The biology and non-chemical control of Common Poppy (*Papaver rhoeas* L.)

W Bond, G Davies, R Turner
HDRA, Ryton Organic Gardens, Coventry, CV8, 3LG, UK

Common poppy

(blindy-buffs, bledewort, canker rose, cheesebowl, cockrose, copper-rose, corn poppy, corn rose, cuprose, field poppy, redweed, soldiers, thunder flower, yedwark)
***Papaver rhoeas* L.**

Occurrence

Common poppy is a summer or more rarely winter annual native in arable land, roadsides and waste places throughout the UK (Stace, 1997). It is not recorded above 1,000 ft (Salisbury, 1961). Common poppy is found primarily in disturbed habitats. It is a weed of cornfields on light, dry, sandy and gravelly soils (Long, 1938). In an early survey of Bedfordshire and Norfolk, common poppy was one of the commonest weeds. It was found chiefly on sand, and was frequent on light loams and chalk (Brenchley, 1913). It is less frequent on clay and peat soils (McNaughton & Harper, 1964). Common poppy is mainly associated with soil of pH 6.0 to 8.0 (Grime *et al.*, 1988). In the UK, it is common in England and SE Scotland but rarer in Wales and much of Scotland. The potential distribution of common poppy has been mapped using botanical survey and soil survey data (Firbank *et al.*, 1998). The probable distribution was seen to be mainly in south and eastern Britain but was not related to soil type. Common poppy can occur as a birdseed alien (Hanson & Mason, 1985).

Common poppy appears to be discouraged by root crops (Brenchley, 1920). In a survey of weeds in conventional cereals in central southern England in 1982, common poppy was found in 3, 1 and 2% of winter wheat, winter barley and spring barley respectively (Chancellor & Froud-Williams, 1984). In a survey of conventional winter oilseed rape in central southern England in 1985, common poppy was present in 21% of fields (Froud-Williams & Chancellor, 1987). Common poppy was shown to be a highly competitive weed in oilseed rape (Lutman *et al.*, 1995). In a study of some arable soils in the English midlands sampled in 1972-3, common poppy was recorded in 59% of fields sampled in Oxfordshire and 19% in Warwickshire (Roberts & Chancellor, 1986). Where it occurred it was often found in large numbers, up to 21,600 seeds per m^2. Common poppy seed was not recorded in a survey of arable soils in Scotland in 1972-1978 (Warwick, 1984). In a seedbank survey of arable fields in France in 1983-85, it was common in the seedbank and relatively more frequent in the standing vegetation (Barralis & Chadoeuf, 1987). In a series of 4 national weed surveys made in Hungary between 1950 and 1997, common poppy moved from 24th to 20th place in the rankings (Tóth *et al.*, 1999; 1997). In trials in Denmark from 1969-1988, common poppy was common in autumn-sown arable crops (Jensen, 1991).

Numerous forms and varieties of common poppy have been recognised. Leaf shape and hairiness are very variable (Clapham *et al.*, 1987). Albino and tricotyledonous seedlings occur occasionally at a ratio of 1 in 63,000 and 1 in 4,000 respectively (Brenchley & Warington, 1936). The different species of poppies often occur together but few natural hybrids have been found. Hybrids between the common and the long-headed poppy (*P. dubium*) created artificially often die prematurely or suffer

various growth distortions (McNaughton & Harper, 1960b). Populations with resistance to 2,4-D and the sulfonylurea herbicide tribenuron-methyl have been reported in Europe (Cirujeda *et al.,* 2001).

Common poppy is unpalatable and is poisonous to livestock only if eaten in large quantities (Grime *et al.,* 1988; Forsyth, 1968). The active principle is rhoeadene, the opium alkaloids are not present in common poppy. The seeds produce a fine oil and are sometimes added to bread and cakes (Barker, 2001). Common poppy has medicinal uses including as a mild sedative. An infusion of the petals applied to the skin is said to reduce wrinkles.

Biology

Common poppy flowers from June to October (Clapham et al., 1987). Flowering begins in mid-June with flushes in late-June and early-July and then intermittent flowering continues to October. A second flush of flowers may appear in the stubble after cereal harvest (Grime *et al.,* 1988). Common poppy is normally the last of the poppies to start into flower and to finish. A common poppy plant may produce 1 to 400 flowers and seed capsules depending on soil fertility and the density of vegetation (McNaughton & Harper, 1964). Poppies are normally insect pollinated, honey and bumble bees being the main pollinators (McNaughton & Harper, 1960a). Bees tend to keep to one species of poppy and this restricts inter-species pollination. Also, common poppy is more or less self-fertile and the anthers dehisce before the flowers open so self-pollination can occur ahead of cross-pollination.

Although it is generally the last poppy to flower its seed capsules ripen faster than those of the other poppies. Seed is set from July onwards and is shed 3-4 weeks after flowering from pores round the lid of the seed capsule (Grime *et al.,* 1988). Common poppy produces the largest number of seeds per capsule (Harper, 1966). The average seed number per capsule is around 1,300 (Salisbury,1961; McNaughton & Harper, 1960a). The average seed number per plant is quoted as 14,500 to 19,500 by Salisbury (1961) and 36,723 (Pawlowski *et al.,* 1970). Other authors give the seed number per plant as 10,000 to 60,000 (Guyot *et al.,* 1962; Long, 1938). The viable seed number for a plant grown in isolation was estimated at 531,273 (Wilson *et al.,* 1988). In competition with winter wheat the number of seeds per plant ranged from 6,221 to 41,059 depending on crop density. Seed numbers correlated well with plant dry weight. The time from germination to fruiting is around 100 days (Guyot *et al.,* 1962).

Common poppy seeds are highly dormant when shed (Holm *et al*., 1977). In fresh seeds the embryos are underdeveloped and physiologically dormant, and will not germinate in light or darkness at a range of alternating temperatures. In Petri-dish tests with seed given alternating or constant temperatures in diffuse light, light had no effect alone but interacted with alternating temperature to promote germination (Vincent & Roberts, 1977). The response was improved in the presence of nitrate and by chilling but germination was not complete. Light, even just a short flash, was needed for germination to occur other than at a very low level in seed exhumed after burial in soil (Milberg & Andersson, 1997). In laboratory tests, germination was substantially increased when seeds were transferred from darkness to daylight (Froud-Williams *et al.,* 1984b). Even with light there was little germination from March to June but this increased from July to October (Andersson & Milberg, 1996). Seed that

was tested after it had been stratified in soil overwinter gave 4 to 15% germination in the light or in darkness with just a 5 second light flash (Andersson *et al.*, 1997). In complete darkness there was 6 to 7% germination. There was no significant effect of treatment. Dormancy was lost during 12 weeks burial in moist soil at alternating temperatures of 15/5, 20/10 and 25/15°C (Baskin *et al*., 2002). After 12 weeks burial at 25/15°C, seeds germinated 100% in the light at 25/15°C. Seeds of common poppy not only require high temperatures to lose dormancy they also need to be imbibed. Dormancy was not broken in seeds stored dry for 12 weeks at room temperature. Dormancy is broken by chilling (Grime *et al.*, 1988). There was 75% germination of seeds during a 3-month period of moist storage at 5°C (Grime *et al.*, 1981). Seed scarification did not improve germination (Holm *et al*., 1977).

Seeds naturally-occurring in field soil, concentrated down by washing and put into dishes germinated best in conditions where temperature fluctuations were around 16°C (Warington, 1936). When temperature fluctuations were no more than 1°C seed germination was 95% lower. Seeds that did not germinate in the first year survived and were able to germinate in subsequent years. Transferring the dishes to the wider temperature fluctuations resulted in a marked increase in germination.

In the field, seedling numbers following cultivation at any time of year are usually less than 1% of the number of viable seeds present in the soil seedbank (Roberts & Ricketts, 1979). Most seedlings emerge from February to April with a secondary flush in August-October (Holm *et al.*, 1977). Seed sown in pans of field soil emerged from summer through the autumn and into winter (Brenchley & Warington, 1930). Seeds showed long periods of dormancy. Seed sown in 75 mm layers of soil in cylinders sunk in the field and stirred periodically, emerged in spring and autumn (Roberts & Boddrell, 1984). There were peaks in March-April and September-October but, unlike the other poppies, the main emergence period was in spring. In plots dug into a grass sward and cultivated at monthly intervals, common poppy seedlings emerged throughout the year but with peaks from February to May and August to October (Chancellor, 1986).

Poppy seedlings emerge in the autumn in autumn cereals and in spring in spring cereals (McNaughton & Harper, 1964). Frost may kill recently germinated seedlings. Seeds of common poppy sown in closed communities such as woodland or grassland failed to establish. In the field, 94% of seedlings emerged from the surface 20 mm of a sandy soil and 100% from the top 30 mm (Chancellor, 1964). In a sandy loam soil, field seedlings emerged from the top 25 mm of soil with most coming from the top 15 mm (Unpublished information). Seed sown in soil at different depths, cultivated and not in pots and boxes out in the field did not emerge when left on the soil surface, sown at 25 mm cultivated or not, or when buried at 75 mm and cultivated in February (Froud-Williams *et al*., 1984a). There was some emergence in autumn when seeds sown at 75 mm were cultivated in June. In a second experiment, a few surface sown seeds emerged in the spring of the first year and after cultivation in the spring and summer of year 2. Seed sown at 50 mm also emerged in low numbers at this time following cultivation in year 2. The optimum depth of emergence was 5 to 10 mm and the maximum was 20 mm.

Persistence and Spread

Dry-stored seed gave almost 80% germination after 5 years (Kjaer, 1940). Seed longevity in dry storage is 9 years and in soil is 6-8 years or longer (Guyot *et al.*, 1962). Seeds mixed with soil and left undisturbed had declined by 79% after 6 years but in cultivated soil the decline was 93% (Roberts & Feast, 1973). Common poppy seeds buried in soil for 5 years retained 30% viability. Seeds had a half-life of 11 years in undisturbed grassland. The decline of seeds broadcast onto the soil surface and then ploughed to 20 cm or flexible tine cultivated to 10-15 cm was followed over a 6 year period of cropping with winter or spring wheat grown as commercial crops (Lutman *et al.*, 2002). The experiment was made on a clay and a silty loam soil. Every effort was made to prevent further seed return to the soil. Common poppy had a mean annual decline rate of 9% and an estimated time to 95% decline of 17 to 50+ years. Common poppy seed sown in the field and followed over a 5 year period in winter wheat or spring barley showed an annual decline of around 40% (Barralis *et al.*, 1988). Emerged seedlings represented 8% of the seedbank.

Soil seedbank numbers for common poppy of between 2.5 and 20 million seeds/ha have been recorded in vegetable fields in the UK (Holm *et al.*, 1977). Seedbank decline was studied in a succession of autumn sown crops (winter wheat and winter OSR) in fields ploughed annually for 3-4 years with seed return prevented (Wilson & Lawson, 1992). Time to 99% decline was estimated at 8.7 years, the annual rate of loss was 35%, and the annual seedling emergence represented 1.5% of the soil seedbank. The decline of seeds under a grass sward was monitored after 1, 2, 3, 19 and 20 years (Chancellor, 1986). Common poppy showed a mean annual decline of 6% and a half life of 11 years.

Seeds are shaken from ripe capsules by the wind and travel up to 3 metres initially (Long, 1938). The seeds are small enough to be further wind dispersed. Birds eat the seeds and seedlings have been raised from bird excreta (Salisbury, 1961).

In a survey of grass and clover seed samples tested in 1960-61, common poppy was found in 3.6% of Italian ryegrass and 8.7% of Timothy seed of English origin tested and 4.0% of white clover seed of Danish origin tested (Gooch, 1963). In a survey of cereal seed sampled in the period 1978 to 1981, common poppy seed was found in up to 3% of wheat and up to 5% of barley samples tested (Tonkin, 1982).

Management

Common poppy germinates mainly in the autumn and has been seen to decline in numbers following a series of spring cereals (Rademacher *et al.*, 1970). Spring germination should be encouraged by keeping seed at or near the soil surface when fresh seeding has occurred (Long, 1938). Deep cultivation should be avoided as it will bring buried seeds to the surface (Morse & Palmer, 1925). Harrowing in dry weather will destroy emerged and germinating seedlings. The inclusion of a root crop may help to reduce overwhelming populations. Control is aided by ensuring only clean crop seed is sown.

Where a high population of poppy seeds had accumulated in the surface soil following 10 years of minimal cultivation, ploughing reduced seedling emergence (Cirujeda *et al.*, 2003). The effect was still evident after two years but a second ploughing at that time brought up the buried seeds and seedling numbers increased again. Annual post-emergence harrowing in cereals with a tine harrow caused a

remarkable reduction in poppy numbers. A combination of annual harrowing with occasional ploughing was considered the best option, however, with high poppy populations additional control methods would be needed. Studies with soil clods of different sizes and hardness showed that seed germination was less and fewer seedlings emerged from larger clods whether they were hard or soft (Terpstra, 1986). Both a lack of light and the depth of incorporation in the clods were factors in limiting germination and successful emergence.

Common poppy is sensitive to trampling (Grime *et al.,* 1988). Studies of the effect of physical damage on the control of common poppy showed that cutting seedlings at or below the soil surface was more effective than partial burial (Jones *et al*., 1995). Complete burial, alone and after pulling seedlings out, was the most consistently effective treatment. There was the potential for recovery if seedlings were left on the soil surface or if just the roots were buried.

Fallowing decreases seedbank numbers (Holm *et al.,* 1977). Seed numbers in soil showed a gradual reduction during a 1 or 2 year fallowing resulting in a 50% reduction after 2 years (Brenchley & Warington, 1933). The land was ploughed, disked and harrowed during this period. The prolonged dormancy of the seed prevented a greater reduction. During cropping with winter wheat for the same period there was a small reduction in seed numbers initially but numbers then remained stable. Fallowing every 5th year over a 15 year period reduced seed numbers progressively by 40% in the first fallow year, 75% in the second and over 90% in the 3rd fallow year. There appeared to be little recovery in seed numbers in the intervening years cropped with winter cereals (Brenchley & Warington, 1945).

Common poppy seedlings that emerge in large numbers at the same time as a winter wheat crop are able to compete from the early stages of crop growth (Wright *et al.,* 1997). In the absence of a well-established crop the weed has the potential to produce a high biomass that depresses crop yield. In winter wheat, crop density is an important factor in limiting seed production by common poppy through its effect on weed biomass (Wright, 1993). Seed production may be halved as crop density is doubled up to 200 crop plants per m^2. Competition from other weeds also reduces growth and seed production by common poppy (Lintell-Smith *et al.,* 1991; McCloskey *et al.,* 1998). However, common poppy can survive after cereal harvest and may produce a late flush of flowers (Grime *et al.,* 1988).

Acknowledgement
This review was compiled as part of the Organic Weed Management Project, OF 0315, funded by DEFRA.

References

Andersson L & Milberg P (1996). Seasonal changes in light requirement and dormancy in seeds of eight annual species. *X^e Colloque International sur la Biologie des mauvaises herbes,* Dijon, 17-23.

Andersson L, Milberg P, Noronha A (1997). Germination response of weed seeds to light of short duration and darkness after stratification in soil. *Swedish Journal of Agricultural Research,* **27**, 113-120.

Barker J (2001). *The medicinal flora of Britain and Northwestern Europe*, Winter Press, West Wickham, Kent, UK.

Barralis G & Chadoeuf R (1987). Weed seed banks of arable fields. *Weed Research* **27**, 417-424.

Barralis G, Chadoeuf R, Lonchamp J P (1988). (Longevity of annual weed seeds in cultivated soil. *Weed Research* **28**, 407-418.

Baskin C C, Milberg P, Andersson L, Baskin J M (2002). Non-deep simple morphophysiological dormancy in seeds of the weedy facultative winter annual *Papaver rhoeas*. *Weed Research* **42**, 194-202.

Brenchley W E (1913). The weeds of arable soil III. *Annals of Botany* **27**, 141-166.

Brenchley W E (1920). *Weeds of Farm Land*, Longmans, Green & Co, London, UK.

Brenchley W E & Warington K (1930). The weed seed population of arable soil. I. Numerical estimation of viable seeds and observations on their natural dormancy. *The Journal of Ecology* **18** (2), 235-272.

Brenchley W E & Warington K (1933). The weed seed population of arable soil. II. Influence of crop, soil and method of cultivation upon the relative abundance of viable seeds. *The Journal of Ecology* **21** (1), 103-127.

Brenchley W E & Warington K (1936). The weed seed population of arable soil. III. The re-establishment of weed species after reduction by fallowing. *The Journal of Ecology* **24** (2), 479-501.

Brenchley W E & Warington K (1945). The influence of periodic fallowing on the prevalence of viable weed seeds in arable soil. *Annals of Applied Biology* **32** (4), 285-296.

Chancellor R J (1964). The depth of weed seed germination in the field. *Proceedings 7th British Weed Control Conference*, Brighton, UK, 607-613.

Chancellor R J (1986). Decline of arable weed seeds during 20 years in soil under grass and the periodicity of seedling emergence after cultivation. *Journal of Applied Ecology* **23**, 631-637.

Chancellor R J & Froud-Williams R J (1984). A second survey of cereal weeds in central southern England. *Weed Research* **24**, 29-36.

Cirujeda A, Recasens J, Taberner A (2001). A qualitative quick-test for detection of herbicide resistance to tribenuron-methyl in *Papaver rhoeas*. *Weed Research* **41**, 523-534.

Cirujeda A, Recasens J, Taberner A (2003). Effect of ploughing and harrowing on a herbicide resistant corn poppy (*Papaver rhoeas*) population. *Biological Agriculture and Horticulture* **21**, 231-246.

Clapham A R, Tutin T G, Moore D M (1987). *Flora of the British Isles*, 3rd edition, Cambridge University Press, Cambridge, UK.

Firbank L G, Ellis N E, Hill M O, Lockwood A J, Swetnam R D (1998). Mapping the distribution of weeds in Great Britain in relation to national survey data and to soil type. *Weed Research* **38**, 1-10.

Forsyth A A (1968). British poisonous plants. *MAFF Bulletin No.* **161**, HMSO, London.

Froud-Williams R J & Chancellor R J (1987). A survey of weeds of oilseed rape in central southern England. *Weed Research* **27**, 187-194.

Froud-Williams R J, Chancellor R J, Drennan D S H (1984a). The effects of seed burial and soil disturbance on emergence and survival of arable weeds in relation to minimal cultivation. *Journal of Applied Biology* **21**, 629-641.

Froud-Williams R J, Chancellor R J, Drennan D S H (1984b). The influence of burial and dry-storage upon cyclic changes in dormancy, germination and

response to light in seeds of various arable weeds. *New Phytologist* **96**, 473-481.

Gooch S M S (1963). The occurrence of weed seeds in samples tested by the official seed testing station, 1960-1. *The Journal of the National Institute of Agricultural Botany* **9** (3), 353-371.

Grime J P, Hodgson J G, Hunt R (1988). *Comparative Plant Ecology*, Unwin Hyman Ltd, London, UK.

Grime J P, Mason G, Curtis A V, Rodman J, Band S R, Mowforth M A G, Neal A M, Shaw S (1981). A comparative study of germination characteristics in a local flora. *Journal of Ecology* **69**, 1017-1059.

Guyot L, Guillemat J, Becker Y, Barralis G, Demozay D, Le Nail Fr (1962). *Semences et Plantules des Principales des Mauvaises Herbes.* Association de Coordination Technique Agricole, Paris.

Hanson C G & Mason J L (1985). Bird seed aliens in Britain. *Watsonia* **15**, 237-252.

Harper J L (1966). The reproductive biology of the British Poppies. *BSBI Conference Report* No. **9** *Reproductive biology and taxonomy of vascular plants*, 26-39.

Holm L G, Plucknett D L, Pancho J V, Herberger J P (1977). *The World's Worst Weeds*. The University Press of Hawaii, Honolulu.

Jensen P K (1991). Weed size hierarchies in Denmark. *Weed Research* **31**, 1-7.

Jones P A, Blair A M, Orson J H (1995). The effects of physical damage to four weed species. *Proceedings of the Brighton Crop Protection Conference – Weeds*, 653-658.

Kjaer A (1940). Germination of buried and dry stored seeds. I. 1934-1939. *Proceedings of the International Seed Testing Association* **12**, 167-190.

Lintell-Smith G, Watkinson A R, Firbank L G (1991). The effects of reduced nitrogen and weed-weed competition on the populations of three common cereal weeds. *Proceedings of the Brighton Crop Protection Conference-Weeds*, Brighton, UK, 135-140.

Long H C (1938). Weeds of arable land. *MAFF Bulletin* **108**, 2nd edition. HMSO, London, UK.

Lutman P J W, Bowerman P, Palmer G M, Whytock G P (1995). A comparison of the competitive effects of eleven weed species on the growth and yield of winter oilseed rape. *Proceedings Brighton Crop Protection Conference - Weeds*, Brighton, UK, 877-882.

Lutman P J W, Cussans G W, Wright K J, Wilson B J, McN Wright G, Lawson H M (2002). The persistence of seeds of 16 weed species over six years in two arable fields. *Weed Research* **42**, 231-241.

McCloskey M C, Firbank L G, Watkinson A R, Webb D J (1998). Interactions between weeds of winter wheat under different fertilizer, cultivation and weed management treatments. *Weed Research* **38**, 11-24.

McNaughton I H & Harper J L (1960a). The comparative biology of closely related species living in the same area. I. External breeding barriers between *Papaver* species. *The New Phytologist* **59**, 15-26.

McNaughton I H & Harper J L (1960b). The comparative biology of closely related species living in the same area. II. Aberrant morphology and virus-like syndrome in hybrids between *Papaver rhoeas* L and *P. dubium* L. *The New Phytologist* **59**, 27-41.

McNaughton I H & Harper J L (1964). Biological flora of the British Isles No. 99. *Papaver* L. *Journal of Ecology* **52**, 767-793.

Milberg P & Andersson L (1997). Seasonal variation in dormancy and light sensitivity in buried seeds of eight annual weed species. *Canadian Journal of Botany* **75**, 1998-2004.

Morse R & Palmer R (1925). *British weeds their identification and control*. Ernest Benn Ltd, London.

Pawlowski F, Kapeluszny J, Kolasa A, Lecyk Z (1970). The prolificacy of weeds in various habitats. *Annales Universitatis Mariae Curie-Sklodowska Lublin-Polonia,* **25** (5), 61-75.

Rademacher B, Koch W, Hurle K (1970). Changes in the weed flora as a result of continuous cropping of cereals and the annual use of the same weed control measures since 1956. *Proceedings of the 10th British Weed Control Conference*, Brighton, UK, 1-6.

Roberts H A & Boddrell J E (1984). Seed survival and periodicity of seedling emergence in four weedy species of *Papaver*. Weed Research **24**, 195-200.

Roberts H A & Chancellor R J (1986). Seed banks of some arable soils in the English midlands. *Weed Research* **26**, 251-257.

Roberts H A & Feast P M (1973). Emergence and longevity of seeds of annual weeds in cultivated and undisturbed soil. *Journal of Ecology* **10**, 133-143.

Roberts H A & Ricketts M E (1979). Quantitative relationships between the weed flora after cultivation and the seed population in the soil. *Weed Research* **19**, 269-275.

Salisbury E J (1961). *Weeds & Aliens*. New Naturalist Series, Collins, London.

Stace C (1997). *New Flora of the British Isles*. 2nd edition. Cambridge University Press, Cambridge, UK.

Terpstra R (1986). Behaviour of weed seed in soil clods. *Weed Science* **34**, 889-895.

Tonkin J H B (1982). The presence of seed impurities in samples of cereal seed tested at the Official Seed Testing Station, Cambridge in the period 1978-1981. *Aspects of Applied Biology* **1**, *Broad-leaved weeds and their control in cereals*, 163-171.

Tóth Á, Benécsné G B, Balázs G (1997). Changes in field weeds in Hungary during the last 46 years. *Proceedings of the 1997 Brighton Conference – Weeds*, 249-254.

Tóth Á, Benécs-Bárdi G, Balzás G (1999). Results of national weed surveys in arable land during the past 50 years in Hungary. *Proceedings of the 1999 Brighton Conference – Weeds*, 805-810.

Vincent E M & Roberts E H (1977). The interaction of light, nitrate and alternating temperature in promoting the germination of dormant seeds of common weed species. *Seed Science & Technology* **5**, 659-670.

Warington K (1936). The effect of constant and fluctuating temperature on the germination of the weed seeds in arable soil. *The Journal of Ecology* **24** (1), 185-204.

Warwick M A (1984). Buried seeds in arable soils in Scotland. *Weed Research* **24**, 261-268.

Wilson B J & Lawson H M (1992). Seedbank persistence and seedling emergence of seven weed species in autumn-sown crops following a single year's seeding. *Annals of Applied Biology* **120**, 105-116.

Wilson B J, Peters N C B, Wright K J, Atkins H A (1988). The influence of crop competition on the seed production of *Lamium purpureum*, *Viola arvensis* and *Papaver rhoeas* in winter wheat. *Aspects of Applied Biology* **19**, *Weed control in cereals and the impact of legislation on pesticide application*, 71-80.

Wright K J (1993). Weed seed production as affected by crop density and nitrogen application. *Proceedings of the Brighton Crop Protection Conference – Weeds,* Brighton, UK, 275-280.

Wright K J, Seavers G P, Wilson B J (1997). Competitive effects of multiple weed species on weed biomass and wheat yield. *Proceedings of the 1997Brighton Crop Protection Conference – Weeds,* 497-502.