et al. 2003; Isenmann et al. 2005). In Morocco, Turtle Doves are mostly found in agricultural landscapes especially in irrigated areas, where olive and orange orchards are broadly represented (Hanane and Baamal 2011; Hanane and Besnard 2014). These areas are mostly located at the crossroads of the Turtle Dove migration routes between Europe and Africa. The simultaneous presence of abundant food resources from large tracts of cereal crops, suitable nesting trees and water availability is highly beneficial for Turtle Doves (Hanane 2009; Hanane and Baamal 2011). In Europe, this type of agricultural landscape interspersed with abundant trees is also known to be attractive for the species (Rouxel 2000; Browne and Aebischer 2003; Dias et al. 2013). In Morocco, the Turtle Dove is a major game species, highly valued by national and international hunters (HCEFLCD 2013).

Most studies on Turtle Doves have focused on breeding biology (Rocha and Hidalgo 2002; Browne et al. 2004, 2005; Hanane and Baamal 2011; Hanane 2012, 2014, 2015), breeding habitat use (Browne and Aebischer 2003; Browne et al. 2004; Bakaloudis et al. 2009; Dunn and Morris 2012; Buruaga et al. 2012; Dias et al. 2013; Yahiaoui et al. 2014), and migration (Eraud et al. 2013). In spite of this, little is known about factors affecting the nesting success of this game species. Consequently, only two quantitative studies have addressed this deficiency in the Mediterranean basin, respectively in Tadla (Morocco) and Guelma (Algeria) (Hanane and Baamal 2011; Kafi et al. 2015).

In this study, I examined the breeding success of Turtle Doves in two major Moroccan irrigated areas (Haouz and Tadla) over two major agro-ecosystems made up of olive and orange orchards. The aim of the present study was to investigate the effect of location (Haouz and Tadla), orchard type (olive and orange), laying period (early and late) and nest position on the reproductive parameters of the Turtle Dove. This is the first study that deals with the combined effects of these four explicit variables on the breeding parameters of Turtle Doves in the Mediterranean basin.

Methods

Study areas

The study was conducted in irrigated agricultural areas of the Tadla and Haouz regions situated, respectively, in the vicinity of Marrakech and Béni-Mellal, two cities in Central Morocco (Table 1; Fig. 1). In both regions the climate is arid to semi-arid, with about 240–300 mm of rain falling annually, mainly during the rainy season in winter (November–March). Temperature varies widely from moderate temperate winters to hot summers in which temperatures can reach up to 48 °C. In both irrigated areas, orchards of olive and oranges are found in patches, isolated as islands within mainly cereal (*Triticum turgidum* and *Triticum aestivum*) and fodder crops (alfalfa *Medicago sativa* and maize *Zea mays*). Orchards of olive and orange trees can occur on the same farm, but typically one type of tree dominates each farm. In olive orchards, trees tend to be old with a round canopy and in rows. Round canopy and regularly spaced plantations also dominate in citrus orchards. Overall, both areas have practically the same characteristics in terms of climate, topography and agricultural landscape (Table 1).

Field procedures

Fieldwork was carried out from February to September in olive and orange agro-ecosystems of the Haouz

Table 1 Characterisatics of the topography, climate and agriculture of irrigated areas of the Haouz and Tadla, Morocco

	Irrigated agricultural area	
	Haouz	**Tadla**
Geographical coordinates		
Latitude	31°37′00″N	32°21′50.97″N
Longitude	8°00′00″W	6°42′17.46″W
Topography		
Maximum altitude (m)	450	400
Climate		
Total annual precipitations (mm)	240	300
Temperature (°C)	20	19
Min. temperature (°C) (January)	4	3.5
Max. temperature (°C) (August)	48	48
Agriculture		
Total area (ha)	311,000	117,500
Medicago sativa	17,060	23,000
Cereal crop area (ha)	51,109	56,940
Fruit farming area (ha)	89,000	38,144
Olea europaea	85,000	26,570
Citrus sp.	4000	11,574

(2004–2005) and Tadla (2006–2008) regions. The homogeneous structure of these stands of fruit trees (average age 31.2 ± 1.09 years) was behind the choice of a stratified random sampling. To avoid density differences between the two orchard types (one olive hectare: 180 ± 20.7 trees; one orange hectare: 449.25 ± 45 trees; $F = 30.521$, $p < 0.001$), in order to make relevant comparisons between these plantations, I selected study plots with the same number of trees ($n = 20$).

Data were collected from a total of 317 Turtle Dove nests (137 nests in the Tadla and 180 in the Haouz irrigated areas, as well as 130 nests in orange orchards and 187 among the olive trees) (Figs. 2, 3). The results of Turtle Dove nest monitoring in Tadla have already been published (Hanane and Baamal 2011).

In each area and orchard type, three farm stations were randomly chosen each year. At each farm station, four sampling plots (each corresponding to the area occupied by 20 trees: 5 rows and 4 columns) were, in turn, randomly selected every year. They were chosen by random selection coordinates x (length) and y (width) from a table of random numbers. Each tree within each sample plot was systematically searched to locate nests. A nest was considered active when eggs, nestlings, or incubating adults were present. The location of each nest tree was marked on a map of the study plot. In order to minimize observer induced disturbance, active nests were visited four times until failing or the young fledged (Nichols et al. 1984; Westmoreland and Best 1985; Götmark 1992; Ponz et al. 1996; Rivera-Milán 1996). For each nest, I noted the number of eggs laid, number of eggs hatched and number of chicks fledged. Laying period was determined either by knowing the date when the first egg was laid or by back-dating from the known hatching date, assuming that incubation lasted 14 days (Browne et al. 2005). The number of chicks hatched was known by the presence of chicks in nests. The number of chicks fledged was determinated by (1) direct observation of chicks fledged, (2) their presence around the nest-tree and (3) observing the chicks just before fledging [minimum age of 12 days, when they start fledging from the nest (Hanane and Baamal 2011)]. To describe nest position, I focused on five variables: nest tree height (TH), nest height above ground (NH), nest-trunk distance (NT), lower canopy distance (LC) and distance from the nest to the external part of the canopy (DE) (Table 2). When there were no Turtle Doves in a nest when located, the five were immediately measured using a clinometer. If doves were present, these measurements were taken early in the morning, when birds often leave the nest to look for food (Hanane 2015). The effort made by prospectors helped to locate all nests in the 120 sample plots and 2400 trees.

Statistical analyses

Before performing statistical analyses, I checked for normality and homogeneity of variance for all variables. In order to approach residuals from normality, variables that did not conform to the requirements for parametric tests were transformed by logarithm or a square-root transformation prior to all analyses (Zar 1984; Underwood 1996; Quinn and Keough 2002).

Laying periods were expressed as the number of days after 1 April, and mean and median laying periods were calculated for each year. Nests were defined as early or late according to whether the laying period was before or after the median laying period for that year. A preliminary analysis revealed a strong correlation between nest position variables. Therefore, I used Principal Component Analysis (PCA) to: (1) reduce the dimensionality of the set of variables to a smaller number of ‘representative’ and ‘uncorrelated’ variables ($n = 5$); (2) investigate multicollinearity and (3) describe dominant ecological gradients (Legendre and Legendre 1998). A varimax normalized rotation was applied to the set of principal components with eigenvalues >1.0 to obtain simpler and more interpretable gradients (Legendre and Legendre 1998). I interpreted the biological meaning of the principal components, which explain the greatest amount of combined variation within the habitat structure data, by examining the component loadings

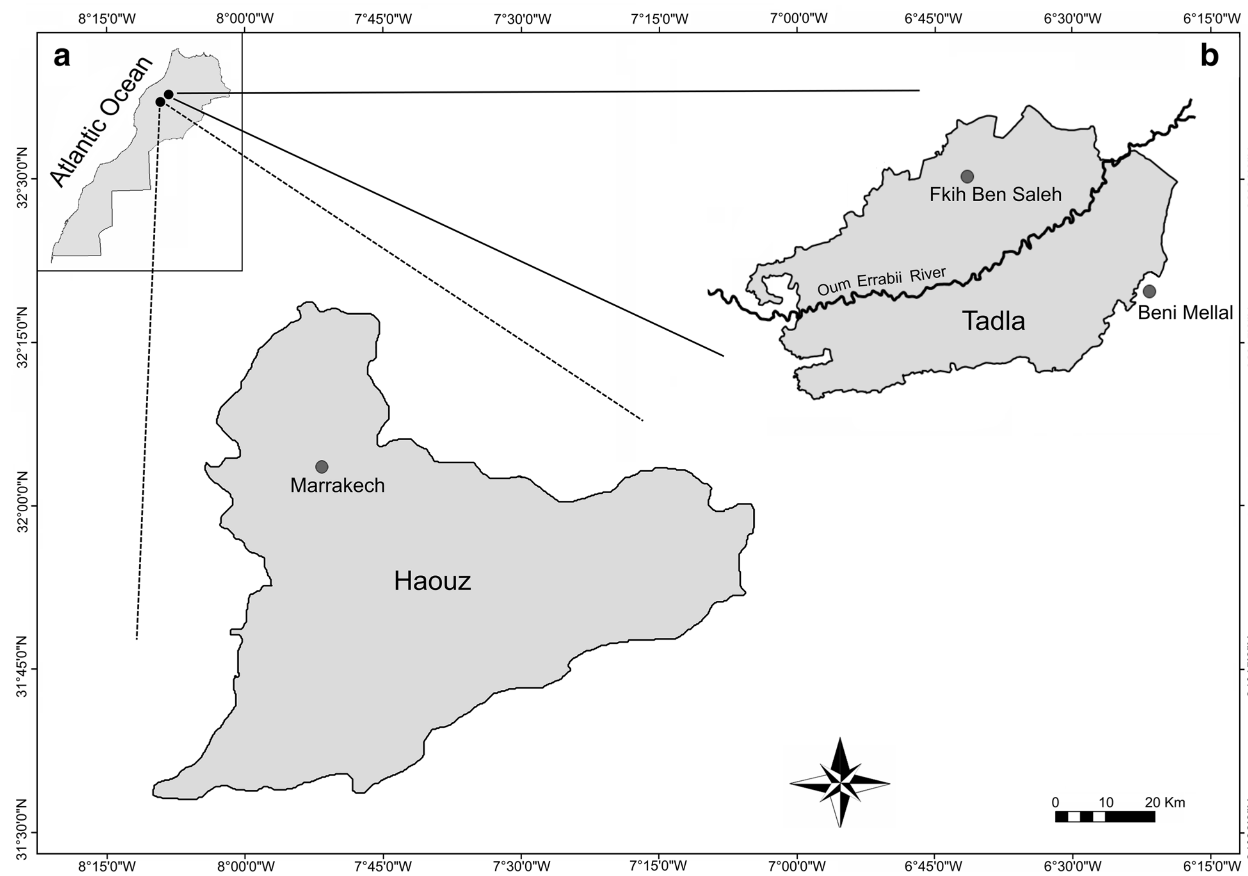

Fig. 1 Map showing the location of the Haouz and Tadla regions in Central Morocco

of each variable (McGarigal et al. 2000). The PCA summarized the field variables under investigation into two independent axes accounting for 84.3 % of the variance of the original dataset [50.8 % (eigenvalue = 2.538) and 33.5 % (eigenvalue = 1.673) respectively)]. The varimax rotation revealed a first gradient ($PC_{\text{Vertical distribution of nests}}$) characterized by high loadings of variables related to nest height, given its positive correlation with tree height ($r = 0.621$, $p < 0.001$), nest height ($r = 0.846$, $p < 0.001$) and distance from nest to the lowest part of the canopy ($r = 0.824$, $p < 0.001$). The second gradient ($PC_{\text{Distal distribution of nests}}$) represents an axis of increasing distal distance of nests, given that it was positively correlated with nest-trunk distance ($r = 0.966$, $p < 0.001$).

After this first stage of analysis, and in order to examine how clutch size and number of chicks at hatching and fledging vary according to location, orchard type, laying period and nest position ($PC_{\text{Vertical distribution of nests}}$ and $PC_{\text{Distal distribution of nests}}$), I used Generalized Linear Models (GLMs) with a Poisson distribution and a log link function (McCullagh and Nelder 1989). The use of plots was tested for random effect within General Linear Mixed Models (GLMM) to avoid pseudo-replication but this factor did not improve model fit, therefore I proceeded without it by using GLMs. No spatial autocorrelation was detected on the residuals of our best models. Nugget/Sill ratios of the best models were close to 1.

For hatching and fledging success, the logarithm of the number of eggs in each clutch was included as an offset. The ratio of residual deviance to residual degrees of freedom after the dependent variables were fitted in the model was close to 1, suggesting that the data were not overdispersed (Dean 1992; Smith and Heitjan 1993). An all-inclusive set of candidate GLMs was developed using multi-model inferences (Burnham and Anderson 2002). In order to prevent any problems due to multicollinearity, all explanatory variables [both quantitative ($PC_{\text{Vertical distribution of nests}}$ and $PC_{\text{Distal distribution of nests}}$) and qualitative (location, orchard type and laying period)] were assessed for collinearity, with the use of Analysis of Variance (ANOVA). Since $PC_{\text{Vertical distribution of nests}}$ and $PC_{\text{Distal distribution of nests}}$ are significantly correlated with location ($F_{1,316} = 50.81$, $p < 0.001$; $F_{1,316} = 18.354$, $p < 0.001$) and orchard type ($F_{1,316} = 21.35$, $p < 0.001$; $F_{1,316} = 183.54$,

Fig. 2 **a** A nest of a Turtle Dove with two eggs on an olive tree. **b** A nest of Turtle Dove with a newly hatched chick on an orange tree. **c** A Turtle Dove at nest with its chicks on an orange tree (© S.Hanane)

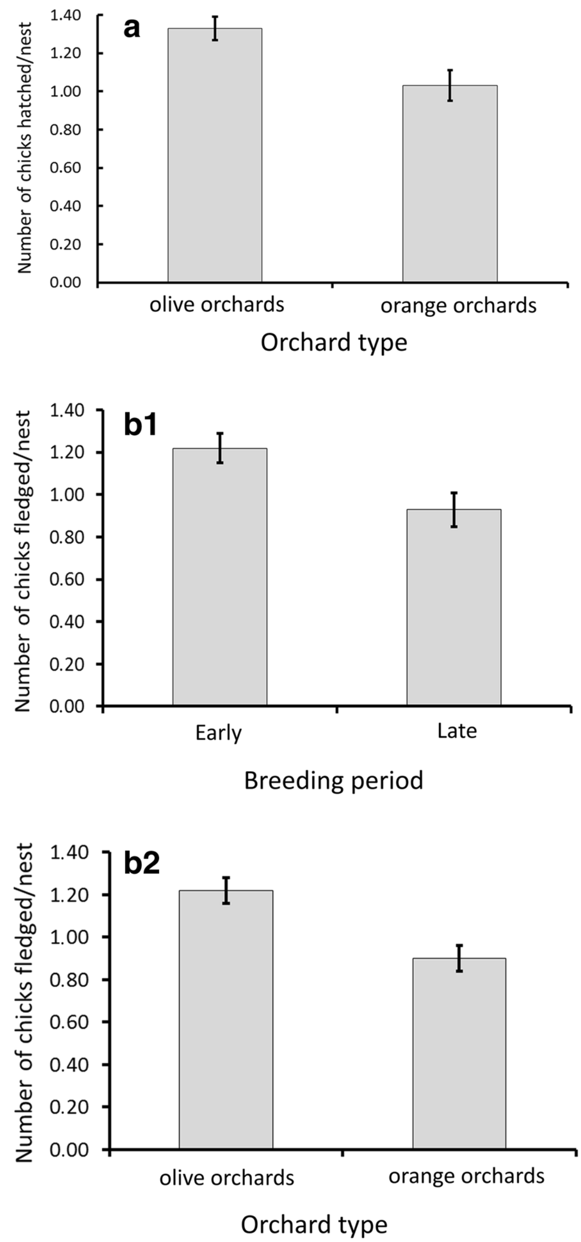

Fig. 3 **a** Number of chicks hatched per nest of Turtle Doves according to orchard type in Haouz and Tadla irrigated areas, Morocco. $\mathbf{b_1}$ Number of chicks fledged per nest of Turtle Doves according to laying period in the irrigated areas of Haouz and Tadla, Morocco. $\mathbf{b_2}$ Number of chicks fledged per nest of Turtle Doves according to orchard type in Haouz and Tadla irrigated areas, Morocco

$p < 0.001$), these were not included in the same models. Taking into account the results of the second step of analyses, explanatory variables (orchard type, laying period and nest position) were tested alone, in addition and with interaction. For each model, Akaike information criteria (AIC) were calculated from the general formula AIC = −2 (log likelihood) + 2 K, where K is the number of parameters. The model with the lowest AIC was selected as the best fitting model. I corrected AIC for a small sample size using AICc (Burnham and Anderson 2002). To test whether the residuals of the best models were normally distributed, and thus acceptable, a

Table 2 Mean values (±SE) of Turtle dove nest position according to location, orchard types and nest-tree features during 2004–2008

	Haouz		Tadla	
	Olive orchards	Orange orchards	Olive orchards	Orange orchards
TH (m)	5.39 ± 0.09	4.09 ± 0.09	6.88 ± 0.09	4.29 ± 0.12
NH (m)	2.77 ± 0.08	2.41 ± 0.09	3.92 ± 0.08	2.61 ± 0.12
LC (m)	2.13 ± 0.08	2.03 ± 0.09	3.19 ± 0.08	2.37 ± 0.11
NT (m)	1.65 ± 0.07	0.71 ± 0.08	2.04 ± 0.07	0.99 ± 0.10
DE (m)	1.65 ± 0.08	1.65 ± 0.08	2.51 ± 0.07	1.74 ± 0.10

TH nest tree height, *NH* nest height above ground, *LC* height of the base of the live crown, *NT* nest-trunk distance, *DE* distance from nest to the external part of the canopy

goodness-of-fit (GOF) test was performed. Because the monitoring was not performed during the same years [Haouz (2004–2005); Tadla (2006–2008)], the annual effect was excluded in the analyses. All statistical analyses were performed in R-3.1.0 software (R Development Core Team 2013), using the package "ade4" for Principal Component Analysis (Dray and Dufour 2007). Throughout, results are expressed as mean ± SE.

Results

Clutch-size

The average clutch size was 1.92 eggs (SE = 0.01, $n = 317$), with either 1 or 2 eggs. The model that best described variation in clutch-size was the null model (Tables 3, 4). None of the other variables, i.e., location ($z = 0.321$, $p = 0.74$), orchard type ($z = -0.095$, $p = 0.92$), laying period ($z = -0.089$, $p = 0.92$) or nest position ($PC_{\text{Vertical distribution of nests}}$: $z = -0.188$, $p = 0.85$; $PC_{\text{Distal distribution of nests}}$: $z = 0.013$, $p = 0.98$) were related to variation in clutch-size.

Hatching success

Across five breeding seasons, average hatching success was 1.21 hatchlings per nest (SE = 0.05, $n = 317$), ranging from 0 to 2 hatchlings. In accordance with the ΔAICc values, the most parsimonious model of hatching success included as explanatory variables fit to orchard type. The goodness-of-fit test indicated an acceptable fit ($p = 0.37$). The model explained 30 % of the deviance in the hatching success and 20 % of their variance. The hatching success of the Turtle Doves was greater in olive orchards than in the orange orchards ($\beta = -0.241 \pm 0.10$; 95 % CI −0.436 to −0.044, $z = -2.253$, $p = 0.02$) (Tables 3, 4; Fig. 3a). Location ($z = 0.038$, $p = 0.96$), laying period ($z = -1.178$, $p = 0.23$) and nest position ($PC_{\text{Vertical distribution of nests}}$: $z = 1.412$, $p = 0.16$; $PC_{\text{Distal distribution of nests}}$: $z = 0.995$, $p = 0.32$) did not affect variation in hatching success.

Breeding success

Among the 317 clutches monitored, 130 (58.9 %) were successful (proportion of fledged nests among the monitored nest sample). Average fledging success was 1.09 fledglings per nest (SE = 0.05, $n = 317$), ranging from 0 to 2 fledglings. The most parsimonious model of breeding success includes orchard type and laying period. The goodness-of-fit test indicated acceptable fit ($p = 0.09$). The model explained 23 % of the deviance in the breeding success and 18 % of their variance. The number of chicks fledged per nest was greater in olive orchards than in orange ones ($\beta = -0.304 \pm 0.11$; 95 % CI −0.526 to −0.081, $z = -2.679$, $p = 0.007$) and in early laying period compared to late period ($\beta = -0.259 \pm 0.11$; 95 % CI −0.475 to −0.043, $z = -2.351$, $p = 0.018$) (Tables 3, 4; Fig. 3b_1, b_2). Neither location ($z = -0.477$, $p = 0.63$) nor nest position ($PC_{\text{Vertical distribution of nests}}$: $z = 1.981$, $p = 0.06$; $PC_{\text{Distal distribution of nests}}$: $z = 0.219$, $p = 0.22$) were related to variation in Turtle Dove breeding success.

Discussion

The present study aimed to investigate the reproductive parameters of Turtle Doves in olive and orange agroecosystems. In Morocco, large areas of olive and orange groves are found in irrigated areas which are characterized to a large extent by cereals, water availability and the presence of suitable nest-trees. The man-made characteristics in this environment explain the high incidence of nesting Turtle Doves (Hanane 2009; Hanane and Baamal 2011). However, the choice of olive and orange trees does not indicate a particular attraction, but is more a reflection of their availability in the study areas (Wiley 1991; Rivera-Milán 1996; Browne et al. 2005; Hanane and Baamal 2011).

In this study, the clutch size of the Turtle Dove was not related to location, orchard type, laying period or nest position. These findings are consistent with the typical pattern shown by Turtle Doves both in Europe (Peiro 1990; Browne et al. 2005) and North Africa (Hanane and Maghnouj 2005; Hanane and Baamal 2011; Kafi et al. 2015). I also found that the number of chicks hatched and fledged per nest are greater in olive orchards than in orange orchards. This suggests that biotic disturbances occur much more in orange orchards than among the olive trees. This is logical since, during spring and summer seasons, orange orchards are under continuous human management compared to olive orchards, where interventions occur only sporadically. Indeed, agricultural practices, such as fruit harvesting, tree pruning and the application of pesticide and herbicide, are exclusively performed in orange orchards during this period, which coincides with the breeding season of Turtle Doves (Hanane and Baamal 2011). The presence of a sizeable

Table 3 Model comparison procedure performed on the data set of Turtle dove reproductive performance considering location (LC), orchard type (OT), laying period (LP) and nest position in Haouz and Tadla irrigated areas, Morocco

Breeding parameters	Models	K	AICc	ΔAICc	AICcw	GOF (*P*)
Clutch size	Null	1	829.63	0	–	–
	LC	2	831.55	1.92	–	
	$PC_{\text{Vertical distribution of nests}}$	2	831.62	1.99	–	
	OT	2	831.65	2.02	–	
	LP	2	831.65	2.02	–	
	$PC_{\text{Distal distribution of nests}}$	2	831.66	2.03	–	
	$LP \times PC_{\text{Distal distribution of nests}}$	4	833.58	3.95	–	
	OT + LC	3	833.58	3.95	–	
	LP + LC	3	833.59	3.96	–	
	$LP + PC_{\text{Vertical distribution of nests}}$	3	833.66	4.03	–	
	OT + LP	3	833.68	4.05	–	
	$LP + PC_{\text{Distal distribution of nests}}$	3	833.69	4.06	–	
	OT × LC	4	835.60	5.97	–	
	OT + LC + LP	4	835.62	5.99	–	
	LP × LC	4	835.63	6	–	
	$LP \times PC_{\text{Vertical distribution of nests}}$	4	835.64	6.01	–	
	LP × OT	4	835.68	6.05	–	
	$LP + PC_{\text{Vertical distribution of nests}} + PC_{\text{Distal distribution of nests}}$	4	835.71	6.08	–	
	OT × LC + LP	5	837.65	8.02	–	
	OT + LC × LP	5	837.67	8.04	–	
	$LP \times (PC_{\text{Vertical distribution of nests}} + PC_{\text{Distal distribution of nests}})$	6	839.78	10.15	–	
	OT × LC × LP	8	843.80	14.17	–	
Number of chicks hatched/nest	OT	1	847.80	0	0.30	0.37
	OT × LC	4	849.98	2.18	0.10	
	OT + LP	3	850.05	2.25	0.10	
	OT × LC + LP	5	850.25	2.45	0.09	
	OT + LC	3	850.74	2.94	0.07	
	OT × LP	4	851.37	3.57	0.05	
	OT + LC + LP	4	851.42	3.62	0.05	
	$PC_{\text{Vertical distribution of nests}}$	2	852.03	4.23	0.04	
	$LP + PC_{\text{Vertical distribution of nests}}$	3	852.21	4.41	0.03	
	OT + LC × LP	5	852.58	4.78	0.03	
	LP	2	852.59	4.79	0.03	
	$PC_{\text{Distal distribution of nests}}$	2	852.99	5.19	0.02	
	$LP + PC_{\text{Vertical distribution of nests}} + PC_{\text{Distal distribution of nests}}$	4	853.15	5.35	0.02	
	$LP + PC_{\text{Distal distribution of nests}}$	3	853.55	5.75	0.02	
	LC	2	853.99	6.19	0.01	
	$LP \times PC_{\text{Vertical distribution of nests}}$	4	854.14	6.34	0.01	
	$LP \times PC_{\text{Distal distribution of nests}}$	4	854.38	6.58	0.01	
	LP + LC	3	854.63	6.83	0.01	
	OT × LC × LP	8	855.34	7.54	0.01	
	LP × LC	4	855.58	7.78	0.01	
	$LP \times (PC_{\text{Vertical distribution of nests}} + PC_{\text{Distal distribution of nests}})$	6	856.37	8.57	0.00	
	Null	1	861.97	14.17	0.00	

Table 3 continued

Breeding parameters	Models	K	AICc	ΔAICc	AICcw	GOF (*P*)
Number of chicks fledged/nest	LP + OT		826.25	0	0.23	0.09
	LP × OT		827.31	1.06	0.14	
	OT × LC + LP		828.29	2.04	0.08	
	OT + LC + LP		828.33	2.08	0.08	
	LP + $PC_{Vertical\ distribution\ of\ nests}$		828.45	2.2	0.08	
	OT + LC × LP		828.54	2.29	0.07	
	LP + $PC_{Vertical\ distribution\ of\ nests}$ + $PC_{Distal\ distribution\ of\ nests}$		828.61	2.36	0.07	
	LP × $PC_{Vertical\ distribution\ of\ nests}$		829.48	3.23	0.05	
	OT		829.83	3.58	0.04	
	LP × ($PC_{Vertical\ distribution\ of\ nests}$ + $PC_{Distal\ distribution\ of\ nests}$)		830.13	3.88	0.03	
	OT × LC		830.60	4.35	0.03	
	OT × LC × LP		831.00	4.75	0.02	
	LP × $PC_{Distal\ distribution\ of\ nests}$		831.51	5.26	0.02	
	LP		831.60	5.35	0.02	
	OT + LC		831.85	5.6	0.01	
	LP + $PC_{Distal\ distribution\ of\ nests}$		831.93	5.68	0.01	
	$PC_{Vertical\ distribution\ of\ nests}$		833.29	7.04	0.01	
	LP × LC		833.33	7.08	0.01	
	LP + LC		833.39	7.14	0.01	
	$PC_{Distal\ distribution\ of\ nests}$		835.74	9.49	0.00	
	LC		837.01	10.76	0.00	
	Null		843.21	16.96	0.00	

Table 4 Turtle Dove breeding productivity during the incubation and brood-rearing periods based on all nests found in orange and olive groves during 2004–2008

	Haouz				Tadla			
	Olive orchards		Orange orchards		Olive orchards		Orange orchards	
	Early	Late	Early	Late	Early	Late	Early	Late
Clutch size	1.94 ± 0.04	1.95 ± 0.04	1.95 ± 0.04	1.95 ± 0.04	1.96 ± 0.04	1.87 ± 0.04	1.83 ± 0.05	1.91 ± 0.06
Chicks hatched/nest	1.55 ± 0.13	1.33 ± 0.15	1.10 ± 0.14	0.81 ± 0.15	1.25 ± 0.13	1.17 ± 0.14	1.55 ± 0.13	1.33 ± 0.15
Chicks fledged/nest	1.49 ± 0.13	1.08 ± 0.15	1.00 ± 0.14	0.60 ± 0.15	1.18 ± 0.13	1.11 ± 0.14	1.13 ± 0.17	0.91 ± 0.20

number of deserted eggs in orange orchards corroborates our findings (Hanane and Maghnouj 2005; Hanane and Baamal 2011). Another possible explanation is that there are different predator communities in the two orchard types, in which the impact on the nests of Turtle Doves would be much more intense in orange orchards than in olive orchards. Westmoreland and Best (1985) also reported a low reproductive success of disturbed nests compared to undisturbed ones when studying the effect of disturbance on the nest success of Mourning Doves (*Zenaidura macroura*).

The present study also highlights the effect of fruit nest-tree types on the number of chicks hatched and fledged per nest. This result is surprisingly inconsistent with the study of Hanane and Baamal (2011), which suggested the absence of such effect in the Tadla region. Although not significant, the effect of location seems to play a tiny and discreet role (the number of chicks hatched per nest: $\beta_{orchard\ type\ *\ location} = -0.399 \pm 0.225$, $z = -1.857$, $p = 0.063$; number of chicks fledged per nest: $\beta_{orchard\ type\ *\ location} = -0.415 \pm 0.227$, $z = -1.824$, $p = 0.068$). In the Haouz location, the intensity of predation and human disturbance are more pronounced than in Tadla (Pers. Obs.). It is all the more true that breeding success is lower in Haouz [48.8 % (Hanane and Maghnouj 2005)] than in Tadla [55.5 % (Hanane and Baamal

2011)]. Differences in productivity of nests between fruit nest-trees are also found in another dove species, i.e., the Mourning Dove (Knight et al. 1984).

In addition to the effect of orchard type, laying period was also identified as a significant predictor of the number of chicks fledged per nest, with more chicks fledging in the early period than in the late period. This result could be explained by: (1) the hunting activity which takes place during the laying period of doves in the two zones under investigation (from 4 July to 24 August), (2) the continuous presence of children, who continually look for nests during the summer holidays (from June to September) and (3) the long period of orange harvesting which is immediately followed by that of tree pruning (from the end of May to September). Overall, in fruit tree orchards Turtle Doves are disturbed by several events, mainly human activities (Mitchell et al. 1996).

Although not included in the analyses, the effect of year may affect the reproductive parameters in this species as recorded in Spain by Peiro (1990) and in Morocco by Hanane and Baamal (2011). Fluctuating ecological conditions from 1 year to another would be the origin of these variations (Zárybnická et al. 2015).

Tree plantations are known to act as sources of generalist predators of various types, including rodents, lagomorphs, feral cats, dogs and corvids (Suvorov et al. 2012; Sánchez-Oliver et al. 2014). Declines in the number of chicks fledged per nest could reflect a change in predator activity over the course of the breeding season (Peak 2007; Sperry et al. 2008). Unfortunately, I did not monitor nest predators or collect data on their activity or behavior; however, it is known that snake activity is more important during the summer months than in the spring (Sperry et al. 2008).

The reproductive parameters of the Turtle Doves did not vary according to position of nests within trees. This result is consistent with a previous study conducted in the Tadla region (Hanane and Baamal 2011), as well as with several studies on Columbid species that have examined the relationship between nest location and nesting success [e.g. Laughing Dove (*Streptopelia senegalensis*) (Hanane et al. 2011), Mourning Dove (Yahner 1983; Miller and Otis 2010), Zenaida Dove (*Zenaida aurita*) (Rivera-Milán 1996), Common Ground-dove (*Columbina passerine*) (Rivera-Milán 1996), Plain Pigeon (*Patagioenas inornata*) (Rivera-Milán et al. 2003), and Wood Pigeon (*Columba palumbus*) (Hanane and Besnard 2013)].

A recent study (Kafi et al. 2015) was carried out in the orange orchards of Guelma in Algeria does however not come in line with the findings of this study. Indeed, nest height and nest-trunk distance have affected the number of chicks fledged per nest in this region. Most likely, ecological conditions, especially anthropogenic, prevailing in the orange groves of Guelma would be responsible for this relationship.

Conclusions

The results of this study show that, in Haouz and Tadla orchards, the number of chicks hatched per nest was lower in orange orchards, as was the number of chicks fledged and, as well, later in the laying period. Based on these findings and given the impossibility to control harvest periods of oranges (responsive to the supply and demand of the citrus market, which changes from year to year), it is important to raise awareness among farmers to reduce disturbance to nesting Turtle Doves. The control of predation is also of major importance. Overall, the civil society, in partnership with government bodies, has a key role to play in protecting Turtle Doves in these man-made environments.

Further studies are needed to improve our understanding of the effects of anthropogenic disturbances, especially agricultural activities in orchards and hunting, on the productivity of Turtle Dove nests. Bird banding is an essential way to study the demography of Turtle Dove populations in such environments. This will allow us to quantify the actual effect of human disturbance on the productivity of this Columbid species. It is also important to understand predator communities in relation to human activities.

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Competing interests

The author declares that he has no competing interests.

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