Observations on two commercial flower mixtures as food sources for beneficial insects in the UK

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Observations on two commercial flower mixtures as food sources for beneficial insects in the UK

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SUMMARY

Observations were made in 1994 and 1995 in Hertfordshire of the flowering phenology and attractiveness to beneficial insects of two commercial mixtures of flowering plants intended for set-aside land. These were the Tübingen Mixture from Germany and Ascot Linde SN from the Netherlands. The mixtures were visited by 14 species of Hymenoptera, 14 species of syrphid Diptera and six species of Lepidoptera. Although the mixtures contained 12 and five plant species respectively, *Phacelia tanacetifolia* was the dominant species to establish, flower and attract insects in both mixtures. The other plants contributed little to flower density or insect diversity. These mixtures are therefore not suitable for UK needs using the present proportions of plant species.

INTRODUCTION

Most (84%) of the crops grown in the European Union (EU), whose pollination requirements have been studied, are dependent on insects for pollination (Williams 1994). The aculeate Hymenoptera, in particular the Apoidea, including *Apis mellifera* (the domesticated honey bee), wild *Bombus* spp. (bumble bees) and solitary bees, are the most important of the insect pollinators (Free 1993). Changes in land use over recent decades (Williams & Carreck 1994) have reduced the availability of sites for nesting and of plants providing nectar and pollen for wild bees, causing a decline in populations of bumble bees (Williams 1986) and solitary bees (O'Toole 1994). In addition, the parasitic mite *Varroa jacobsoni* Oudemans is causing serious damage to populations of *A. mellifera* (Beetsma *et al.* 1983; Martin 1996).

Loss of pollinators is expected to adversely affect not only the yields of insect-pollinated crops but also to threaten the survival of many species of wild flowers (Corbet *et al.* 1991). Wild bees, unlike honey bees, store little food and thus starve, or fail to reproduce, when faced with even short-term food shortages. Arable crops such as oilseed rape (*Brassica napus* L.) and field bean (*Vicia faba* L.) provide abundant nectar, but flower for only a short period. Indigenous plants such as bramble (*Rubus* spp. L.), clovers (*Trifolium* spp. L.), hawthorn (*Crataegus* spp. L.) and ivy (*Hedera helix* L.), formerly ubiquitous in hedgerows and unimproved grassland, providing a succession of nectar and pollen, are now scarce in areas of intensive arable production (Williams & Carreck 1994).

Hover flies (Syrphidae: Diptera) are, after the bees, the next largest group of pollinators (Free 1993; Proctor *et al.* 1996), visiting flowers for both nectar and pollen. The larvae of many species are carnivorous, with a potential role in the biological control of crop pests, particularly aphids (Von Klinger 1987; Wratten *et al.* 1995). Their populations may also have been diminished by the recent scarcity of nectar- and pollen-producing food plants in farmland.

To overcome the problem of overproduction of food within the EU, the set-aside scheme was introduced in 1988. By 1993/94, this had resulted in 781000 ha of arable land being taken out of production in the UK. The set-aside regulations require that farmers claiming aid on more than 15·51 ha must set-aside 15% of the area for rotational (1-year) set-aside or 18% for non rotational set-aside (Stedman 1994). The potential for using this set-aside land to grow food plants for bees and syrphids is enormous (Osborne & Corbet 1994). This would help sustain their populations in arable areas and improve pollination and pest control in nearby commercial crops.

Phacelia tanacetifolia is a valuable food plant for bees (Williams & Christian 1991) and syrphids (Von Klinger 1987; Lövei *et al.* 1992; MacLeod 1992). Mixtures of bee forage plants, usually containing *P. tanacetifolia*, intended for 1-year set-aside are commercially available. They are designed to provide a succession of food sources for beneficial insects. Two such are the Tübingen Mixture (Tübinger Mischung),

Table 1. *Composition of bee forage mixtures* (% *by seed weight*)

Specific name	Common name	Nectar (N) or pollen (P) producer	Tübingen Mixture	Ascot Linde SN
Anethum graveolens L.	Dill	P	2	—
Borago officinalis L.	Borage	N	1	—
Brassica nigra (L.) Koch	Black mustard	N+P	—	20
Calendula officinalis L.	Marigold	P	5	—
Centaurea cyanus L.	Cornflower	P	3	—
Coriandrum sativum L.	Coriander	P	6	—
Fagopyrum esculentum Moench	Buckwheat	N	20	20
Helianthus annuus L.	Sunflower	N+P	5	—
Lupinus albus L.	Lupin	P	—	15
Malva sylvestris L.	Mallow	P	3	—
Nigella spp. L.	Caraway	P	5	—
Phacelia tanacetifolia Bentham	Phacelia	N+P	40	25
Raphanus sativus L.	Radish	N+P	3	20
Sinapis alba L.	White mustard	N+P	7	—

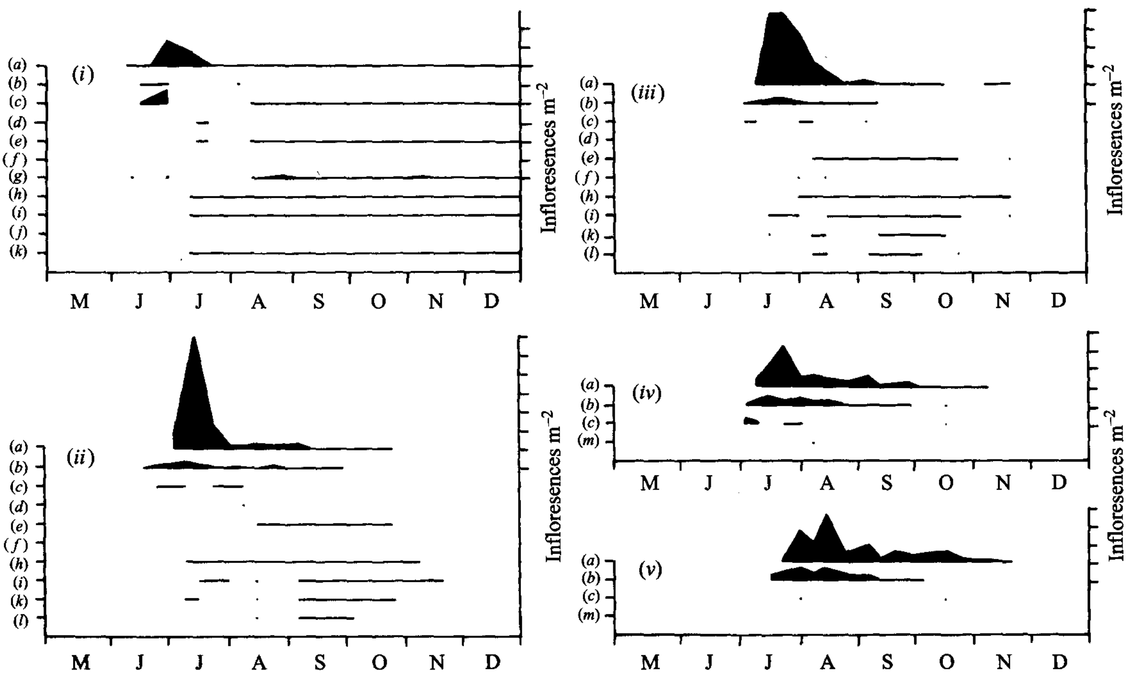

Fig. 1. Flowering period and infloresence density (vertical divisions represent 100 infloresences/m^2) of; (*a*) *P. tanacetifolia*, (*b*) *F. esculentum*, (*c*) *S. alba*, (*d*) *C. sativum*, (*e*) *C. officinalis*, (*f*) *Nigella* spp. (*g*) *R. sativus*, (*h*) *C. cyanus*, (*i*) *M. sylvestris*, (*j*) *A. graveolens*, (*k*) *B. officinalis*, (*l*) *H. annuus*, (*m*) *L. albus* in; (*i*) April 1994 sown Tübingen Mixture, (*ii*) April 1995 sown Tübingen Mixture, (*iii*) May 1995 sown Tübingen Mixture, (*iv*) May 1995 sown Ascot Linde SN, (*v*) June 1995 sown Ascot Linde SN.

developed at the Zoologisches Institut, Tübingen, Germany (Bauer 1991; Bauer & Engels 1992; Engels *et al.* 1994) and Ascot Linde SN (SN means Stuifmeel = pollen, Nektar = nectar) devised by Cebeco Zaden BV, Vlijmen, Netherlands in conjunction with the Stichting Imerij Fortmond, Olst, Netherlands. Their composition is given in Table 1. This paper describes the flowering of these two mixtures under UK conditions, and the insects which visited them.

Table 2. *Number of insects seen visiting the flowers of two bee forage mixtures in 1994 and 1995 in the UK*

	Tübingen Mixture			Ascot Linde SN	
	April 1994	April 1995	May 1995	May 1995	June 1995
Hymenoptera					
Apidae					
Apis mellifera L.	143	339	121	149	121
Bombus hortorum (L.)	8	1		4	1
Bombus lapidarius (L.)	115	1483	1396	1062	813
Bombus lucorum/terrestris (L.)	96	326	88	90	48
Bombus pascuorum (Scopoli)	40	40	32	16	8
Bombus pratorum (L.)	3				
Psithyrus barbutellus (Kirby)	1				
Psithyrus bohemicus (Seidl)	4				
Psithyrus vestalis (Geoffroy in Fourcroy)			1		
Andrenidae					
Andrena fulva (Mulleer in Allioni)					1
Megachilidae					
Megachile centuncularis (L.)	1		1		
Osmia rufa (L.)		2			
Vespidae					
Vespula vulgaris (L.)	10			2	1
Diptera					
Syrphidae	58				
Episyrphus balteatus (Degeer)		2			
Eristalis arbustorum (L.)				1	1
Eristalis pertinax (Scopoli)			1	1	11
Eristalis tenax (L.)					2
Leucozona lucorum (L.)		2			
Melanostoma mellinum (L.)		25		15	30
Melanostoma scalare (Fabricius)		1	5	6	1
Meliscaeva auricollis (Meigen)		7	26	2	8
Metasyrphus luniger (Meigen)			1		1
Neoascia podagrica (Fabricius)		1	2	1	5
Platycherius albimanus (Fabricius)		2			
Sphaerophora scripta (L.)		6	19		33
Syrphus ribesii (L.)		1	3	3	
Xanthogramma pedissequum (Harris)		1			1
Lepidoptera					
Lycaenidae					
Polyonmatus icarus (Rottemburg)	1	1			
Nymphalidae					
Aglais urticae (L.)		1			
Pieridae					
Pieris rapae (L.)	31	9	8	4	8
Satyridae					
Coenonympha pamphilus (L.)		1			
Maniola jurtina (L.)	2	1			1
Pyronia tithonus (L.)	1				

MATERIALS AND METHODS

In 1994 and 1995, plots of forage mixtures were sown at IACR-Rothamsted on a well drained flinty clay loam soil overlying clay with flints (Batcombe series) (Rothamsted Experimental Station 1977). Plots were 25 × 25 m in 1994 and 19 × 14 m in 1995. Seed was broadcast and then harrowed. In 1994, Tübingen Mixture was sown on 27 April. In 1995, two sowing dates were compared for each mixture, with Tübingen Mixture sown on 25 April and 18 May, and Ascot Linde SN sown on 18 May and 16 June. Seed rates used were those recommended by the seed merchants: 7 kg ha^{-1} for Tübingen Mixture and 75 kg ha^{-1} for Ascot Linde SN. The plots were irrigated as necessary.

At plant emergence, four 1 m^2 quadrats were marked at random on each plot and the plants of each species within them were counted. Once the first flowers had opened, weekly counts were made of the inflorescences in flower in each quadrat area. To assess floral density, inflorescences rather than flowers were counted because of the large variation in inflorescence and flower structure between the plant species. For example, *Malva sylvestris* and *Calendula officinalis* have large single flowers, *P. tanacetifolia* has large clusters of many individual flowers and *Helianthus annuus* has a composite inflorescence of many small flowers.

Records of insect density and diversity were made throughout flowering. An observer walked each plot at least three times per week, recording the species and number of insects foraging in the 3 m nearest the perimeter strip. Records of *Bombus terrestris* and *Bombus lucorum* were combined because of the difficulty of distinguishing between them in the field. In 1994, syrphids were counted, but not assigned to species.

RESULTS

Weather

Maximum daily temperatures in the two years differed little from the 30-year mean, except in July and August 1995 when they exceeded it by 18 and 20%, respectively. Summers were drier than average. Although, overall, 1994 and 1995 received 106 and 96% of the mean annual rainfall, June–July 1994 and March–August 1995 received only 40 and 49% of the mean, respectively.

Crop growth and flowering

Not all the plant species sown emerged or flowered. In 1994, *Anethum graveolens* and *Nigella* spp. and in 1995, *A. graveolens*, *Coriandrum sativum* and *Nigella* spp. in the Tübingen Mixture did not establish. In 1995, *Brassica nigra*, *Raphanus sativus* and *Sinapis alba* were seriously infested by *Brevicoryne brassicae* L. (cabbage aphid) and failed to flower normally.

The site used in 1994 had recently been ploughed from grassland, and was initially infested with common couch grass (*Elymus repens* L.), ground elder (*Aegopodium podagraria* L.) and creeping thistle (*Cirsium arvense* (L.) Scopoli). The 1995 site had long been in arable cultivation and initially contained black bindweed (*Fallopia convolvulus* (L.) Á. Löve), mayweed (*Matricaria* spp.), cleavers (*Galium aparine* L.) and creeping thistle (*C. arvense*). Numbers of weed plants were not counted, but in both years the forage mixtures competed well against these weeds.

Phacelia tanacetifolia flowered for a long period on all plots (Fig. 1). The main flush of flowers lasted about 4 weeks, with sporadic flowering thereafter until the plants were killed by frost. The density of *P. tanacetifolia* was greater in the Ascot Linde SN than in the Tübingen Mixture (Fig. 1), but the plants were smaller in the former than in the latter and the main flowering period was less pronounced, although it continued for *c.* 12 weeks.

In 1994, a few flowers of *R. sativus* and *S. alba* were present from early August onwards, and in both years the Tübingen Mixture had a few plants of *Borago officinalis*, *C. officinalis*, *Centaurea cyanus* and *M. sylvestris* plants continuously flowering until killed by frost. In 1995, *Fagopyrum esculentum* produced a few flowers for *c.* 10 weeks.

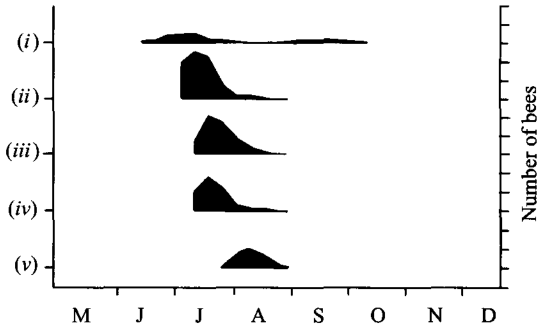

Fig. 2. Numbers (means per observation) of bees (all species) foraging on (*i*) April 1994 sown Tübingen Mixture, (*ii*) April 1995 sown Tübingen Mixture, (*iii*) May 1995 sown Tübingen Mixture, (*iv*) May 1995 sown Ascot Linde SN, (*v*) June sown Ascot Linde SN. Vertical divisions represent 100 bees.

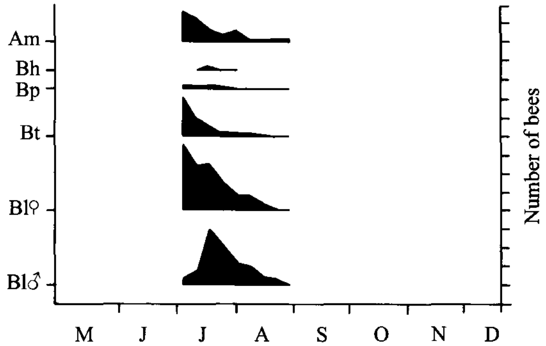

Fig. 3. Numbers (means per observation) of bees foraging (means of all 1995-sown plots). Am, *A. mellifera* workers; Bh, *B. hortorum* workers; Bp, *B. pascuorum* workers; Bt, *B. terrestris/lucorum* workers; Bl♀, *B. lapidarius* workers, Bl♂, *B. lapidarius* males. Vertical divisions represent 25 bees.

Insect visitors

The flowers of the forage mixtures attracted a total of 14 species of Hymenoptera, 14 species of syrphid Diptera, and six species of Lepidoptera (Table 2). Figure 2 shows the total number of bees visiting the five plots.

Table 3. *Percentage distribution of bees (all species) visiting the flowers of different plant species in two bee forage mixtures in the UK, 1994 and 1995*

	Tübingen Mixture			Ascot Linde SN	
Plant species	April 1994	April 1995	May 1995	May 1995	June 1995
Borago officinalis	1	< 1	1	—	—
Calendula officinalis	< 1	< 1	< 1	—	—
Centaurea cyanus	3	2	1	—	—
Fagopyrum esculentum	< 1	< 1	1	1	1
Helianthus annuus	—	< 1	< 1	—	—
Malva sylvestris	2	< 1	1	—	—
Phacelia tanacetifolia	87	97	95	99	99
Raphanus sativus	4	—	—	—	—
Sinapis alba	2	—	—	—	—

Table 4. *Percentage distribution of syrphids (all species) visiting the flowers of different plant species in two bee forage mixtures in the UK, 1994 and 1995*

	Tübingen Mixture			Ascot Linde SN	
Plant species	April 1994	April 1995	May 1995	May 1995	June 1995
Centaurea cyanus	9	0	3	—	—
Calendula officinalis	2	0	0	—	—
Fagopyrum esculentum	0	2	7	7	36
Malva sylvestris	3	0	2	—	—
Nigella spp.	—	0	2	—	—
Phacelia tanacetifolia	31	98	86	93	64
Raphanus sativus	27	—	—	—	—
Sinapis alba	28	—	—	—	—

— indicates species not present in mixture.

All species of bees common in Hertfordshire (Williams 1982) were observed. *Bombus lapidarius* was the most abundant species. Numbers of *B. lapidarius* workers reached a peak in early July, whilst that of males reached a peak in late July, when few other bumble bees were present (Fig. 3). *Bombus pratorum*, an uncommon species in the area, was observed only in 1994 (Table 2). Numbers of *A. mellifera* showed two peaks, in early July and early August (Fig. 3). This probably reflected the dearth of alternative nectar- and pollen-producing plants such as *B. napus*, *V. faba* and *Tilia* spp. in the vicinity.

The most frequently visited plant was *P. tanacetifolia* (Tables 3 and 4). *Fagopyrum esculentum*, considered to be a prolific nectar-producing plant (Howes 1979), attracted few bees but many syrphids. The *B. officinalis*, *C. cyanus*, *C. officinalis*, *M. sylvestris*, *P. tanacetifolia* and *S. alba* continued to flower until killed by frosts in late autumn, but by then had too few flowers to attract many foraging insects.

DISCUSSION

In 1995, the April-sown Tübingen Mixture attracted the most bees, but flowered mainly in early July, when other nectar sources such as *Tilia* spp. were available. The June-sown Ascot Linde SN had a peak of flowering in early August when there are few other sources of forage (Hooper 1976). This plot attracted the largest numbers of syrphids. Adults of *Episyrphus balteatus* and *Melanostoma* spp. feed on pollen alone, whilst the other syrphid species feed on both pollen and nectar (Gilbert 1993). The larvae of all of the most commonly observed syrphids, except *Eristalis pertinax* and *Neoascia podagrica*, feed, or are believed to feed, on aphids (Stubbs & Falk 1983).

The common wasp (*Vespula vulgaris*), which was occasionally observed collecting nectar, may be beneficial as it collects other insects to feed its larvae, although quantitative data on its role as a predator are lacking (Spradbery 1973). The Lepidoptera visited the flowers for nectar, although the small white butterfly (*Artogea rapae*), a pest of brassica crops, may have been attracted to the crop for oviposition as well as for food.

The practical requirements for a forage mixture for beneficial insects are that it should be capable of being sown with conventional equipment available on an arable farm, with the minimum of seedbed preparation, should establish well, overcoming competition from arable weeds, should not require agrochemicals and should be inexpensive. It should provide a succession of nectar- and pollen-producing flowers attractive to beneficial insects, and be particularly productive at times when other forage is scarce.

Some species in the mixtures tested failed to establish. This may have been due to non-viable or dormant seed, competition from other sown species, or more likely, to an unsuitable seedbed. The various species in the mixtures probably have differing seedbed requirements. The lack of germination or growth of some species could have been because the seed was imported from mainland Europe, and was therefore produced under different climatic conditions. Both seasons were unusually dry, and although crop growth was not affected by drought, as irrigation was available, nectar secretion may have been intermittent. Commercially, irrigation may be unavailable, or reserved for higher value crops, making June sowing undesirable due to the likelihood of drought preventing plant emergence and subsequent growth.

Engels *et al.* (1994) reported a total of 35 species of bee foraging on the flowers of the Tübingen Mixture in Germany, as compared to 13 in the current study, confirming the relative impoverishment of the bee fauna in arable south-east England (Williams 1982).

These mixtures appear not to be ideally suited to UK conditions, offering little advantage over successive sowings of *P. tanacetifolia* alone. When maximum numbers of flowers were present, other forage such as *B. napus*, *V. faba* and *Tilia* spp. is often available, so the mixtures attracted relatively few insects. A better mixture for UK conditions would be one with fewer early flowering species and more of the later ones. A reduction in the number of species in the mixture would reduce seed costs without reducing continuity of floral succession, although inclusion of appropriate plant species could provide food for oligolectic bees.

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