Journal of Pollination Ecology, 19(13), 2016, pp 93-97

— Short Communication —

INSECT POLLINATORS BOOST THE MARKET PRICE OF CULTURALLY IMPORTANT CROPS: HOLLY, MISTLETOE AND THE SPIRIT OF CHRISTMAS

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Abstract—Animal pollination is a vital ecological process in both natural and agricultural ecosystems. Economic valuation studies have demonstrated that pollination services may underpin a significant proportion of global crop market outputs. However these assessments are probably under-estimates because they have rarely included non-food crops, for which very few data are currently available. In particular, culturally symbolic plants have received no attention. Here we show that pollinators have considerable economic benefits to sales of European holly and mistletoe, two seasonal cultural crops that are almost wholly dependent upon insect pollinators for the production of ornamental berries. Analyses of a time series of auction records spanning 11 years indicates that wholesale prices paid for holly with berries are twice those paid for the crop without berries, whilst mistletoe with berries sells for almost three times the price of the crop lacking fruit. The benefits of this insect pollination ecosystem service to this market are therefore considerable. These findings demonstrate that pollinators can play a significant role in adding value to crops that provide resources other than food. In the future such crops should be included in assessments of regional and global value of animal pollination to increase the accuracy of assessments of the value of pollination as an ecosystem service. Our results also support arguments for continued efforts to conserve pollinator diversity and abundance in agro-ecological systems, not least for their contribution as providers of ecosystem services.

Keywords: Ilex, Viscum, cultural services, pollination value, ecosystem services, natural capital, insect pollination

INTRODUCTION

"The shepherd, now no more afraid, since custom doth the chance bestow,
Steps up to kiss the giggling maid beneath the branch of mistletoe
That 'neath each cottage beam is seen, With pearl-like berries shining gay"

John Clare *The Shepherd's Calendar* (1827)

"The general complaint of the retail purchasers this season seems to be that holly is much too dear, and that there are fewer berries than ever…"

Anon. (1872)

An estimated 87.5% of the 352,000 species of flowering plants are biotically pollinated, the majority by insects (Ollerton et al. 2011), whilst 75% of the 115 most productive crop plants, accounting for 35% of worldwide crop production, are likewise dependent to some extent upon pollinators for seed and fruit production (Klein et al. 2007). Estimates of the economic benefits of pollinators to agriculture has focussed primarily on food crops and includes global, national, and regional estimates, as well as estimates for specific crops; e.g. the additional output added by animal pollination to agriculture is estimated at €153 billion per year, almost 10% of the economic value of food crop production (Gallai et al. 2009).

Not all agricultural plant production is edible, with many species cultivated for fibres, construction materials, pharmaceuticals, and ornamentals contributing significantly to the world's economy. In the latter category are included a number of culturally significant plants. However with the exception of cotton (Pires et al. 2014) and some industrial crops such as oilseed rape, the benefits of pollination services to non-food crops has hardly been studied (Klein et al. 2007; Ollerton et al. 2011). Furthermore, no previous research has considered the impacts of pollination services on markets for culturally symbolic species.

European holly (*Ilex aquifolium* – Fig. 1A) and mistletoe (*Viscum album* – Fig. 1B) have similar distributions across most of Europe and into southern Scandinavia (though mistletoe is a naturalised introduction to Ireland – Nelson 2008). In some areas they are semi-domesticated and have a strong symbolic cultural association with both Christian and Pagan winter festivities in many north European countries (Mabey 1996; Peterken & Lloyd 1967; Zuber 2004), and other parts of the world following European colonisation (e.g. North America – see below). For example Christian folklore interprets holly wreaths as a

Received 30 September 2016, accepted 1 November 2016
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FIGURE 1: (A) Mistletoe and (B) holly berries growing on female plants *in situ*, and the same species packaged displayed for retail (C & D) Photos by J. Ollerton.

symbol of Christ's blood (berries) amidst his crown of thorns (the sharp leaves) while older Celtic lore describes holly wreaths as a ward against evil (Varner 2006). Mistletoe's usage is linked with pre-Christian winter solstice customs and with Norse mythology. Its use as an ancient symbol of fertility underwent a resurgence of interest in the 18th and 19th centuries and consolidated into the kissing tradition with which it is most commonly associated nowadays (Mabey 1996). As a result of these past associations, holly and mistletoe are commercially valuable non-food crops that are harvested and traded for their seasonal ornamental value. Although the traditions and folklore surrounding holly and mistletoe originate in Europe, their cultural value as ornamental plants has spread to many parts of the world, with other species of holly and mistletoe being used beyond the European range of *I. aquifolium* and *V. album*. For example, the mistletoe *Phoradendron leucarpum* shares a similar ecology to *V. album* and performs a comparable cultural and ornamental role in the USA.

Holly is a small to medium-sized multi-stemmed tree, whilst mistletoe has a hemi-parasitic lifestyle. Both species possess evergreen foliage, a significant factor in their use as home decoration in the northern winter. The flowers of holly are thought to mainly be pollinated by a range of bees (Hymenoptera – including honey bees and unmanaged species of *Bombus*, *Andrena* and *Osmia*) and hoverflies (Syrphidae). Mistletoe is pollinated by a number of taxa of flies (Diptera – Zuber 2004). The pollination ecology of neither species has been well studied, however, and a limited amount of wind pollination and/or parthenocarpic fruit production may be possible (Peterken & Lloyd 1967; Zuber 2004). Both species produce fleshy berries that are inedible to humans but regularly consumed by birds (Peterken & Lloyd 1967; Zuber 2004). Importantly, holly and mistletoe are dioecious species with separate male and female individuals. As such, self-pollination, a significant source of uncertainty in valuing pollination services (Melathopolous et al. 2015), is impossible, making dependence upon insect pollination likely to be near 100%. It is also highly unlikely that the benefits of pollination services could be supplanted by changes to cultivation techniques or additional inputs (Melathopolous et al. 2014).

A significant fraction of the mistletoe and holly that is produced in Britain is traded through an annual set of auctions in Tenbury Wells, Worcestershire (Sanderson & Prendergast 2002). There are many ways in which the value of ecosystem services such as animal pollination can be assessed (Breeze et al. 2016). In this study we focused only on the financial value of these culturally important crops, whilst acknowledging that their cultural value could also be assessed using different approaches. To do this we used a data set comprising 11 years of auction records to address the question of the extent to which insect pollinators add

commercial value to these crops via the production of berries on female plants.

MATERIALS AND METHODS

Holly and mistletoe auction reports for the period 2005 to 2015 were provided by Nick Champion, Auctioneer, of Tenbury Wells and are summarised in the electronic supplementary material. Each report consists of a summary of the general prices paid by buyers for the two crops, together with total number of lots (not split by crop and only available systematically for post-2006 auctions). In each year, three auctions were conducted in late November, and early and mid December, giving a total of 33 wholesale auctions on which to base the analyses. Records up to and including 2009 were provided as price per lb, which were then converted to price per kg to match the post-2009 records.

Each auction comprised 550 to 1450 lots of ~10 kg (holly) or 10 to 25 kg (mistletoe) each. The records include both maximum price and average price paid; in each year average and maximum prices were highly correlated ($N = 33$ auctions: $R^2 = 0.87$ for holly with berries; $R^2 = 0.73$ for mistletoe with berries – see Appendix 1) therefore only average values were used in the subsequent analyses. Data from the 3 auctions in each year were then averaged to give mean price paid per year for the two crops for each of the 11 years.

In each year, average price paid for 1st quality holly with berries was compared with that of 1st quality plain holly; 2nd quality holly was not considered as the findings were similar for this category, with a clear difference in the relative value of berried and plain 2nd quality holly (see Results and Discussion and electronic supplementary material). For mistletoe, the comparison was between average price of 1st quality and 2nd quality material; although factors such as leaf colour and woodiness are important, number of berries is a major factor determining mistletoe quality (Rachel Farmer, Nick Champion Auctions, pers. comm.). We therefore assume that 2nd quality mistletoe has few if any berries, in comparison to 1st quality material.

RESULTS AND DISCUSSION

As the 19th century quote at the beginning of this paper demonstrates, there has long been known to be a link between the quantity of berries on decorative crops such as holly, and their market and symbolic values. Analyses of over a decade of auction records shows that average prices per kilogram for the two crops have fluctuated significantly and in parallel ($N = 11$ years, $R^2 = 0.85$). Nonetheless, auction lots of mistletoe and holly which possess berries command a price premium which is typically 1.2 to 3.7 (holly) and 1.9 to 4.3 (mistletoe) times the price for material without berries (Fig. 2).

Year-to-year variations notwithstanding, averaged over the whole eleven years, the price of holly without berries was £1.05 per kg, whilst holly with berries was double the price, selling for £2.09 per kg. Similarly mistletoe without berries sold for £0.49 per kg, and mistletoe with berries was almost three times as valuable at £1.36 per kg. These wholesale prices are comparable to or greater than the price/kg of high value fruit crops such as strawberries (£2.52/kg, class 1) and apples (£0.64/kg, class 1) over the same period (Defra 2016). Final retail prices of mistletoe and holly can be at least an order of magnitude higher, e.g. £10 to £20 per kg is not exceptional (Intermistletoe 2016; Fig. 1 C & D).

By influencing the supply of a crop with berries, variations in pollination services can also have a strong impact on inter-annual variation in prices, lowering average and premium prices in years where the berry crop is plentiful relative to demand, potentially increasing consumer welfare (Gallai et al. 2009). Indeed an auction report for 2006 notes that "The bumper year for berries has resulted in a very large supply of berried holly and mistletoe and prices were down on last year". Longer term time series data would be required to determine the precise extent of such benefits, as well as the impacts on producer profits (lower per kg profit may be compensated with higher bulk sales), however better management of these price fluctuations is likely to be beneficial for both producers and consumers. As far as we are aware differences in prices for different quality categories of these crops do not reflect different production practices (e.g. inputs of fertilisers, pesticides or managed pollinators) because holly is not commercially grown for harvest and mistletoe is a by-product of apple orchards or collected from the wild (Sanderson & Prendergast 2002). Leaf quality can be affected by herbivores and by growing conditions, but the large price differentials are due mainly to the presence of the berries.

No statistics on the annual crop of holly and mistletoe in Britain are officially collected by the Department for the Environment, Food and Rural Affairs (Defra), and it is known that a large quantity is imported from northern France (Sanderson & Prendergast 2002) and has been since at least the latter half of the 19th century (Anon. 1872). Therefore it is impossible to accurately assess the total market for these crops or to quantify the economic benefits of pollination services for the British market as a whole. However it is clear that they contribute to a small but significant element of seasonal spending: in 2014 the British public spent £623 million on Christmas decorations, averaging around £23.35 per household, which was 3% of their total Christmas spending (similar averages and proportions were recorded for 2015 - Centre for Retail Research 2016). This does not include the decorations used by shops, businesses and other commercial properties, so the true value is probably much higher.

Locally, the economic and cultural significance of holly and mistletoe can be considerably higher. Tenbury Wells has proclaimed itself to be the "mistletoe capital" of the UK and has obtained UK parliamentary endorsement for a National Mistletoe Day on 1st December each year. The town runs a series of annual cultural events based around the plant, culminating in the Tenbury Mistletoe Festival and the crowning of the Mistletoe Queen with a wreath of berried mistletoe (The Tenbury Mistletoe Association 2015).

There are on-going concerns about declines in pollinator abundance and diversity in Britian and elsewhere in the

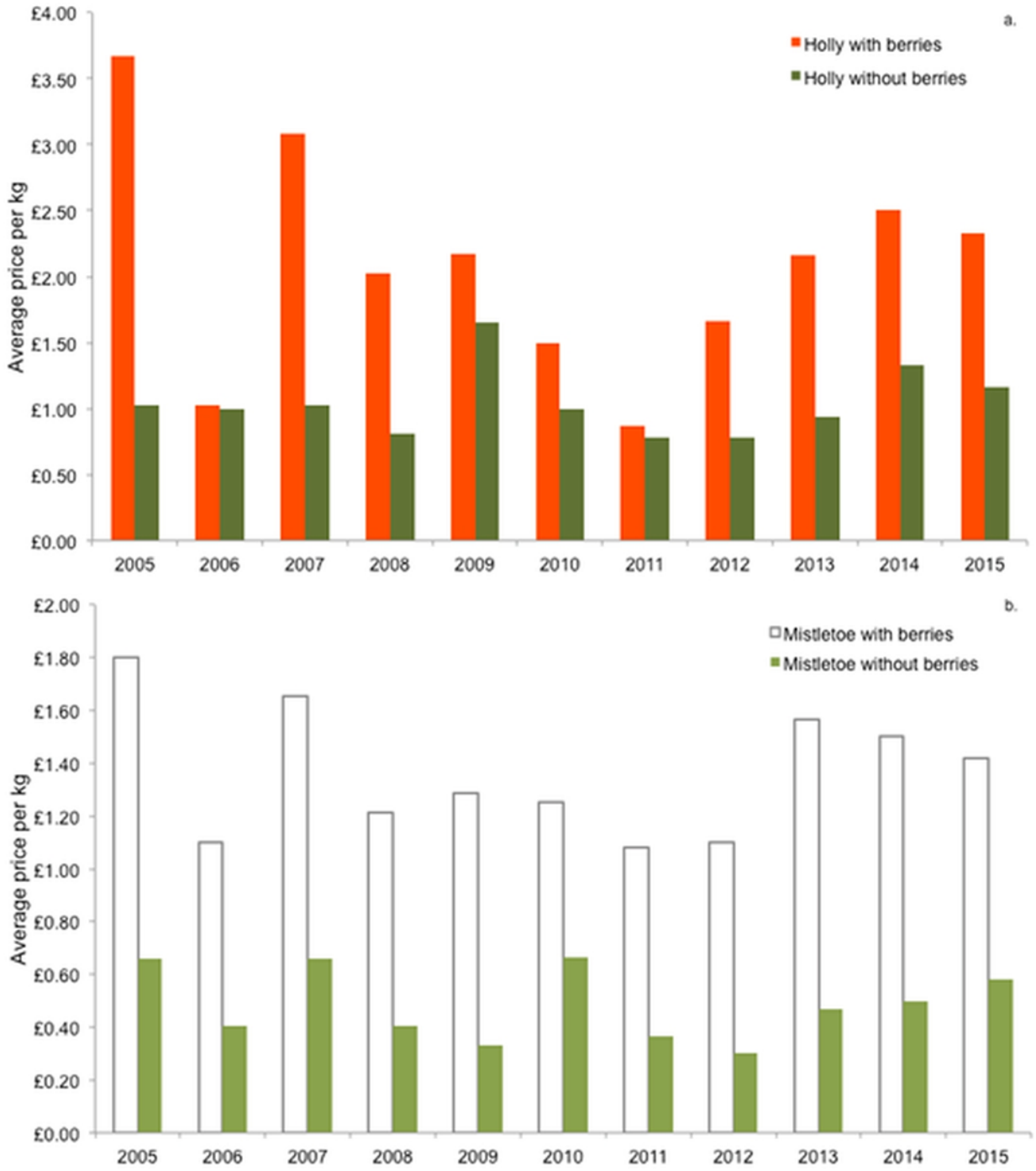

FIGURE 2: Average auction prices (£ per kg) between 2005 and 2015 of (A) holly and (B) mistletoe, with and without berries.

world in the face of habitat loss and degradation, and changes in agricultural practices (Biesmeijer et al. 2006; Potts et al. 2010; Ollerton et al. 2014). A wide range of these pollinators support agricultural outputs and their role is becoming more important as the area of animal-pollinated crops is increasing (Aizen et al. 2008) which means that a fuller understanding of the ecology and evolution of plant-pollinator interactions could play a role in securing global food supplies, e.g. through focussed selective breeding of varieties (Bailes et al. 2015). In the case of holly and mistletoe, loss of pollinators would have both ecological and economic impacts because as well as facilitating the reproduction and dispersal of these plants, the berries of both species are an important food source for birds in winter and (as we have demonstrated) add considerably to the market price of these crops.

This unique case study demonstrates the potential benefits of pollination services to markets for minority non-food crops. Furthermore, it serves to emphasise the need to examine values beyond economics alone by demonstrating direct links between cultural, symbolic value and pollination services. As such, this work highlights the requirement to consider the wide range of non-food crops that also benefit from animal pollinators, directly for crop yield and indirectly

for crop reproduction. The study also emphasises the fact that there are large gaps in our knowledge of the contribution of these and other culturally significant plants to local and national economies, even for a country such as Britain where detailed agricultural statistics are widely collected and readily available. Future research on the role of pollinators in enhancing the value of such crops will require focused data collection on both their ecology and their ecological economics.

ACKNOWLEDGEMENTS

Thanks to Nick Champion and Rachel Farmer for providing the auction reports and answering questions, and two anonymous reviewers and Jane Stout for their comments which improved the final manuscript.

APPENDICES

Additional supporting information may be found in the online version of this article:

APPENDIX I. Auction prices data for holly and mistletoe (2005-2015) used in the analyses.

REFERENCES

Aizen MA, Garibaldi LA, Cunningham SA, Klein AM (2008) Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. Current Biology 18:1572-1575.

Anon. (1872) Christmas in Covent Garden. The Morning Post (London, England) Issue 31352, 25th December, p8.

Bailes E, Ollerton J, Pattrick J, Glover BJ (2015) How can an understanding of plant-pollinator interactions contribute to global food security? Current Opinion in Plant Biology 26:72-79.

Biesmeijer JC, Roberts SPM, Reemer M, Ohlemüller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J, Kunin WE (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 313:351-354.

Breeze TD, Gallai N, Garibaldi LA, Li XS (2016) Economic measures of pollination services: shortcomings and future directions. Trends in Ecology and Evolution 31: 927-939.

Centre for Retail Research (2016) http://www.retailresearch.org/shoppingforxmas.php Accessed 1st November 2016.

Defra (2016) Dataset of weekly prices https://www.gov.uk/government/statistics/wholesale-fruit-and-vegetable-prices. Accessed 1st November 2016.

Gallai N, Sallesc J-M, Setteled J, Vaissière BE (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics 68:810–821.

Intermistletoe (2016) http://www.intermistletoe.co.uk/index.shtml. Accessed 1st November 2016.

Klein A-M, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society series B 274:303–313.

Mabey R (1996) Flora Brittanica. Sinclair-Stevenson, London.

Melathopolous AP, Cutler GC, Tyedmers P (2015) Where is the value in valuing pollination ecosystem services to agriculture? Ecological Economics 109:59–70.

Melathopoulos AP, Tyedmers P, Cutler GC (2014) Contextualising pollination benefits: effect of insecticide and fungicide use on fruit set and weight from bee pollination in lowbush blueberry. Annals of Applied Botany 165:387-394.

Nelson EC (2008) Mistletoe (*Viscum album* L.) in Ireland: a review of records and status. The Irish Naturalists' Journal 29: 87-94.

Ollerton J, Winfree R, Tarrant S (2011) How many flowering plants are pollinated by animals? Oikos 120:321-326.

Ollerton J, Erenler H, Edwards M, Crockett R (2014) Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes. Science 346:1360-1362.

Peterken GF, Lloyd PS (1967) Biological Flora of the British Isles: *Ilex aquifolium* L. Journal of Ecology 55:841-858.

Pires VC, Silveira FA, Sujii ER, Torezani KRS, Rodrigues WA, Albuquerque FA, Rodrigues SMM, Salomão AN, Pires CSS (2014) Importance of bee pollination for cotton production in conventional and organic farms in Brazil. Journal of Pollination Ecology 13:151-160.

Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE (2010) Global pollinator declines: trends, impacts and drivers. Trends in Ecology and Evolution 25:345-353.

Sanderson H, Prendergast HDV (2002) Commercial uses of wild and traditionally managed plants in England and Scotland. Unpublished report; Centre for Economic Botany, Royal Botanic Gardens, Kew, London.

The Tenbury Mistletoe Association (2015) http://www.tenburymistletoe.org/index.html. Accessed 1st November 2016.

Varner GR (2006) The Mythic Forest, the Green man and the Spirit of Nature; Algora Publishing, New York.

Zuber D (2004) Biological flora of Central Europe: *Viscum album* L. Flora 199:181–203.