Project Title	**An investigation into the adoption of green manures in both organic and conventional rotations to aid nitrogen management and maintain soil structure.**
Project number:	FV 299
Project leader:	Peter Knight, VCS
Report:	Annual report, 2007
Previous report	Review of green manures, submitted December 2006
Key staff:	Francis Rayns (HDRA) Anton Rosenfeld (HDRA) Emily Heading (VCS) Tom Will (VCS) Andrew Mead (Warwick HRI)
Location of project:	Norfolk, Suffolk and Cambridgeshire
Project coordinator:	Nathan Dellicott Barfoots of Botley Ltd Sefter Farm Pagham Bognor Regis West Sussex PO21 3PX
Date project commenced:	July 2006
Date completion due:	December 2008
Key words:	Fertility-building crops, green manures, nitrogen, nutrition, winter cover crops, *Dactylis glomerata, Melilotus spp., Lolium perenne, Trifolium pratense*, nitrogen mineralisation, soil organic matter, organic vegetables.

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The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headlines

- The autumn sown grass clover leys reduced the amount of nitrogen in the soil that could be leached over the winter period, compared to the bare soil controls.
- The perennial rye grass/red and white clover mixture was quicker to establish and produced more biomass over the winter period than a cocksfoot/red and white clover mixture.
- All grass clover leys were easily managed. Regular topping controlled weeds despite high infestations of weeds at the time of establishment.

NOTE:-

1. Water framework directive legislation will mean that growers will have to pay more attention to preventing nitrogen leaching into ground water.
2. Cross compliance requires a soil management action plan. The use of green manure crops will help with compliance.
3. Limited availability of acceptable sources of nitrogen, in organic production, means that the correct use of green manures as an aid to nitrogen management is essential.

Background and expected deliverables

Whether organic or conventional producers, the management and care of our soils is essential for the sustainability of our business and to meet current and future legislation. Cross compliance and its requirement for a soil management action plans, NVZ's and the need to address leaching, EU legislation relating to on farm storage of FYM which may prevent its use in certain circumstances will all require solutions. HDRA has researched a range of green manures in organic rotations and assessed their ability to conserve nitrogen and maintain/enhance soil fertility and structure. This project aims to quantify the costs, benefits and negatives of specific green manures, collating the nitrogen conservation/accumulation and mineralization characteristics of three different grass/ legume mixtures sown both in the autumn and the following spring. We will record and investigate possible negatives, specifically bean seed fly and slug populations, and volunteers and residue issues after incorporation that may adversely affect the establishment or growth of the following crop. Finally through yield and quality assessment of the following crop just prior to harvest to gauge any stimulatory affect. Husbandry guidelines for green manure crops will be produced.

Summary of the project and main conclusions

The trial is being undertaken on two conventional, one organic and one in conversion site, all within the eastern counties on soil types varying from well drained sandy soil through deep well drained coarse loamy soil to a well drained calcareous coarse/fine soil. At each site three grass/clover mixtures have been drilled, two of which have been drilled both in the autumn (2006) and again in the spring (2007) and one only in the spring (2007). All treatments were drilled in triplicate with associated controls, the layout being randomized as advised by a statistician. The preceding crops were, on three sites, bulb onions and on the in conversion site it was barley. That site will be cropped with bulb onions in 2008 and the other three with potatoes. The swards have all been recently incorporated. At the time of compiling this annual report, we can conclude that: All sites were weedy during sward establishment (both in the autumn and spring drillings) but that timely topping kept the weeds under control and by June 2007 there were few weeds evident, the autumn drillings being cleaner than the spring. The ground cover of clover increased and the grass decreased on all sites and in all

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mixes as the season progressed so that by August 2007 the clover ground cover was 75% on all plots. The perennial ryegrass mixture produced more dry matter between September 2006 and April 2007 than the cocksfoot mixture and visually covered the ground quicker. Levels of soil mineral N in the autumn of 2006 were as a general rule higher in the bare controls/non drilled plots than those where mixtures had been established, indicating that the swards had begun to capture/utilize the available N. Bean seed fly populations were not influenced by the different treatments. The slug populations were greater where swards had been established.

Financial benefits

At this stage in the project it is not possible to assess whether the green manures will, due to increased yield or better quality show positive cost benefit. This detail will be developed when crop yield and quality are assessed in 2008.
For any grower considering green manures the establishment and management costs are relevant and listed below.

Seed Prices

Commercial cost of mixtures utilized in trial are:
Mix 1 £80.70/Ha (Cocksfoot 12.5Kg. Red Clover 7.5Kg. White Clover 1.25Kg.)
Mix 2 £68.50/Ha (Perennial Ryegrass 12.5Kg. Red Clover 7.5Kg. White Clover 1.25Kg.)
Mix 3 as mix 2
Mix 4 £71.50/Ha (Cocksfoot 5Kg. Red Clover 3.7Kg. White Clover 1.25Kg. Crimson Clover 2.5Kg. Sweet Clover 3.7Kg. Trefoil 2.5Kg.)
Mix 5 as mix 1

Establishment and maintenance cost (Costs based on average contract price indicated in Agro Business Consultants “Farm Machinery” Costs Book)

Seed bed preparation, drilling and rolling (if required)	£75.00/Ha
Topping @ £12.50/Ha by an average of 5 times per season	£62.50/Ha
Total	£137.50/Ha

Additional cost will be incurred when sward is incorporated prior to cropping.

Action points for growers

- Currently the project shows that the perennial rye grass/red and white clover mixture, when sown in September, produces the greatest biomass, with quickest ground cover.
- Regular topping is essential for weed control and to prevent the sward from flowering and becoming woody. The frequency of topping will depend on the soil type and prevailing weather conditions. It may vary from four to ten times in the growing season.
- Monitor any slug population increase when utilizing green manures and affect control strategy.
- Be sure to read the final report in early 2009 when the ability of each mixture to capture/fix nitrogen should be quantified. It will contain additional information relating to release profiles and the possible negatives being investigated.

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Science Section

Introduction

There is an increasing need to improve nitrogen management to reduce leaching, particularly during the winter months when much land is left bare. Leguminous green manures are the principle source of nitrogen in all organic farming systems but there is a place for green manures within both organic and conventional field vegetable production. Cross-compliance necessitates that all farmers draw up a soil management plan. This plan must address strategies for minimizing soil erosion and nutrient leaching; special considerations apply in Nitrate Vulnerable Zones.

In large-scale vegetable production straw crops have provided commercially viable breaks in light soil rotations. In recent years cereal production became more marginal, giving a real opportunity to introduce green manures into the rotation. Light land soils traditionally rely on FYM to boost soil organic matter; this approach has led to increasing soil phosphate levels, lush crop growth and, often, the introduction of alien weed species. The introduction of green manures in these rotations would provide a more sustainable approach to maintaining soil organic matter and fertility. Potential new EU legislation may severely restrict the on-farm storage of FYM, effectively preventing its use in certain circumstances. Green manures may present a viable alternative.

A number of projects have examined the use of 'fertility-building crops' in the UK. Most of this work has been conducted in organic systems, although some of the results are of relevance to conventional systems as well. HDRA has researched a range of green manures/fertility building crops in organic rotations and assessed their ability to conserve nitrogen as well as maintain and enhance soil fertility and structure. This work has considered both short-term winter cover crops and also the role of longer-term leys in crop rotations.

The main research focus of this research has been on the use of winter green manures, or cover crops, since these offer the greatest potential for reducing the leaching of nitrogen. HDRA investigated the nitrogen dynamics of a range of winter green manures (conservation, mineralization and utilization of N by subsequent crops) in two DEFRA funded projects (OC 9016 and OF 0118T). Another DEFRA project (NT 2302) summarized these findings, together with other cover crop research that had been conducted by ADAS and HRI.

Subsequent work has also considered longer-term crops. HDRA has led three DEFRA funded projects which have considered the impact of contrasting fertility-building strategies during the period of conversion to organic field vegetables and in the early years of full organic production (OF 0126T, OF 0191 and OF 0332). The fertility-building strategies have differed in terms of duration (six months to two years), species (eg pre clover or grass and clover) and method of establishment (eg some have been undersown). The effects on crop yields, soil fertility, weeds, pests, diseases and economics of production have all been monitored. This work began in 1995 and will continue until 2009 (OF 0363).

Fertility-building crops were also the subject of a recently completed ADAS project (OF 0316). A major review of the effects of these crops was conducted and there were also trials to test the performance of a range of novel legumes (although these concentrated on the growth of the crops rather than their effects). Research has also been done in other northern European countries (eg Denmark).

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Computer modeling offers one way to draw together research findings and make them of relevance in a particular situation. An EU project, EU-Rotate-N (QLK5-CT-2002-01100) had the aim pf producing a model that will enable farmers, advisors and policy makers to evaluate the agronomic and economic effects of various nitrogen management strategies. This was developed specifically for field vegetables and considers issues specific to fertility building crops (eg litter loss, nitrogen fixation and the effects of mowing and mulching).

Whilst most of this work concentrated on the effects of green manures on soil fertility, a recent HDC project (FV273) also investigated the role of Caliente mustards for nematode and pythia control.

Despite this research, there remains a serious under-utilization of green manure crops. This is often because their establishment is poorly prioritized in relation to work on cash crops since the benefits they bring are difficult to quantify. The costs, benefits and negative effects of key green manures are not known and need quantifying. More information is still needed, particularly with regard to the effects of longer-term crops and short-term 'summer' green manures. There is also a lack of appropriate husbandry guidelines. Quantification of the benefits (and costs) and field demonstrations should result in better take up by growers.

Overall aim of the project

The overall aim of the project is to improve the utilization of green manures in organic and conventional systems by providing a better understanding of their effects on nitrogen management and soil structure. Effects on soil structure are long term and difficult to quantify within the time scale available. We will draw together findings from the literature and, in the field, measure any changes in total organic matter, which do occur. We will also record anecdotal observations, (eg ease of cultivation, control of erosion).

Specific objectives

- Provide a desk study summary of previous green manure work, identifying types, cropping periods, relative performances etc. This will concentrate on the green manures that have been most extensively investigated (winter cover crops) which therefore will not be included in the field trials. (Completed December 2006)
- Replicated field trials will be conducted to investigate opportunities to adopt various types of green manures within a typical light land, root or vegetable crop rotation. (Commenced September 2006)
- To measure the biomass and nitrogen conservation/accumulation and mineralization characteristics for each green manure sward.
- To write husbandry guidelines for each green manure sward.
- To record and investigate any associated negatives such as slugs and bean seed fly populations, volunteers after incorporation and trash affecting the drilling of the following crop etc.
- To determine any stimulatory or detrimental effects on the performance of the following commercial crops.

Materials and Methods

Field sites

Four field trials were set up, two on conventional land, one on organic land and one on land in conversion. All the trials followed a crop of onions grown in 2006 (except a Site Y where the trial followed winter barley). In 2008 a test crop of potatoes will be grown at three of the sites; onions will be grown at site Y.

Site W (Conventional). Elveden Farms Ltd, Thetford, Norfolk. The soil association was Newport 4; a well drained sandy soil.

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Site X (Conventional). Westrope Park Farm (site located close to Bawdey in Suffolk). The soil association was Newport 4; a deep well drained sandy soil.

Site Y (In conversion). Russell Smith Farms (site located close to Duxford in Cambridgeshire). The soil association was Swaffam Prior, a well-drained calcareous coarse/fine loamy soil over chalk rubble.

Site Z (Organic). Bagthorpe Farm, Bircham, Kings Lynn, Norfolk. The soil association was Barrow; a deep well drained coarse loamy soil.

Results of a soil analysis conducted at each site at the start of the work (and near the end of the growing period of the fertility building crops) are given in Appendix A.

Experimental design

The trials were set up to compare the effect of two sowing date and three species mixtures on fertility building crop performance, soil nutrients, pest incidence and on yield and quality of a following potato crop. There were six treatments in each trial:

1. Crop sown autumn 2006 (cocksfoot, 12.5kg/ha; red clover, 7.5kg/ha; white clover, 1.25kg/ha)
2. Crop sown autumn 2006 (perennial rye grass, 12.5kg/ha; red clover, 7.5kg/ha; white clover, 1.25kg/ha)
3. Crop sown spring 2007 (perennial rye grass, 12.5kg/ha; red clover, 7.5kg/ha; white clover, 1.25kg/ha)
4. Crop sown spring 2007 (cocksfoot, 5kg/ha; red clover, 3.7kg/ha; white clover, 1.25kg/ha; crimson clover, 2.5kg/ha; sweet clover, 3.7kg/ha; trefoil, 2.5kg/ha)
5. Crop sown spring 2007 (cocksfoot, 12.5kg/ha; red clover, 7.5kg/ha; white clover, 1.25kg/ha)
6. Control (bare ground maintained by herbicides or cultivations)

These treatments were decided on following discussions with Ian Wilkinson of Cotswold Seeds Ltd. This company supplied the seeds. They were not organic but derogations for the use of non-organic seed were obtained where necessary. The trefoil and sweet clover in Treatment 4 are not true clovers but are closely related.

A randomized complete block design (with three replicate blocks) was used. Plans of the trials are given in Appendix B. There was some variation in layout of the plots due to the shape of the available fields but individual plot size was between 1000 and 2000m^2.

Crop Husbandry

The farmers under the direction of the project leader conducted all husbandry operations. After cultivations of the land to produce a seedbed the mixtures were drilled and rolled in. Different machines were used at each site but an even spread of seeds was always achieved. The control plots (and plots remaining unsown over the 2006/2007 winter) were kept bare by means of cultivations (and also herbicides at Site X). No additional fertilizers were applied until after the fertility building crops had been incorporated.

The swards were cut and mulched (to approximately 10-15cm) with flail mowers at appropriate dates. The frequency of this depended on the growth of the crop at the various sites.

Details of sowing, mowing and incorporation dates are given in Appendix C.

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Monitoring methods
Crop emergence was assessed using six 50x50cm quadrats per plot. The number of grass, legume and weed seedlings was counted and their heights measured.

The amount of mulched biomass was assessed by cutting six 50x50cm quadrats per plot just before each mowing event. The combined sample was weighed fresh and a subsample was used to determine the dry matter and the nitrogen content. At the same time ground cover was estimated and crop height measured in each quadrat.

The amount of incorporated biomass was assessed by digging up four 50x50cm quadrats per plot just before incorporation. The soil was washed from the plants, which were separated into grasses, legumes and weeds. Above ground parts were separated from the recoverable roots which were weighed fresh, and after drying at 80^{o} for 48 hours. In April 2007 the overwintered biomass of the autumn sown plots was assessed in the same way.

Soil was sampled at strategic dates. A pooled sample composed of several auger cores was taken from each plot (0-30 and 30-60cm samples were kept separately). Sampling below this depth was very difficult at most of the sites. On one occasion in summer 2007 the land was too dry for normal auger sampling and so the 30-60cm samples were taken with the aid of a mini-digger. The samples were kept cool and rapidly transferred to a laboratory for analysis (by Anglian Soil Analysis Ltd). Mineral nitrogen and soil moisture was determined at every date. Other nutrients were only tested for at the beginning and end of the growth of the fertility building crops.

Bean seed fly (*Delia platura)* populations were assessed using sticky yellow flytraps *(*ECOgrid orange supplied by ECOspray). Three traps were placed in each plot, each mounted on a cane and distributed randomly within the area, but with a minimum of 5 meters from any boundary shared with another treatment. The traps were first introduced to all sites 05/04/2007 and removed for identification and counting purposes on 18th April, 4th, 18th and 31st May and the 13th and 29th June. The entomology department of Warwick HRI undertook identification and counts.

Slug populations (mainly the field slug, *Derocereas reticulatum* and the keel slug, *Tandonia budapestensis)* were assessed using traps and bait supplied by Agralan Ltd. Two traps were placed at ground level in each plot a minimum of 5 meters from any boundary shared with another treatment. The traps were first introduced on 08/10/2007 and inspected and counts taken on the 24th October and the 7th and 19th of November. After each inspection the baits were renewed.

A comprehensive photographic record of crop performance was also made.

Results and Discussion

Weather
- Weather data from Cambridge (the nearest weather station with available data) is presented in Appendix J.
- At the time of the autumn sowing (Sep 06), it was dry with slightly above average temperatures.
- Over the winter of 2006 / 2007, there were above average temperatures and rainfall, making ideal conditions for overwintering slugs.
- The time of sowing the spring crops (Mar / Apr 07) was exceptionally dry, but there were few problems with establishment.
- May was exceptionally wet (more than twice the average rainfall). Sunshine during this period (May and June) was also well below average, making for slow growth.
- The remainder of the summer (Jul and Aug) was slightly cool and with above average rainfall.

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Ground cover

- Ground cover measurements were taken in Nov 06, April 07, June 07, and August 07. In Nov 06 only the autumn sowings could be measured. In April 07, due to the timing of topping, only the spring sowings could be measured. Graphs showing changes in ground cover are given in Appendix D.
- All sites were weedy at early stages of establishment at both autumn sowings (assessed in November 06) and spring sowings (assessed in April 07). At both the autumn and spring sowings, Elveden (W) was initially the weediest with up to 20% ground cover of weeds.
- Topping kept the weeds under control and the ground cover of weeds decreased with time. By June there were very few weeds, and these were only present in the spring sowings, which had had less time for the crop to establish than the autumn sowings. However by August, there were negligible amounts of weeds at all sites and sowing dates.
- Weed species differed between sites. Annual nettle and wild chervil were the key species at Elveden (W) at both sowing dates. Volunteer potatoes were initially a problem at Westrope (X) but there were many other weeds including nettle, mayweed and groundsel. At Russell Smith (Y), volunteer oilseed rape was predominant at the autumn sowing, whilst charlock and blackgrass were the main weeds at the spring sowing. Topping easily controlled both of these. At Bagthorpe (Z), fat hen was the main weed at both sowings; despite going to seed this did not present a problem later in the season after being topped.
- The ground cover of clover increased and that of the grass decreased throughout the season at all sites and treatments. In June the autumn sown plots had a higher clover content than the spring sown plots as they had been grown for longer, but, by August, these differences were very small.
- By August, all plots had a clover ground cover of at least 75%. This may have reflected the weather during the season
- Mixture 4 which had a higher rate of legume seed had a higher ground cover of legumes earlier in the season; by August these differences were either small or non-existent.
- By the summer of 2007 differences in grass and clover contents between the grass types (cocksfoot or ryegrass) were only small and were not consistent between sites.
- The variability within the treatments increased with time (shown by the LSD bars on the graphs) and by August, there was a very high degree of variability, which masked any treatment differences.

Crop development and problems

- By April 07, the autumn sown crops were showing good growth although they were quite weedy. At this stage there was a large difference in the clover content between sites with Bagthorpe having 40 – 50% ground cover of clover but Westrope only 1 –2 %.
- By May 07 both the autumn sown cocksfoot and the perennial ryegrass were flowering. White clover was also flowering. Some yellowing of the cocksfoot was observed.
- In July / July 07 the white clover in the autumn plots was still in flower. The cocksfoot was showing further yellowing. In the spring sown plots there was no flowering of clover, except crimson clover. The proportions of clover in the spring sown clover mix (treatment 4) differed between sites. The sweet clover was especially variable where it dominated at Russell Smith but was much less at Elveden and Westrope. The sweet clover was also much more susceptible to weevil damage than the other clovers.
- In August 07,cocksfoot was showing yellowing and rust problems at all sites in both spring and autumn sowings. The white clover had mostly finished flowering and the red clover and yellow trefoil was in flower. There was very little sweet clover flowering throughout the season. Downy mildew was a problem on the sweet clover at all sites.

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Biomass accumulated over winter by the autumn sown crops

- This was measured to assess the over winter performance of the crops, specifically with regard to their nitrogen uptake.
- The perennial ryegrass mixture produced more dry matter between September 06 and April 07 than the cocksfoot (see Appendix E).
- Clover content was lowest at Westrope and highest at Elveden; this may have been associated with poor distribution of the clover seed because of the machinery used at the former site.

Material returned to the ground after mowing

- All sites were regularly 'cut and mulched' in 2007.The first mowing at sites W, X and Y was not assessed because it was primarily done for weed control and so very little biomass was cut. For the other dates the material returned to the ground was estimated by collecting samples from 0.25m^2 quadrats cut at the height of mowing (see Appendix F).
- In May and June, the Westrope site was the slowest to get going, producing less dry matter than the other sites.
- The autumn sown plots produced more dry matter than the spring sown plots. This difference was greater in May and June than in August and was greatest at Westrope, the slowest growing of the sites.
- Differences between the seed mixtures were not consistent between sites or sampling dates. (In June and July, mixture 4 produced the most dry matter of the spring sown crops at 3 of the 4 sites (only just significant). In August, mixture 3 (containing perennial ryegrass) produced less than the other spring sown mixes.)

Final incorporated biomass

- This was assessed in December 07 but the samples are still being processed and so the results are not included in this report.

Soil mineral nitrogen

4. There were marked differences in soil mineral nitrogen levels at the different sites (see Appendix G). Soil mineral nitrogen is ammonium plus nitrate (ie the forms available to plants).
5. The patterns of mineral N in the 0-30 and 30-60cm soil were generally similar. On one occasion (August 2007) it was impossible to sample the 30-60cm soil at Sites Y and Z because of the hardness of the dry ground.
6. The lowest levels of mineral N remaining after harvest of the onion crop in 2006 were at Site W. Levels were generally highest in the bare plots (ie the control plots, 6, and those not yet sown, 3, 4 and 5). By November 2007 there was no difference between the treatments.
7. Site X had the greatest levels of mineral N remaining after harvest of the crop in 2006. Most of this will have been leached, certainly from the plots bare over winter. In April 2007 levels were lowest in the cropped plots but thereafter there was little difference between the treatments. By November 2007 mineral N had declined to particularly low levels.
8. Site Y initially showed a similar pattern of mineral nitrogen. In the autumn of 2007 there was much more mineral N (especially in the topsoil) in the bare control plots. This mineral N was formed as a result of mineralization of crop residues/soil organic matter in moist yet warm conditions.
9. Site Z showed a similar pattern of mineral N to Site Y although with relatively less extra nitrogen in the bare soil in autumn 2007.
10. Soil mineral nitrogen in bare soil (especially in relatively sandy soil as found on these trial sites) is at risk of being leached away. The measured values shown here will be used to estimate leaching losses from the cropped and uncroppped plots at each site in the winters of 06/07 and 07/08.

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Other soil nutrients

11. As expected, there were few changes during the period of growth of the fertility building crops. Data averaged across the whole of each site is presented in Appendix A.
12. There was a slight decline in available K at all of the sites (although this was only shown in a change of Index at three of them.
13. There were no significant effects related to the different green manure crops.

Bean seed fly populations

14. There were large differences in the number of flies trapped on different dates (see Appendix H). By far the most flies were found in the trap inspection on 31/5/07.
15. The highest fly numbers were recorded at Site Y (Russell Smith).
16. There was no overall relationship between treatment and fly numbers.
17. A second series of trappings will be undertaken in 2008.

Slug populations

18. The majority of the slugs trapped were field slugs (*Derocereas reticulatum).*
19. There were big differences in slug populations between the sites and on different dates– see Appendix I. The greatest numbers were found at Site Y (Russell Smith) and on the 7/11/07 trap inspection.
20. Least slugs were found in the fallow plots (Treatment 6).
21. Trapping will be done again in the potato crop to investigate the after effects of green manures; the potato tubers will also be assessed for damage.

Conclusions

At all four experimental sites both autumn and spring sowings resulted in the successful establishment of the various ley mixtures. Early problems with weed competition were effectively controlled by mowing. Mixtures containing perennial ryegrass were quicker to get going from an autumn sowing. Differences in the amounts of material returned by mowing at the four sites were not consistently related to sowing date or seed mixture. Overall growth was greatest at Site Y and poorest at Site X. The mixture containing the greatest proportion of legume seed (and a greater variety of species) initially resulted in the highest legume ground cover but this effect disappeared later in the season. The proportion of clover in the swards generally increased throughout 2007.

Bare soil was associated with high levels of mineral nitrogen that was at risk of being leached. Leaching losses will be quantified in the final report of this project.

None of the treatments had any effect on bean seed fly populations. Least slugs were found in the bare plots; it remains to be seen if this difference is reflected in populations in the following potato crop.

Technology transfer

A review of green manures was prepared. This is intended to be a practical guide rather than and academic publication. It is available from HDC.

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An open day was held at the Elveden site on 16/8/07. This was well attended by both conventional and organic farmers. After some introductory talks there was an opportunity to view the trial plots.

The project has also been mentioned at a number of other events, in particular at a seminar held at Warwick HRI. This formed part of the DEFRA Project OF0363 which is also concerned with fertility building crops and so is complementary to FV 299.

Glossary

Full names of the species used in the trials:

Legumes:	
Red clover	*Trifolium repens*
White clover	*Trifolium pratense*
Crimson clover	*Trifolium incarnatum*
Yellow trefoil (or black medick)	*Medicago lupulina*
Sweet clover	*Melilotus* spp.
Grasses:	
Perennial ryegrass	*Lolium perenne*
Cocksfoot	*Dactylis glomerata*

References

Reports submitted to DEFRA:

OC 9016. The use of green manures in organic horticultural systems (1995). Project led by HDRA in collaboration with SCRI.

OF 0118T. Optimisation of nitrogen mineralization from winter cover crops and utilization by subsequent crops (1999). Project led by HDRA in collaboration with Warwick HRI.

NT 2302. Utilising N in cover crops (2000). Project led by ADAS in collaboration with HDRA and HRI Wellesbourne.

OF 0126T. Conversion to organic field vegetable production I (2000). Project led by HDRA in collaboration with HRI Wellesbourne, EFRC and Aberystwyth University.

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OF 0332. Organic field vegetable production - baseline monitoring of systems with different fertility building strategies (2006). Project led by HDRA in collaboration with Warwick HRI and EFRC.

OF 0316. The development of improved guidance on the use of fertility building crops in organic farming (2003). Project led by ADAS in collaboration with IGER and ABACUS.

Reports submitted to the EU:

QLK-CT-2002-01100. EU-rotate_N (2007). Development of a model based decision support system to optimize nitrogen use in horticultural crop rotations across Europe. Project led by Warwick HRI with partners in six countries.

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Reports submitted to HDC:

FV273. A costed study in the use of selected green manures/biofumigants to control selected nematode pests and pythia and their influence on soil nutrition status (2006). Project led by VCS in collaboration with CSL.

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Appendix A: Basic soil analysis conducted at each of the four sites

Soil was sampled from individual plots but only the averaged results are presented here.

Soil (0-30cm) sampled in October 2006:

Site	pH	P Index	K index	Mg Index	Organic matter (percentage)
W	7.6	4	2+	2	2.9
X	7.8	4	2-	1	2.0
Y	7.8	2	2-	2	3.7
Z	7.3	4	1	1	2.4

Soil (0-30cm) sampled in November 2007:

Site	pH	P Index	K index	Mg Index
W	7.4	4	2-	2
X	7.4	4	1	2
Y	7.9	2	1	2
Z	7.5	4	1	2

Organic matter will be analyse for again after incorporation of the fertility building crops.

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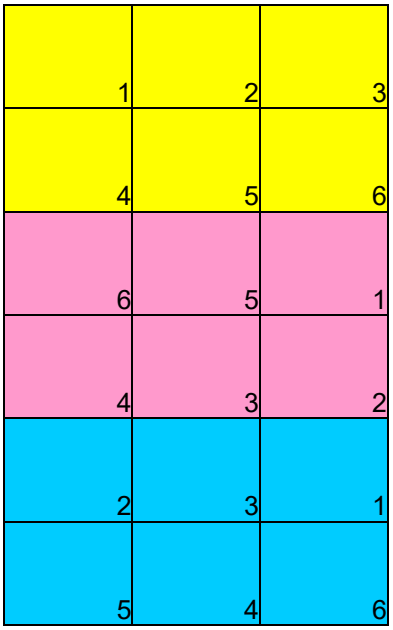
Appendix B: Experimental plot layout

Plan of the experiment at Site W (Elveden). Plots were 46 by 48m.

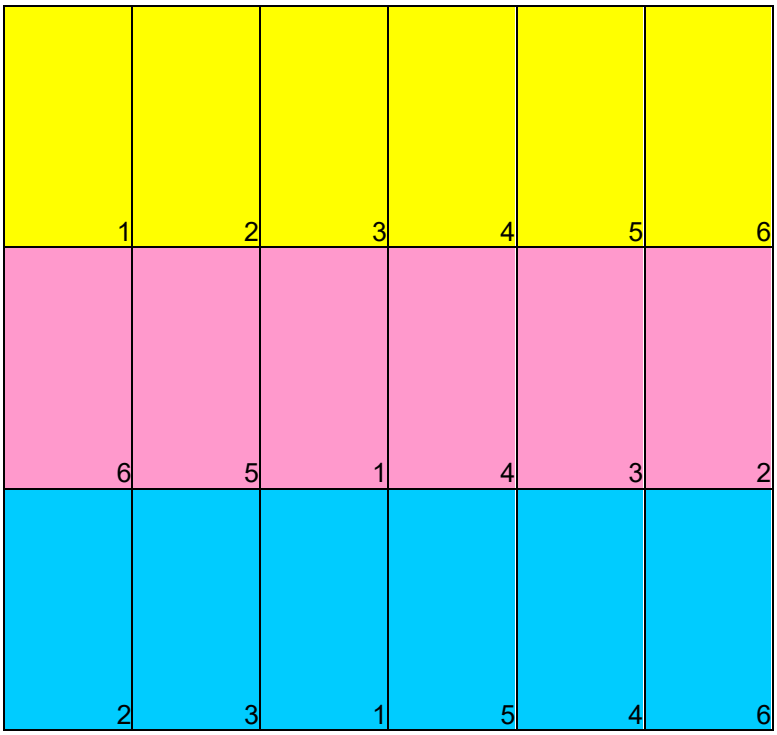


Block A

Block B

Block C

Plan of the experiment at Site X (Westrope), Site Y (Russell Smith) and Site Z (Bagthorpe). At X and Z plots were 24m by 84m; at Y they were 18m by 60m.



Block A

Block B

Block C

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Appendix C: Dates of husbandry operations at the four sites

	W	**X**	**Y**	**Z**
Previous crop	Onions	Onions	Barley	Onions
Cultivations	Discs	Cultipress	Germinator	Plough/press
Seed drill used	Leyy combi	Ransome Nordsten Lifto-matic combi	Accord combi	Accord combi on ridged tine cultivator
Sowing of autumn swards	22/9/06	21/9/06	11/9/06	25/9/06
Sowing of spring swards	19/3/07	30/3/07	23/3/07	29/3/07
Mowing 1	3/5/07	14/5/07	3/5/07	1/6/07
Mowing 2	4/6/07	5/6/07	4/6/07	14/7/07
Mowing 3	9/7/07	14/7/07	5/7/07	10/9/07
Mowing 4	20/8/07	10/9/07	13/8/07	
Mowing 5			28/9/07	

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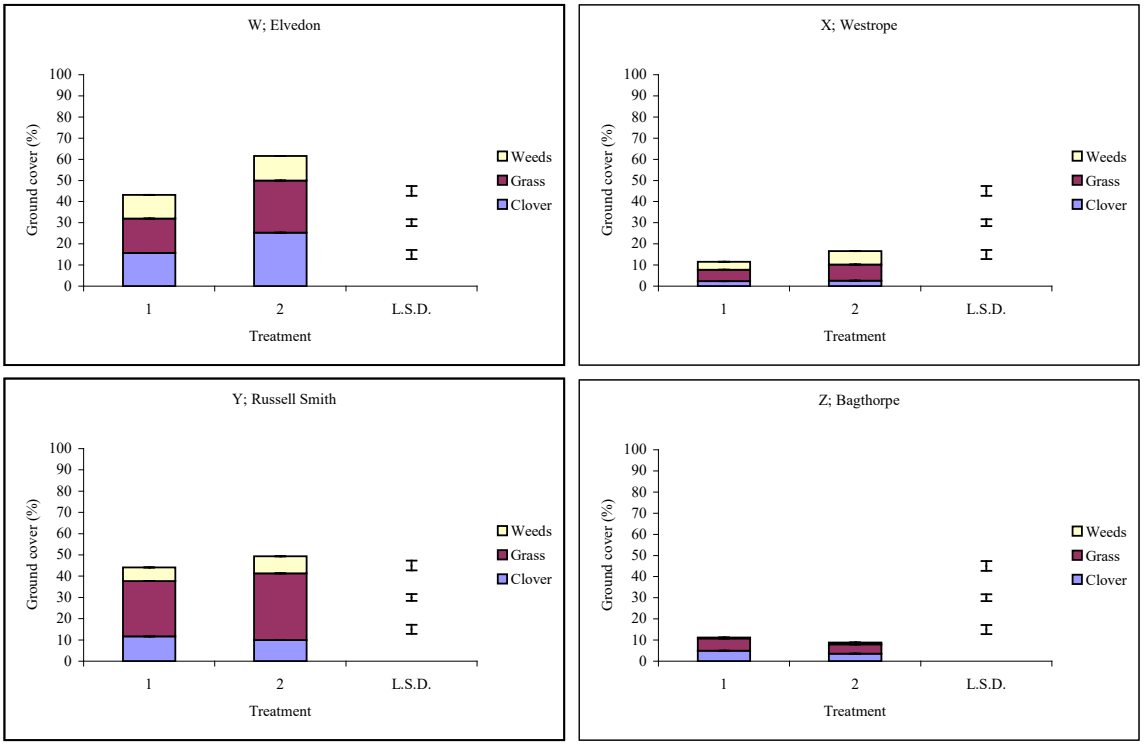
Appendix D: The results of ground cover assessments at the four sites

The graphs all show averages of six quadrats made in the three replicates of each treatment; the Least Significant Difference bars show the degree of variability associated with assessments of weed, grass and legume cover (any differences greater than the LSD bar are significantly different at the 95% level).

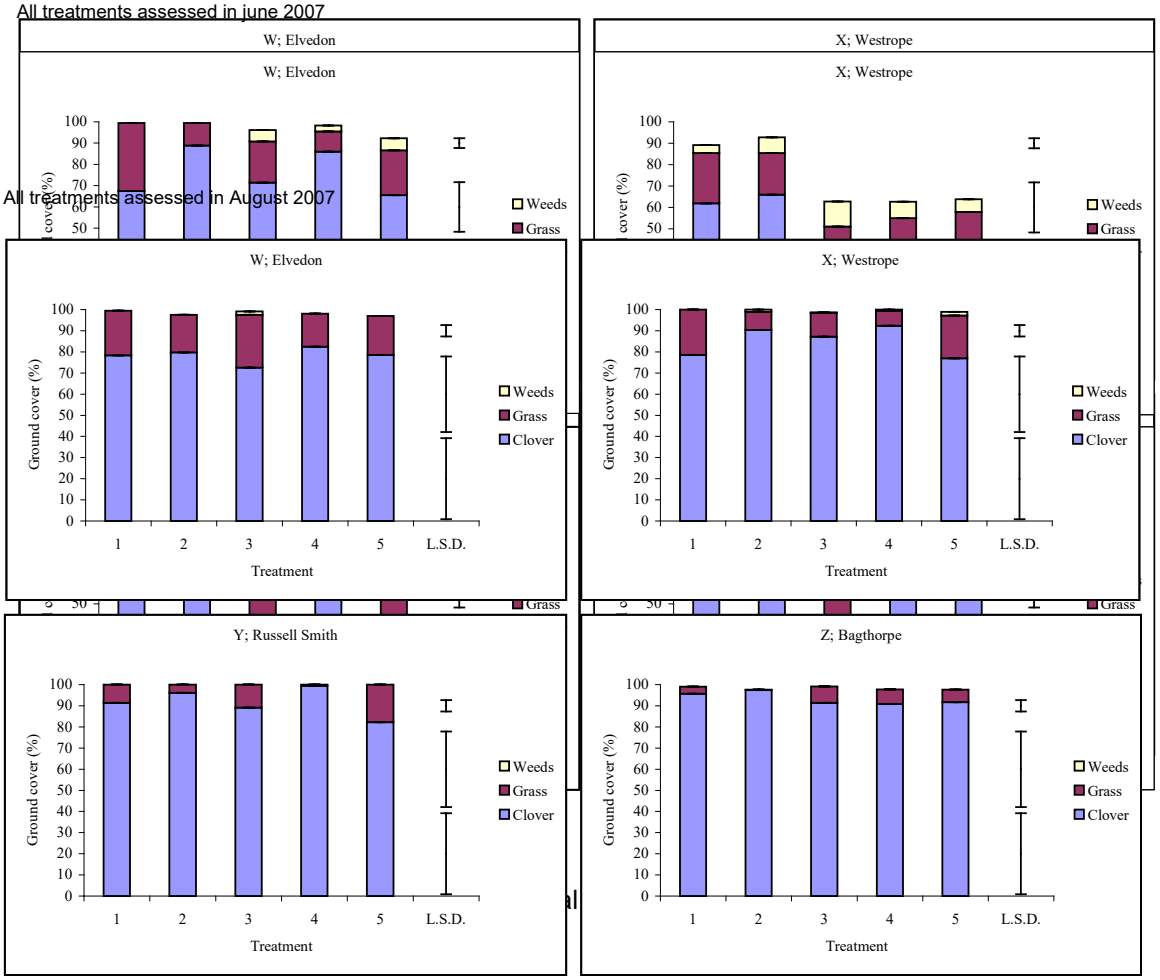
Autumn sown treatments assessed in November 2006



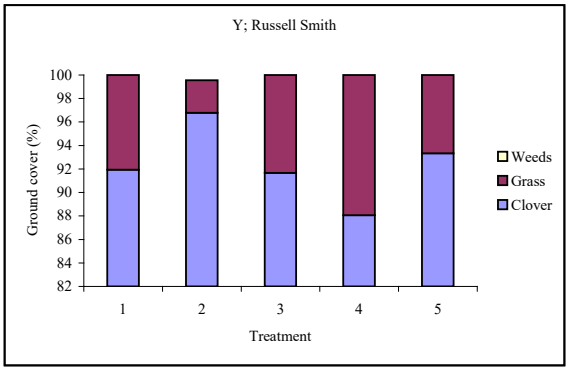
Spring sown treatements assessed in April 2007

All treatments assessed in june 2007

All treatments assessed in August 2007



All treatments assessed in October 2007. Only Site Y was assessed on this date.



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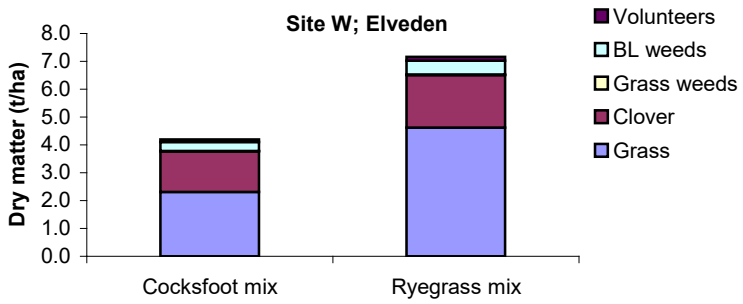
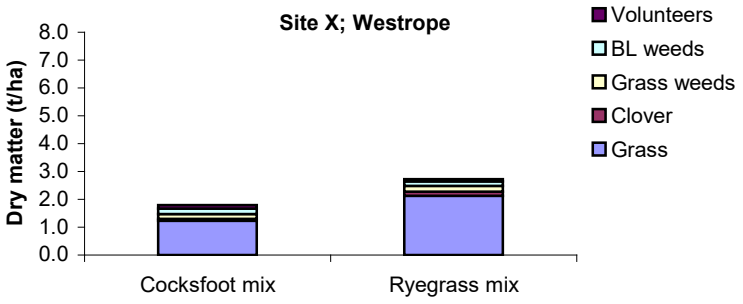
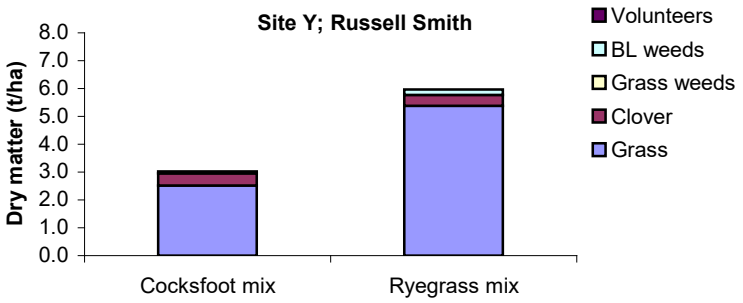
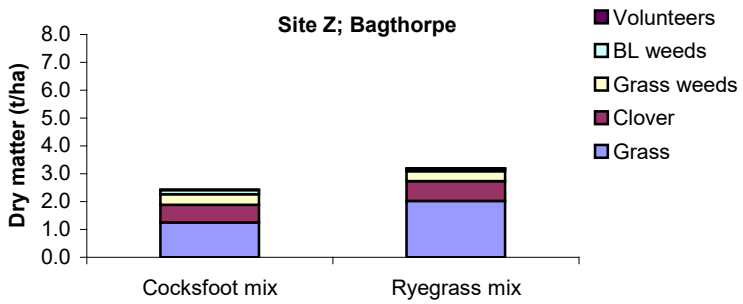
Appendix E: Overwintered biomass at the four sites

Assessments made in April 2007 of the two autumn sown treatments (Treatments 1 and 2). The values represent total biomass (above ground and recoverable roots).









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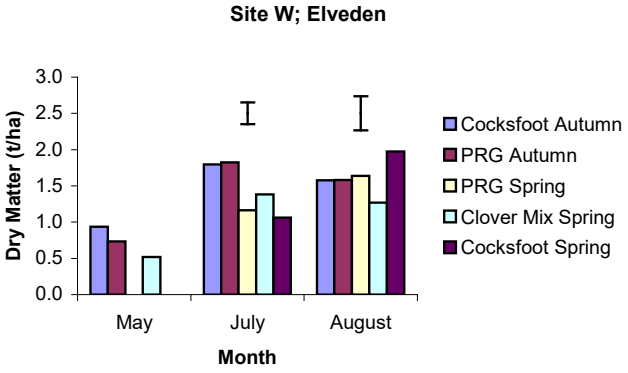
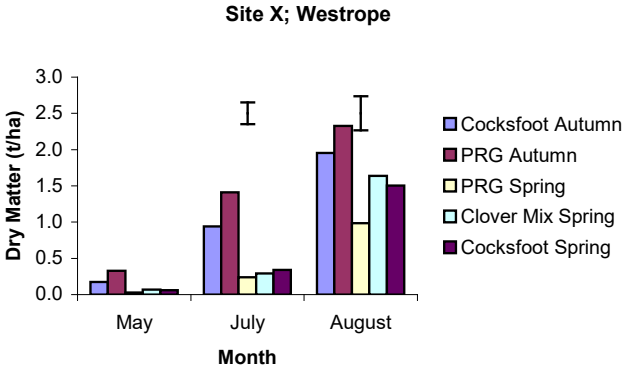
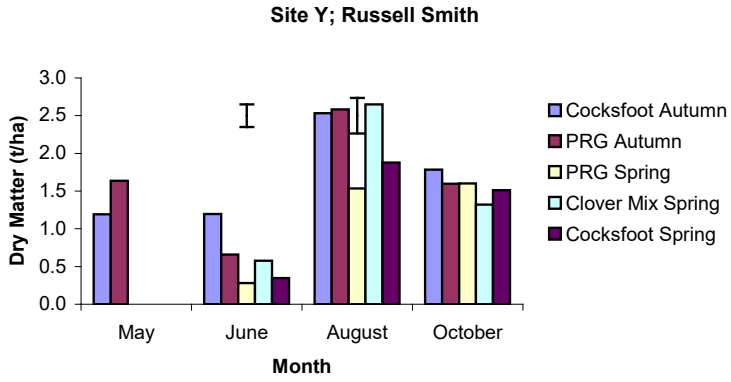
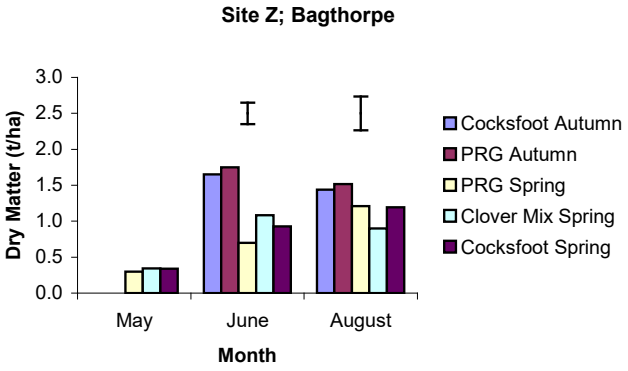
Appendix F: Material returned to the ground by mowing at the four sites

These assessments were usually made a few days before the actual mowing dates shown in Appendix C. The error bars represent Least Significant Differences for one sampling date over all site and treatment combinations. No LSD bar is shown for the May assessment because this data was incomplete; at Site Z the autumn sown plots had been mown just before the assessment and so no data could be collected.









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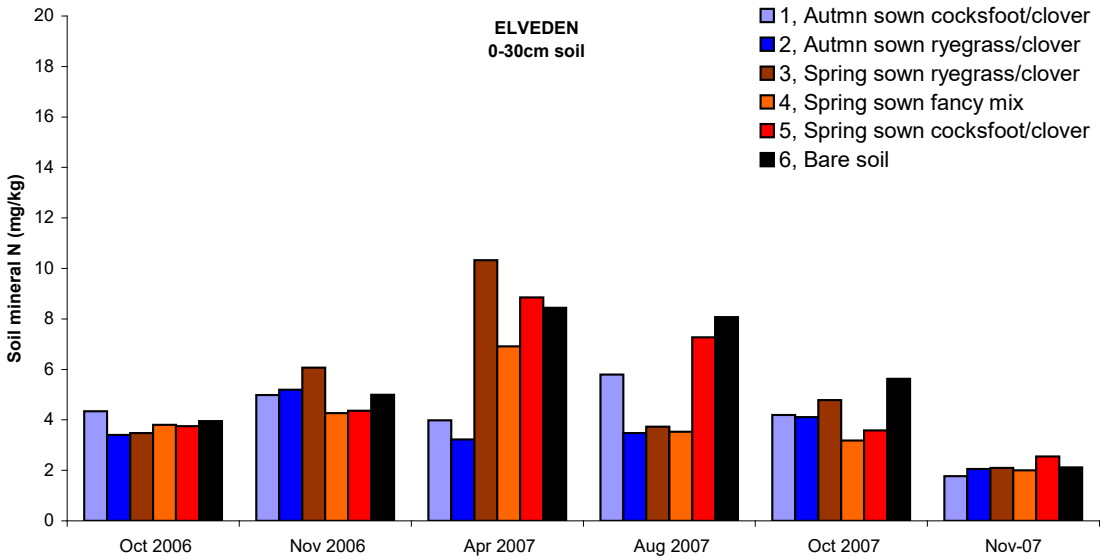
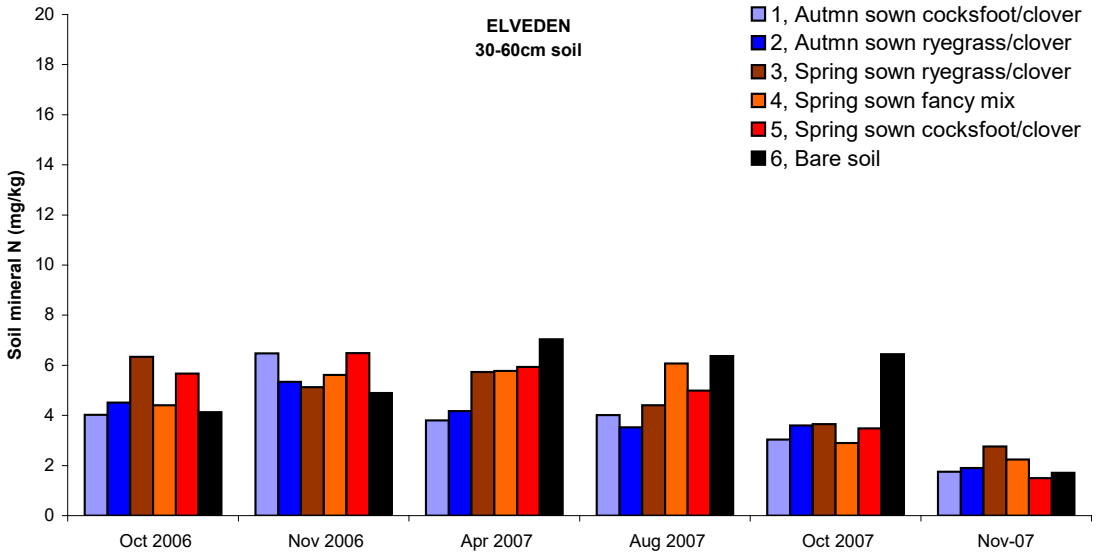
Appendix G: Soil mineral nitrogen at the four sites

Note that for the first three sampling dates Treatments 3, 4, 5 and 6 were effectively bare (spring sown swards were established in March 2007)

SITE W





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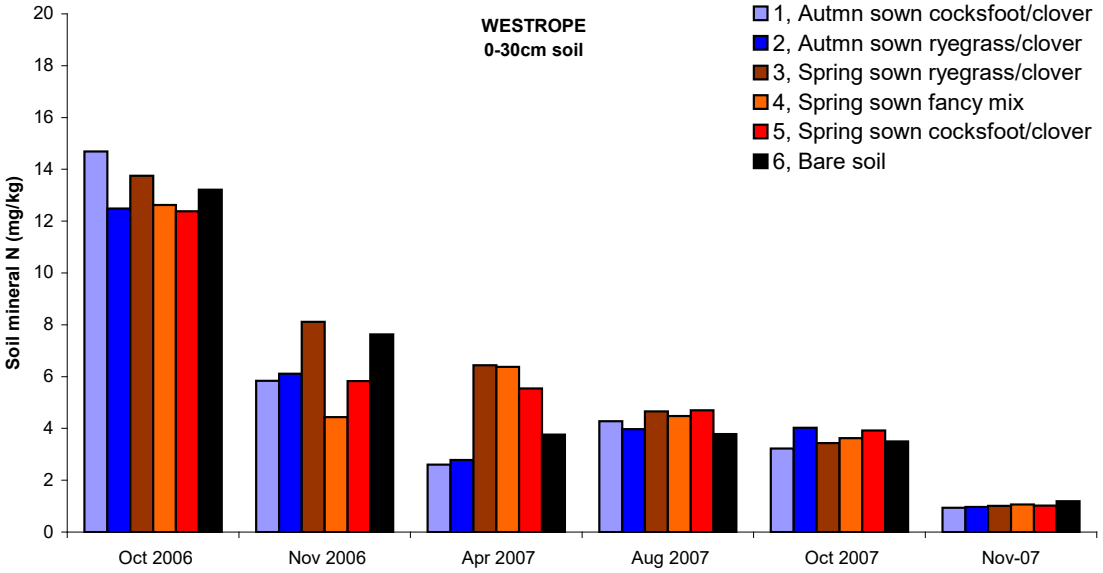
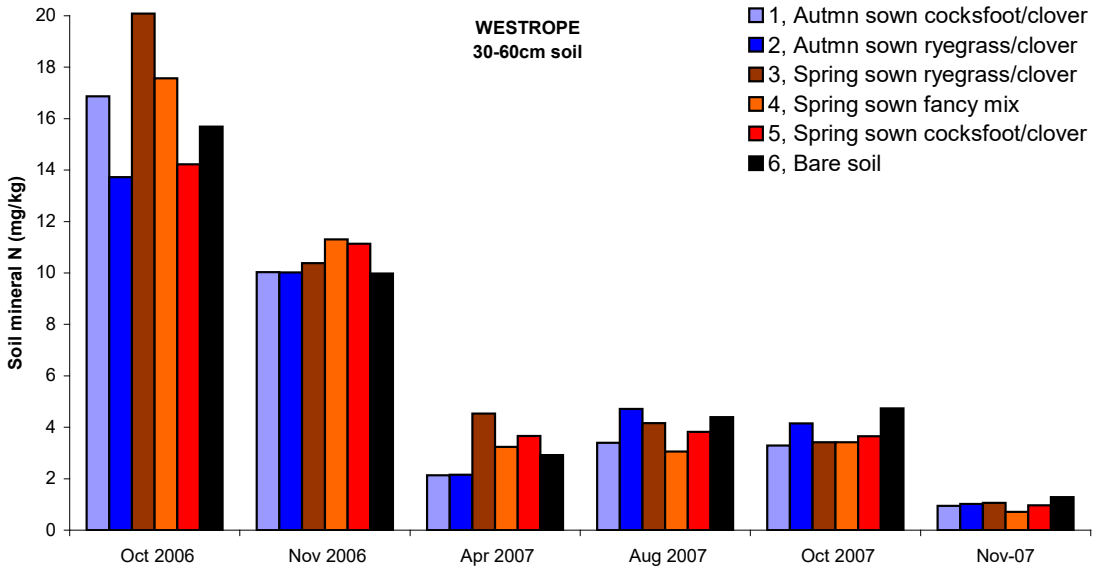
SITE X





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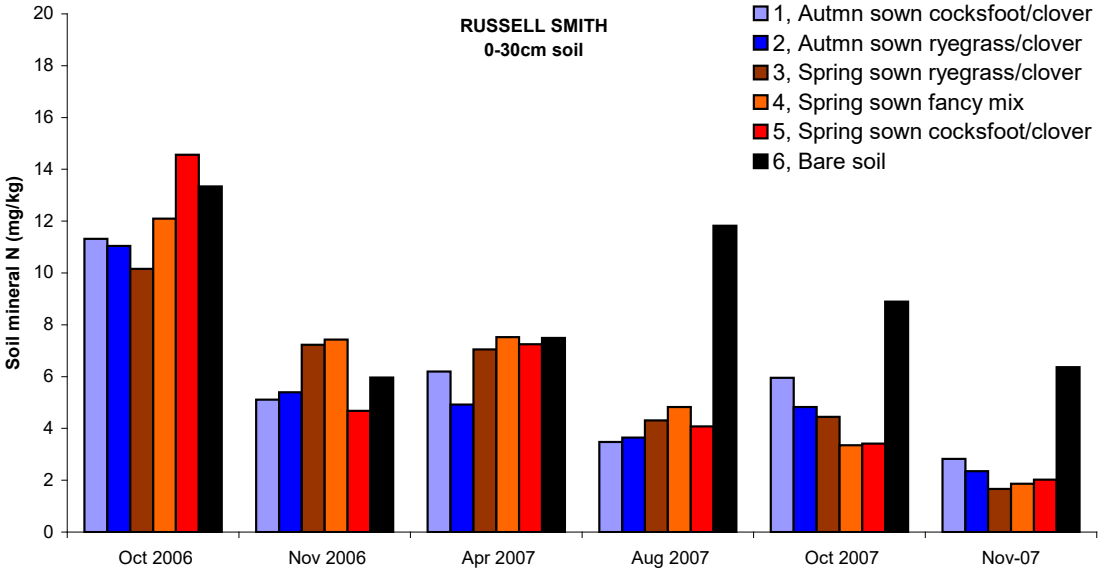
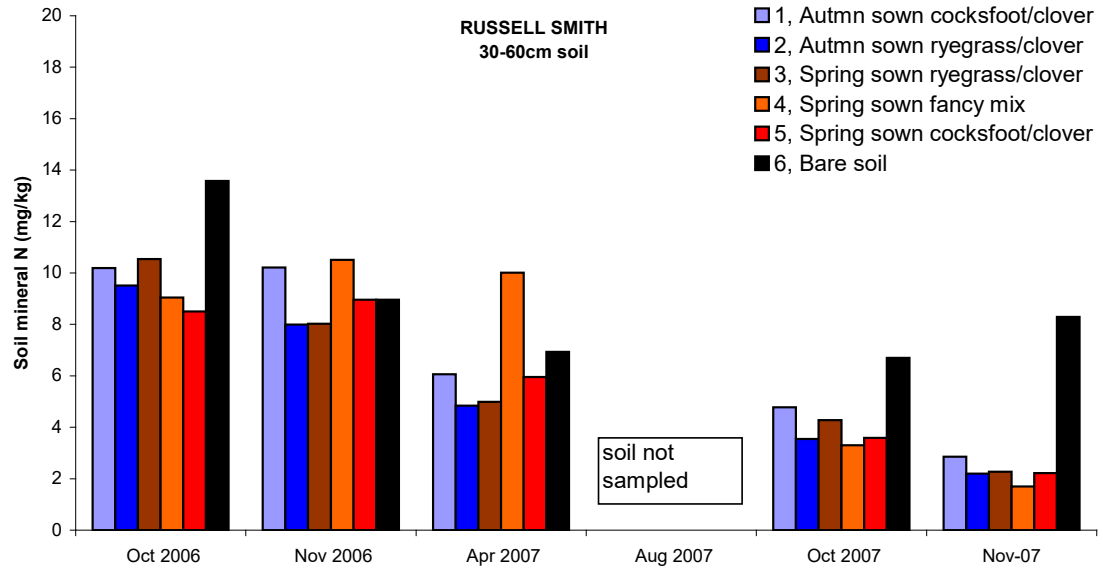
SITE Y





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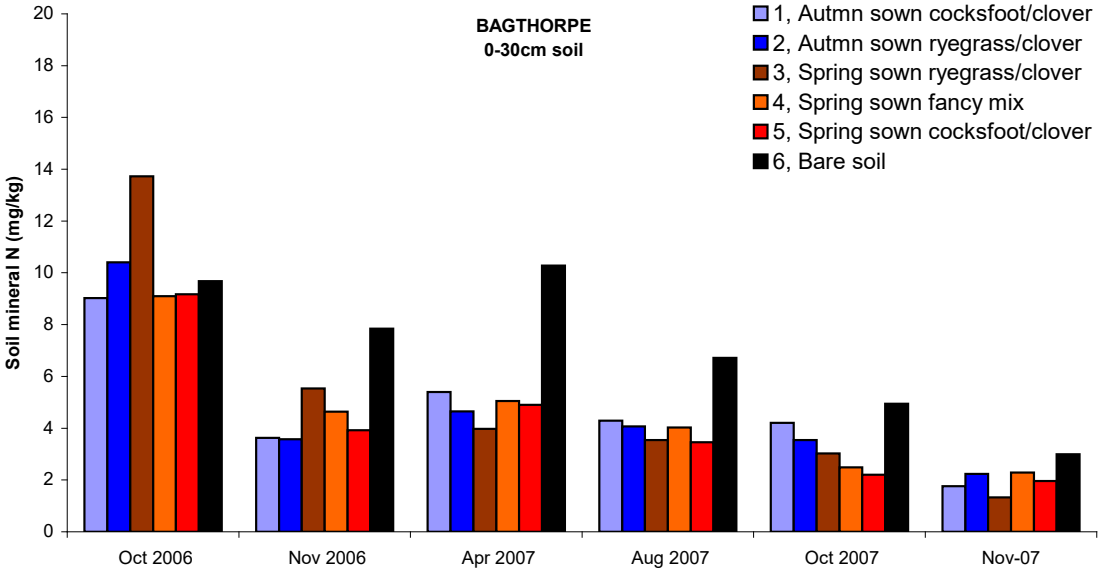
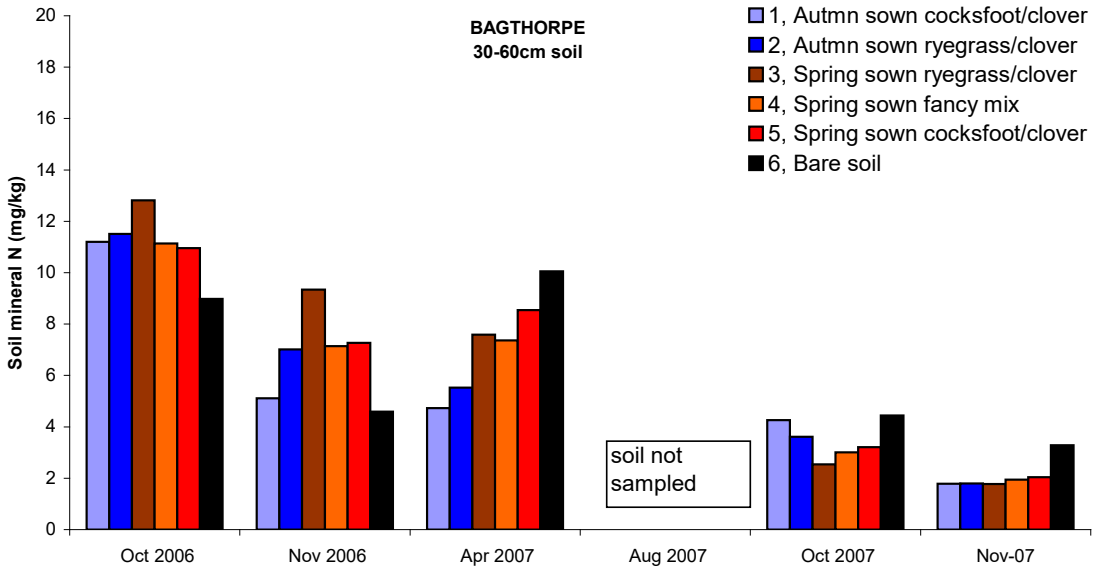
SITE Z





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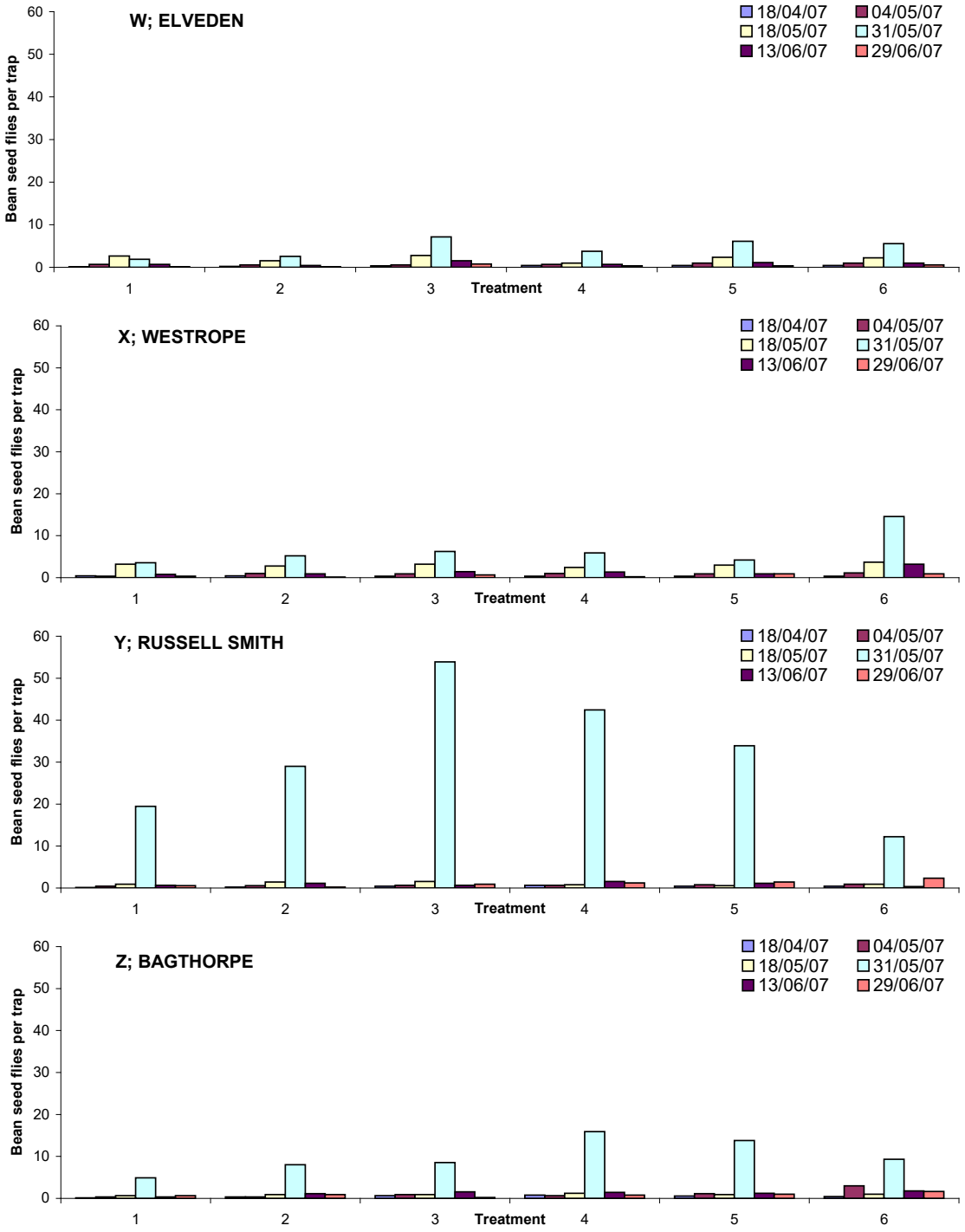
Appendix H: Bean seed fly populations at the four sites



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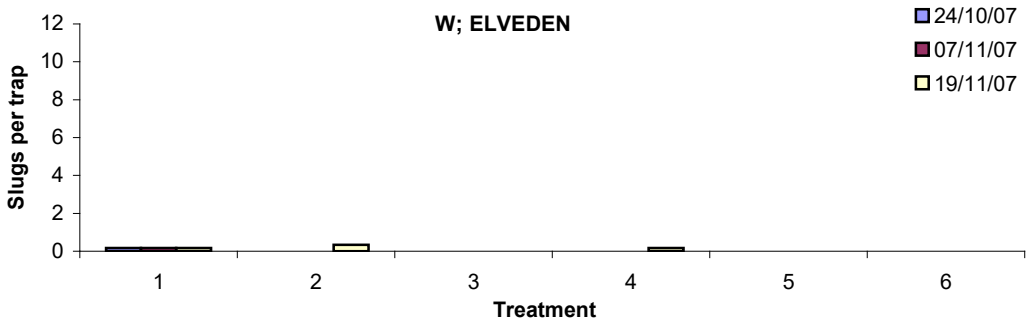
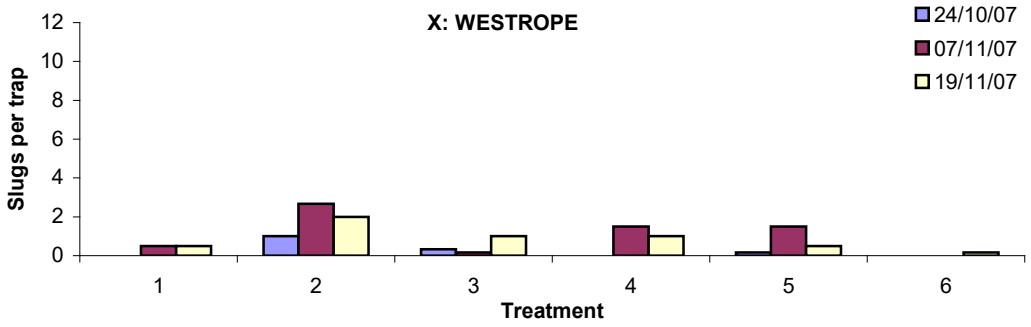
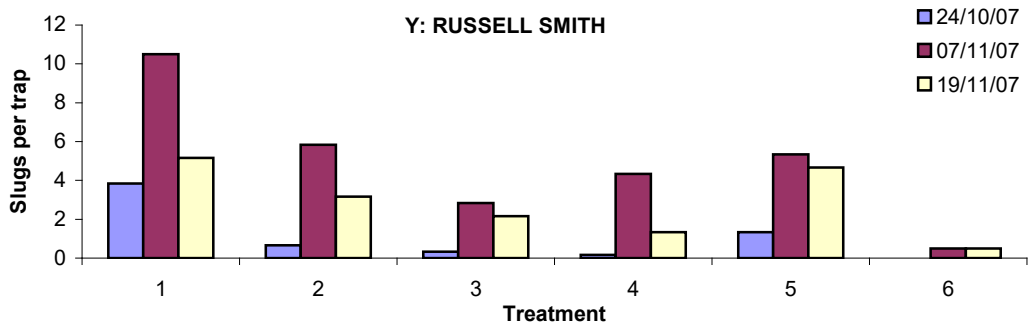
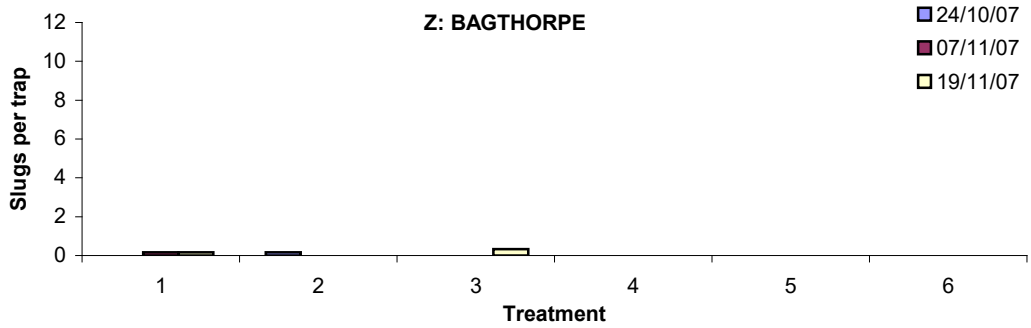
Appendix I: Slug populations at the four sites









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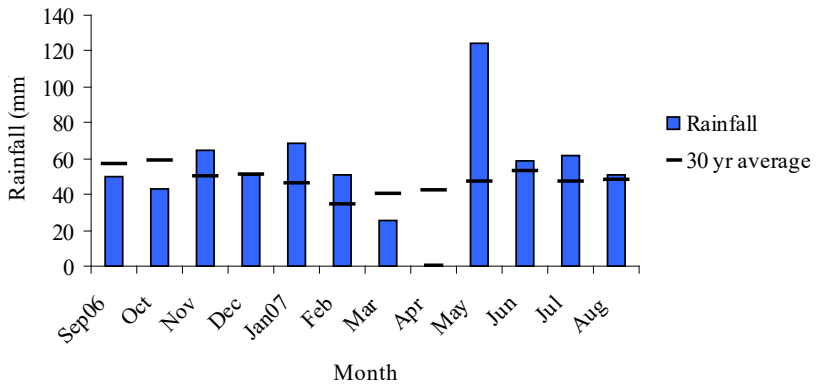
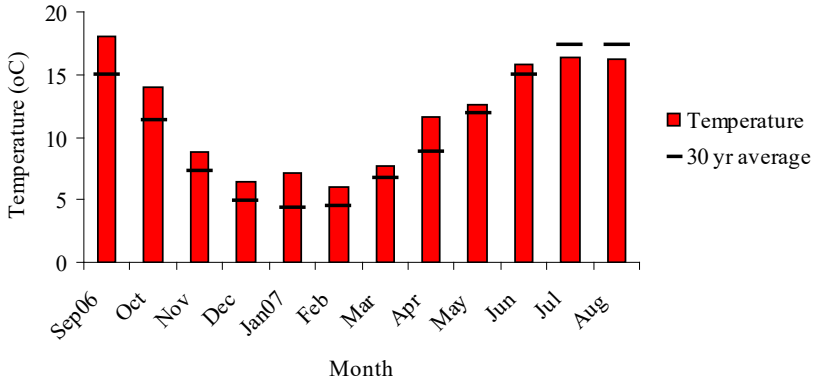
Appendix J: Weather data from Cambridge NIAB weather station

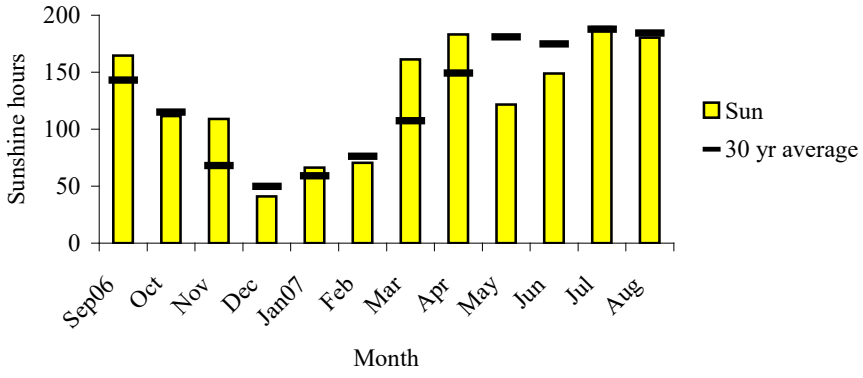
Rainfall



Temperature



Sunshine



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