Using Genstat to compare the responses of sweet corn varieties to fall armyworm, *Spodoptera frugiperda*.

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Introduction

Fall armyworm (FAW) was first detected in 2020 in Queensland. It quickly spread to several locations in Australia, causing up to 80% losses in sweet corn and maize[1]. In 2021, economic studies estimated the potential annualised loss for the industry across Northern Australia to be $59 million[1].

This poster describes a plot trial that assessed the susceptibility and preference of eight commercially available sweetcorn varieties to FAW infestation. It was conducted at DAF's Research Facility in Bowen, north Queensland, during high FAW pressure in October to December 2023.

This poster also demonstrates how the development of statistical software has assisted in implementing more complex design and analyses structures.

Image 1. The sweet corn trial site at the DAF Research Facility, Bowen.

Fall Army worm – some biology

Moths are active during late evening and night. The moths are sensitive to light so infestations occur mostly in the middle of the crop area, rather than the edges.

Eggs take approximately 3 days to hatch and it is the larvae that do the damage. There are often multiple infestations within a crop and even a small trial plot area.

Image 2. Selection of FAW life stages: a) Egg mass, b) Fourth instar larva, c) Male moth.

Images supplied by Siva Subramaniam

Experimental Design

The trial area was 80m long x 16 'plant rows' wide. A plot (experimental unit) was 10m long by 4 'plant rows' (3m) wide.

This enabled the layout to be an array of 8 'design rows' (row) by 4 'design columns' (col) (Figure 1), which could neatly accommodate four replicates of the 8 sweet corn varieties.

There were approximately 200 plants per plot (potentially closer to 180, as 100% germination does not normally occur).

- A (latinised) doubly resolvable row-column design was used to allow for the patchiness of FAW infestation (Figure 2).
  - As there was more chance of varying amounts of FAW lengthways down the 80m of trial area, the replicates were chosen to consist of two rows of plots.
  - The design ensured that a treatment does not occur more than once down a column.
- The design can be easily generated in Genstat v22 using AFRCRESOLVABLE procedure or the menu's [8 rows, 4 columns, 8 treatment levels]

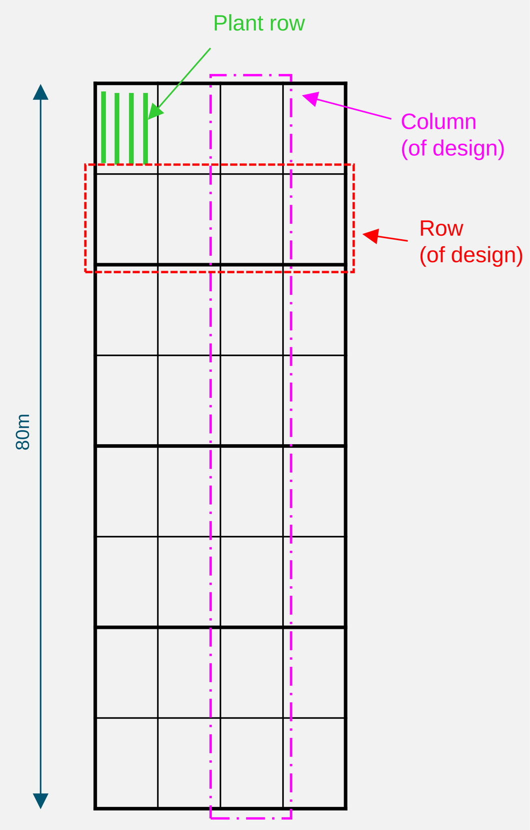

Figure 1. Overall design layout.

Sweet corn variety names are not specified due to confidentiality reasons. Variables measured are included in Table 1.

Table 1. Variables measured.

Variable measured (per plant)	Plants/plot	Date
Damage score[2] (0=no damage; 10=severe damage)	8 4	18.10.23 1.11.23*
Total number of alive FAW larvae	4	1.11.23*
Egg count	8	18.10.23
Number of egg masses	10	23.10.23

* Destructive sampling – removed 4 plants and assessed. Scored using Davis rating scale for foliage damage[2].

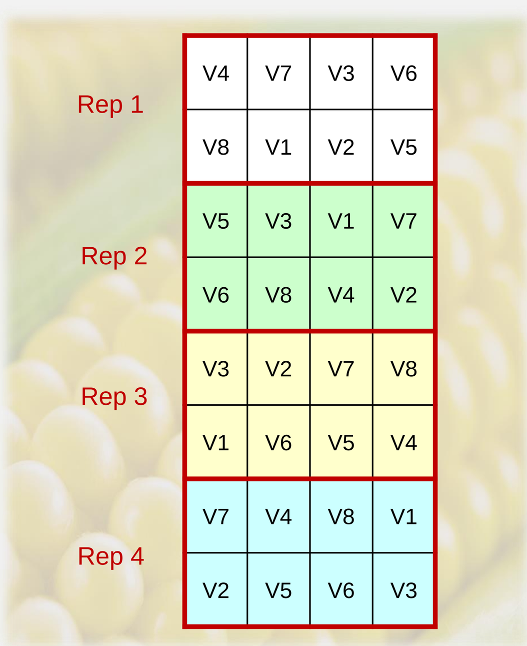

Figure 2. Design layout with variety allocation. The four replicates are indicated by the colours white, green, yellow and blue.

Statistical Analysis methods

Measurements were made on different plants and a varying number of plants each measurement time, thus they were not considered as repeated measures data. They have been analysed separately for each time using Genstat v22. Variety was included as the fixed effect for all analyses.

Damage score and total alive FAW

- Values averaged per plot [Damage score 18.10.23: transformed as square root (mean score + 0.5)]
- Spatial models allowing for trend down rows and across columns were considered for the analysis.
  - The Genstat procedure VAROWCOLUMNDESIGN is a convenient way to do this.
  - This procedure analyses the data using restricted maximum likelihood (REML) and automatically selects the best random and spatial covariance model as determined by the lowest Schwarz (Bayesian) information coefficient (SIC). Being a regular grid, an auto-regressive model was used.
- Residual plots were used to check method assumptions.

Egg counts and egg mass count

- Values mostly 0 or 1 thus redefined as proportion: number of plants (out of 8 or 10 respectively) with eggs present/ egg masses present.
- Proportion of plants with eggs present:
  Hierarchical generalised linear models (HGLM) with a binomial distribution and logit link.
  Random effect (Replicate) required beta distribution and logit link.
- Proportion of plants with egg mass present:
  HGLM with a binomial distribution and logit link. Normal distribution for random term.

Results

Damage score:

No spatial model required for 10.10.23, but AR(1) process for columns for 1.11.23.

There was no significant difference in mean damage scores between varieties on both 18.10.23 or 1.11.23. (Table 1).

Presence of eggs / egg masses:

There was no significant difference between the varieties in the proportion of plants with eggs present or with egg masses present (Table 2).

Table 2. Predicted means for damage score, eggs present and egg masses present.

Variety	Damage Score		Eggs present (ppn plants)	Egg masses present (ppn plants)
	18.10.23	1.11.23	18.10.23	23.10.23
1	1.05	6.36	0.156	0.075
2	0.98	6.29	0.281	0.100
3	1.46	6.37	0.125	0.125
4	1.31	5.85	0.094	0.150
5	0.71	5.98	0.219	0.275
6	0.58	5.79	0.312	0.150
7	1.25	5.94	0.125	0.225
8	0.59	6.48	0.094	0.175
P-value	0.281*	0.521	0.363	0.509
s.e.d. (av)	0.170*	0.401	0.108	0.679
l.s.d.(av)				

* Values for analyses on transformed scale

Total alive FAW:

Best model was that with no spatial model.

There was a significant difference (p=0.015) between varieties in the mean total number of FAW alive 1.11.23 (Figure 3).

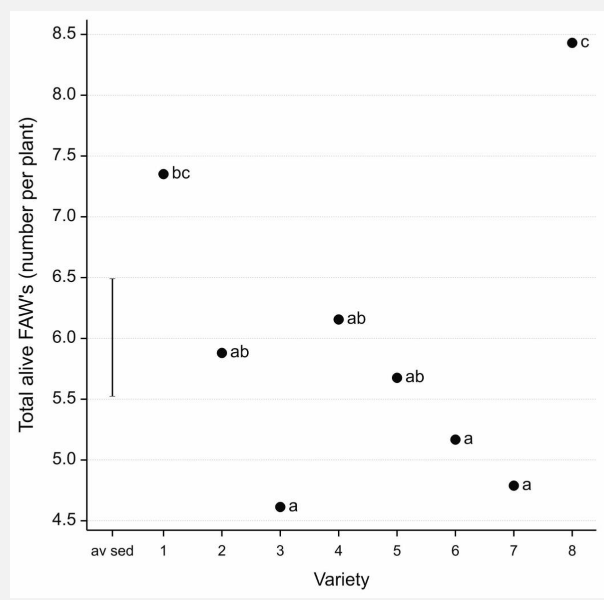

Figure 3. Predictions of total alive FAW's. (points followed by a common letter are not significantly different (p=0.05)).

Conclusions

Whilst the design array was not extensive, this paper provides an example of using Genstat to allow for a spatial trend when designing a field layout and analysing the data generated from the trial.

Among the varieties tested, many had similarly low numbers of alive FAW. However, Variety 8 had significantly higher numbers than all other varieties, except for that of Variety 1. This information can now be used in recommending less susceptible varieties to growers.

This is one of many trials analysed investigating issues related to the control of FAW's. A future step will be to consider how information from multiple trials may be combined.

References

[1] Subramaniam, S et al (2022). Identifying potential parasitoids of the fall armyworm, *Spodoptera frugiperda*, and the risk to Australian horticulture. Final report MT19015. https://www.horticulture.com.au/globalassets/laserfiche/assets/project-reports/mt19015/mt19015-final-report-complete.pdf

[2] Davis, F. and Williams, W. 1992. Visual rating scales for screening whorl stage corn for resistance to fall armyworm. (Technical Bulletin No. 186). Mississippi State University, MS39762, USA.