Biometrics and Statistics Technical Report No. 1/2017[$]

Project: Range Ecology and Management Research

Experimental Designs for Alley Cropping to Estimate Shrub × Grass Interaction

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March 2017

Citation: Murari Singh (2017). Experimental Designs for Alley Cropping to Estimate Shrub × Grass Interaction. Biometrics and Statistics Technical Report No. 1(2017). BSS/DDG-R, ICARDA, Amman. 48pp.

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Abstract

Alley cropping, an agroforestry system, comprises rows of perennial shrubs or trees bordering the alleys of grasses/crops. An appropriately chosen alley cropping provides improvement in feeds for small ruminants, food for human consumption, and contributes to economic and environmental sustainability. Rangeland and forage development studies aim at evaluation of interference of shrubs such as saltbush Atriplex, with the grasses or fodder/forage crops such as vetch/barley. In such studies a number purposely selected species of shrubs and grasses are evaluated under an alley cropping. This presentation discusses a number of experimental designs and statistical models for analysis of responses on the grasses/crops in the alleys. The experimental designs considered are the complete block with or without split-plot frames for the border and alley experimental units. The treatment designs include a factorial structure of shrub-borders and grasses. The shrub-borders considered are of self-types, i.e. same shrub on both sides of the alley, and partial diallel-type, i.e., different shrubs on the borders. The linear models consisting of shrubs effects, grasses effects and their interaction with different structures are considered with parameters defined for shrub × grass interaction. A statistical analysis of the alley- responses has been illustrated with a simulated dataset.

Key words: Alley cropping, Shrub and Grass Effects and Interaction, Self and Diallel Designs, Blocks, Split-plots,

Introduction

Alley cropping, an agroforestry practice, is a low input system for forage and food production and serves as a mechanism for sustainable agriculture. With suitable choice of crop, shrub or tree species in the system it supports diverse needs of human and other domestic animals, and arrest the land degradation and soil erosion, and plays a major role in mitigating climate change. Alley cropping manages the soil nutrients more effectively between the species, e.g., perennial trees/shrubs and annual crops, and different layers of soil depth. A wide range of references are available on various types of crop production systems including alley cropping (Solaimalai et al., 2005; AFNTA 1992a, b;

http://forest.mtu.edu/pcforestry/resources/studentprojects/Alley%20Cropping.htm#Definition).

Alley cropping is practiced in rangeland research where shrubs are established as borders to the alleys which grow grasses or crops. Alley cropping systems look like the following pictures.

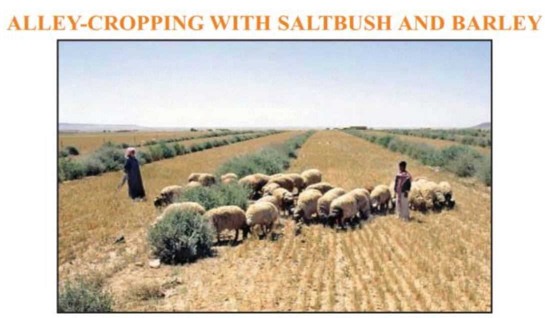

Photo 1. Source: Page 30 of ICARDA (2005). Sustainable Agricultural Development For Marginal Dry Areas: Khanasser Valley Integrated Research Site. 51pp.

http://libcatalog.cimmyt.org/download/reprints/94078.pdf

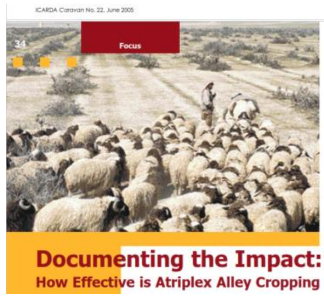

Photo 2. Source: Page 34 (ICARDA (2005). ICARDA Caravan: Review of agriculture in the dry areas. Issue No. 22, 43pp.

Photo 3. Rehabilitating degraded steppe lowlands with damage cause by continuous grazing, notably a large increase in invasive species. http://www.icarda.org/features/rehabilitating-degraded-steppe-lowlands#sthash.SrVLk5i0.dpuf

The following links also exhibit alley crops and hedgerow intercrops in the fields.

Link: http://www.fao.org/wairdocs/ilri/x5546e/x5546e0b.htm

http://www.cof.orst.edu/pubs/cof/plntdfor/tnxch/ch12.htm

http://www.igfri.res.in/pdf/AR-15-16/AR-15-16-eng.pdf

http://www.igfri.res.in/pdf/AR-15-16/AR-15-16-eng.pdf

The purpose of this presentation is to discuss experimental designs and data analysis for evaluating shrub × grass interaction. These designs can also be used to estimate main effects and interaction of crops involved in inter-cropping systems.

Experimental Designs and Models for Statistical Analysis

Consider a set of shrubs denoted by $S_1,..., S_s$ for planting as the borders and a number of grasses/crops $G_1,…, G_g$ for the alleys. The following frames of experimental units, or, shrub – grass plots will be considered. Experimental units receive

1. combinations of shrubs and grasses
2. shrubs with long borders and all grasses in smaller alleys within these borders

The following two treatment designs

1. Self-borders and grasses combination, and
2. Diallel-borders and grasses combination

can be implemented with any one of the above two frames of the experimental units.

The resulting designs may or may not share borders between two alleys. In case they do, search for appropriate covariance structures for grass plot errors would be needed. Examples of such designs are given in the following schemas along with models for data analysis.

Non-shared borders

Consider the case where the borders are not shared between the alleys, i.e. same shrub does not affect the grasses on its opposite sides of alleys.

Self- borders: Further consider the situation of using the same shrubs on both sides of the borders.

Design 1. Self-borders and grasses combinations in RCBD.

Schema 1: A randomized plan for 4 shrubs (S1…S4), 3 grasses (G1…G3), self-borders, factorial in RCBD, one replicate shown.

Replicate	1											
Left-border	S1	S1	S2	S2	S1	S3	S4	S4	S3	S2	S4	S3
Alley	G2	G3	G2	G3	G1	G3	G2	G1	G2	G1	G3	G1
Right-border	S1	S1	S2	S2	S1	S3	S4	S4	S3	S2	S4	S3
Plots	101	102	103	104	105	106	107	108	109	110	111	112

Let

$y_{i,jj,l}$ = response from the alley under grass G_i or i, self-borders (left, right): (S_j, S_j) or jj, block/replicate l

μ = general mean; β_l =Effect of block l; γ_i = effect of grass i; ψ_j =effect of borders, jj, under shrub j from both sides; δ_{ij} = interaction between grass i and shrub borders jj; $i=1,\ldots,g$; $j=1,\ldots,s$; and $l=1,\ldots,r$.

The following response model can be assumed.

Response = general mean + block effect + grass effect + shrub-effect + shrub × grass interaction + Error, or,

$$y_{i,jj,l} = \mu + \beta_l + \gamma_i + \psi_j + \delta_{ij} + \varepsilon_{i,jj,l}$$

where independently distributed errors $\varepsilon_{i,jj,l} \sim N(0,\sigma^2)$.

For generating this class of experimental design and carrying out data analysis, see the Genstat software (VSN Inc., 2015) codes in Appendix 1.

Design 2. Self-borders in main plots in RCBD and grasses in sub-plots.

Schema 2. A randomized plan for 4 shrubs (S1…S4), 3 grasses (G1…G3), self-borders, split-plot (Shrub-borders main plot) in RCBD, one replicate

Replicate	1											
Left-border	S2	S2	S2	S3	S3	S3	S1	S1	S1	S4	S4	S4
Alley	G1	G3	G2	G2	G3	G1	G1	G2	G3	G1	G2	G3
Right-border	S2	S2	S2	S3	S3	S3	S1	S1	S1	S4	S4	S4
Plots	101	102	103	104	105	106	107	108	109	110	111	112

Response = general mean + block effect + shrub-effect + Error (a)[Block × Shrub interaction] +

grass effect + Shrub × grass interaction + Error(b), or,

$$y_{i,jj,l} = \mu + \beta_l + \psi_j + (\beta\psi)_{jl}[= \mathrm{E}rror(a)] \;\; + \gamma_i + \delta_{ij} + \varepsilon_{i,jj,l}[= Error(b)]$$

For generating this class of experimental design and carrying out data analysis, see the Genstat codes in Appendix 2.

Diallel- borders: Different shrubs on the borders will be used in the following two designs.

Design 3. Diallel-borders and grasses combinations in RCBD

Schema 3. A randomized plan for 4 shrubs, 3 grasses, diallel-borders, factorial in RCBD, one replicate.

Replicate	1											
Left-border	S1	S4	S2	S2	S1	S3	S4	S1	S3	S2	S3	S4
Alley	G2	G1	G1	G3	G3	G3	G2	G1	G1	G2	G2	G3
Right-border	S3	S2	S1	S1	S3	S4	S2	S3	S4	S1	S4	S2
Plots	101	102	103	104	105	106	107	108	109	110	111	112

In case of diallel-borders, the number of borders (shrub pairs) p say, may not necessarily be equal to s, the number of shrubs. For generating this class of experimental designs based on diallel boders, we may use the partial crosses designs presented in Curnow and Kempthorne

(1961), Curnow (1963), Arya (1983), Singh and Hinkelmann (1990) among other papers, and also reviewed in Singh et al. (2012). These designs are constructed for estimation of general combining ability (gca) effects while specific combining ability (sca) effects are assumed absent or can be ignored. In case of the complete diallel crosses, sca effects are also estimable.

Let $y_{i,jk,l}$ = response from the alley under grass i, diallel-borders (left , right): (S_j, S_k) or jk (shrub j left border and shrub k on the right) and block/replicate l

A statistical model for the response is

$$y_{i,jk,l} = \mu + \beta_l + \gamma_i + \psi_j + \psi_k + \psi_{jk} + \delta_{ij} + \delta_{ik} + \delta_{ijk} + \varepsilon_{i,jk,l}$$

In the above model, the parameters ψ_j in the alley cropping design is the general effect of shrub S_j (irrespective of border direction) on the grasses (gesg) and is equivalent to the gca in the case of partial dial crosses. The ψ_{jk}, is the specific effect of the shrub borders (S_j, S_k) on the grasses (sesg) and would be equivalent to the sca in the diallel crosses situation. The quantity δ_{ij} is the interaction between shrub effect ψ_j and grass effect γ_i and may be termed as grass-specific general effect of shrub S_j (irrespective of border direction) on the grass (gs-gseg), and δ_{ijk} is grass-specific specific effect of the shrub borders (S_j, S_k) on the grass (gs-sesg). Errors $\varepsilon_{i,jk,l} \sim N(0, \sigma^2)$.

There may be situations where the following assumption may apply.

Assumption: sesg ψ_{jk} and gs-sesg δ_{ijk} may be absent or negligible

In this case the model reduces to

$$y_{i,jk,l} = \mu + \beta_l + \gamma_i + \psi_j + \psi_k + \delta_{ij} + \delta_{ik} + \varepsilon_{i,jk,l}$$

Further, ψ_j's under the designs 1 and 2 (self-borders) would be different from those under the diallel borders. However, in case ψ_{jk} (specific border combination effects) are absent, then ψ_j's under Designs 1 and 2 would be twice of those under Design 3 and Design 4 in the following.

Genstat codes for generating Design 3 for a chosen diallel set, also included there, are given in Appendix 3. The data analysis can be carried out using the Genstat codes given for the next Design 4, by using the Blockstructure of Appendix 3.

Design 4. Diallel-borders in main plots in RCBD and grasses in sub-plots

Schema 4. A randomized plan for 4 shrubs, 3 grasses, diallel-borders, split-plot (Shrub-borders main plot) in RCBD

Replicate	1											
Left-border	S2	S2	S2	S4	S4	S4	S1	S1	S1	S3	S3	S3
Alley	G2	G3	G1	G3	G1	G2	G3	G2	G1	G2	G3	G1
Right-border	S4	S4	S4	S1	S1	S1	S3	S3	S3	S2	S2	S2
Plots	101	102	103	104	105	106	107	108	109	110	111	112

Model:

$$y_{i,jk,l} = \mu + \beta_l + \psi_j + \psi_k + \psi_{jk} + (\beta\psi)_{jk,l}[= \mathrm{E}rror(a)] \ + \gamma_i + \delta_{ij} + \delta_{ik} + \delta_{ijk} + \varepsilon_{i,jk,l}[= Error(b)]$$

Assumption: sesg ψ_{jk} and gs-sesg δ_{ijk} may be absent or negligible

$$y_{i,jk,l} = \mu + \beta_l + \psi_j + \psi_k + (\beta\psi)_{jk,l}[= \mathrm{E}rror(a)] \ + \gamma_i + \delta_{ij} + \delta_{ik} + \varepsilon_{i,jk,l}[= Error(b)]$$

Design for diallel boders as discussed in Design 3 can be used for conducting the trial in split-plots with diallel-borders in mainplots and grasses in sub-plots. The codes for generating the Design 4 are given in Appendix 4.

Estimation of the effects and interactions

A practical approach would be to estimate the response of the combinations of shrub-borders and gasses with adjustment for block differences, covariates for slope and fertility trend in the alleys, spatial error structures. Let the adjusted mean for the treatment combination: grass i and diallel-border (left, right) (j,k) be denoted by $\bar{y}_{i,jk}$. In vector notation, we can use

$\bar{y} = (\bar{y}_{1,12}, \bar{y}_{1,13}, \bar{y}_{1,1s}, ..., \bar{y}_{g,s-1s})'$. One may use all pairs of shrubs (S_j, S_k), equivalent to (S_k, S_j), as borders, but limited resouces may lead to the choice of partial diallel-borders. Based on a simple cyclic structure in shrubs may give a set of diallel-borders as: $(S_1, S_2), (S_2, S_3), ..., (S_s, S_1)$, which could be chosen for all the replicates, or even a better spread could carried over the replication by using a different spacing between the shrub numbers, e.g., $(S_1, S_3), (S_3, S_5), ..., (S_{\_}, S_{\_})$ in replicate 2, etc. Let the estimated variance covariance of vector $\bar{y}$ be denoted by $\hat{\Sigma}$. For the full factorial of border and alley treatment factors in an RCBD with r

replicates and estimated residual mean square $\hat{\sigma}^2$, $\hat{\Sigma} = (\hat{\sigma}^2 / r)I$. Let the grass effects, shrub effects and their interaction be represented in vector form respectively as:

$\gamma = (\gamma_1, ..., \gamma_g)'$, $\psi = (\psi_1, ..., \psi_s)'$ and $\delta = (\delta_{11}, \delta_{12} ..., \delta_{1s}, ..., \delta_{g1}, \delta_{g2}, ..., \delta_{gs})'$.

Let the interaction between grass and border combinations (not the shrubs) be denoted by

$\phi = (\phi_{11}, \phi_{12} ..., \phi_{1p}, ..., \phi_{g1}, \phi_{g2}, ..., \phi_{gp})'$.

Thus $\phi_{im} = \delta_{ij} + \delta_{ik}$ where m stands for the border comprising of the shrubs S_j and S_k; $m = 1, ..., p$.

A model for estimation of γ, ψ and ϕ may be wriiten as

$$\bar{y} = \mu J + X_1 \gamma + X_2 \psi + X_3 \phi + \bar{\varepsilon}$$

where μ is general mean, J a vector of 1s and length of $\bar{y}$, and vector of mean errors with $\bar{\varepsilon} \sim \text{MVN}(0, \hat{\Sigma})$.

Conditions on the vectors of effects are: $\gamma' J = 0$, $\psi' J = 0$ and more than one conditions on the interaction vector: $(I_p \otimes J_g')\phi = 0_{p,1}$ and $(J_p' \otimes I_g)\phi = 0_{1,\text{g}}$.

The estimation can have one of the several approaches, particularly in case of orthogonal structure between grasses and diallel-borders.

Approach 1: One can estimate grasses and borders effects and interaction using ANOVA directives. The border effects overall the grasses or for individual grasses data can be modelled by fitting columns of X_2 (no intercept) to estimate ψ s and δ respectively.

Approach 2: Another could be based on matrices but still using the ANOVA estimates of border effects with variance-covariance matrix or ignoring the covariances. This may be completed in the following two stages:

Stage 1: Estimate γ gamma and ψ, we can fit the general model, ignoring ϕ deltas and fitting a reduced model for $\bar{y} \sim MVN(X\beta, \hat{\Sigma})$, where $X = [J : X_1 : X_2]$ of order $(p, 1+g+s)$ and $\beta = (\mu, \gamma', \psi')'$.

Using Rao (1973), $\hat{\beta} = (\hat{\mu}, \hat{\gamma}', \hat{\psi}')' = S^{-1}Q$ where

$S = X'\hat{\Sigma}^{-1}X$ and $Q = X'\hat{\Sigma}^{-1}\bar{y}$, assuming that the design keeps matrix S non-singular, otherwise replace S^{-1} by its Moore-Penrose psuedoinverse denoted by S^{+}.

Estimated variance-covariance matrix of $\hat{\beta}$ is $D(\hat{\beta}) = S^{-1}$.

Borders × grass interaction vector ϕ can be estimated as residual vector

$$\hat{\phi} = \bar{y} - X\hat{\beta} \text{ with } \mathrm{D}(\hat{\phi}) = \Sigma - XS^{-1}X' = \Sigma^{*}, \text{ say.}$$

Actually the variance-covariance matrix $D(\hat{\phi})$ may be available along with $\hat{\phi}$ while using ANOVA in may software, e.g., Genstat (VSN Inc. 2015).

Stage 2: Next step would be to partition $\hat{\phi}$ into δ 's estimates as follows. Obtain a matrix Z with its column number $i_j = j + (i-1)s$ obtained by element-wise multiplication of i th column of X_1 and j th column of X_2, i.e. Schur multiplication of all possible cross combinations between columns of X_1 and X_2. The order of Z is $p \times gs$. We can obtain gs parameters in δ delta by solving the equation

$$\hat{\phi} = Z\delta \text{, where } D(\hat{\phi}) = \Sigma^*$$

to obtain

$$\hat{\delta} = (Z'\Sigma^{*+}Z)^+ Z'\Sigma^{*+}\hat{\phi} \text{ and } D(\hat{\delta}) = (Z'\Sigma^{*+}Z)^+$$

where for a matrix A, A^+ denotes its Moore-Penrose psuedoinverse.

<u>Optimal design</u>: Optimality and efficiency of the design can be studied in terms of the respective covariance matrices for $\hat{\gamma}$ gamma, $\hat{\psi}$ s and $\hat{\delta}$'s.

There could be alternative options to estimate the effects using a software. Genstat codes are given on the set of data generated for illustration in the following section.

Shared borders

Design 5. Sharing of borders between the alleys would lead to a resource saving design. However, data analysis may be based on a relatively more complex model due to the feature that the same shrub may affect grasses on its opposite sides of alleys. Self-borders or diallel-boders can be used. Due to sharing of the same border between the alleys the randomization of the shrubs as borders would become quite restricted.

Schema 5. Shared diallel-borders (S1S3, S3S2, S2S4, S4S3, S3S1…), grasses (G1…G3) in sub-plots.

Left-border	S1	S1	S1
Alley	G1	G3	G2
Shared-border	S3	S3	S3
Alley	G2	G3	G1
Shared-border	S2	S2	S2
Alley	G1	G2	G3
Shared-border	S4	S4	S4
Alley	G3	G1	G2
Shared-border	S3	S3	S3
Alley	G2	G3	G1
Shared-border	S1	S1	S1
Alley	G3	G2	G1
Shared-border		.	
Alley		.	

In this case correlated responses may be assumed and covariance modelling would a worthy exercise to induct in the analysis.

Model:

$$y_{i,jk,l} = \mu + \beta_l + \psi_j + \psi_k + (\beta\psi)_{jk,l}[= \mathrm{E}rror(a)] \ + \gamma_i + \delta_{ij} + \delta_{ik} + \varepsilon_{i,jk,l}[= Error(b)]$$

Correlated model structures:

$\mathrm{Cov}((\beta\psi)_{jk,l},(\beta\psi)_{km,l})$ and $Cov(\varepsilon_{i,jk,l},\varepsilon_{i,km,l})$ may need to be simplified using a criterion such as Akaike Information Criterion (AIC) (Akaike, 1974). The selected covariance structure(s) can then be used for estimation of the effects and interaction.

An Illustration:

Dataset: A dataset was generated for experimental design situation, Design 4 is given in Table 1. The following set of values of effects taken for random generation of data.

General mean: $\mu = 5$
Block effects: β_l (l =1…3)= -1.0, -0.5, 0.0
Grasses effects: γ_i (i =1…3) = -2,-1, 3
Shrubs effects: ψ_j (j) = -1.,-.5, 1., 0.5, 0.0

Interactions δ_{ij} :

	Shrubs				
Grasses	S1	S2	S3	S4	S5
G1	0.2	-0.4	-0.2	0.0	0.4
G2	-0.3	0.2	0.4	0.1	-0.4
G3	0.1	0.2	-0.2	-0.1	0.0

The plot-wise values of the experimental design factors and the datasets are given in Table 1 and the associated Genstat codes are listed in Appendix A5.

For the analysis of data the approaches used were:

1. ANOVA and Regression

   These involved BLOCKSTRUCTURE, TREATMENTSTRUCTURE, ANOVA, MODEL, TERMS, FIT. The Genstat codes are in Appendix 6C and the resulting output in Appendix 6O for Approach 1.

2. Matrices, accounting for covariances

   The codes and outputs for Approach 2 are given Appendices 7C and 7O respectively.

Table 2 displays the effects of grasses, borders and their interactions, while Table 3 presents gesg (ψ_j s general effects of shrubs on the grasses) and δ_{ij} is the interaction (or gs-gseg, the grass-specific general effect of shrub S_j on the grass G_i). The simulated data had mean of 4.7 compared to μ=5. To see the behavior of these estimates, averages over 100 simulation runs gave a much closer values indicating low bias of the estimates (Table 4).

Remarks

The motivation for this manuscript arose from the discussions held with Dr. Mounir Louhaichi and Ms Sawsan Hassan, Range Ecology and Management Research Team, SIRPS, ICARDA. The designs discussed are recommended for conducting alley cropping trials. Once the real data become available, the above steps may be used for analysis. These designs and the approach of analysis can also be adapted for examining interactions or interference in intercropping experiments, which would need further extension to analyze two or more correlated responses on the component crops.

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Table 1. Experimental design and randomly generated data for illustration

Rep	Border	Grass	Yield
1	S1S2	1	0.614
1	S1S2	3	4.801
1	S1S2	2	1.925
1	S2S3	2	3.622
1	S2S3	1	1.417
1	S2S3	3	4.35
1	S4S1	3	5.82
1	S4S1	2	4.185
1	S4S1	1	4.047
1	S3S5	1	2.984
1	S3S5	2	4.022
1	S3S5	3	6.098
1	S5S4	3	5.846
1	S5S4	1	4.581
1	S5S4	2	4.408
2	S1S2	2	2.914
2	S1S2	1	2.278
2	S1S2	3	5.779
2	S5S4	1	3.999
2	S5S4	2	5.288
2	S5S4	3	6.432
2	S2S3	2	3.565
2	S2S3	3	5.656
2	S2S3	1	1.581
2	S3S5	1	4.672
2	S3S5	3	5.523
2	S3S5	2	5.169
2	S4S1	1	1.777
2	S4S1	2	3.446
2	S4S1	3	5.319
3	S4S1	1	3.94
3	S4S1	2	3.397
3	S4S1	3	7.101
3	S3S5	2	6.133
3	S3S5	3	8.36
3	S3S5	1	5.21
3	S1S2	3	7.002
3	S1S2	1	3.23
3	S1S2	2	4.652

3	S2S3	3	8.165
3	S2S3	1	4.414
3	S2S3	2	8.435
3	S5S4	3	9.083
3	S5S4	2	5.587
3	S5S4	1	5.214

Table 2. Estimates of grass and diallel- border effects and their interaction

Grass	1	2	3		
	-1.38	-0.26	1.64		
SE		± 0.17			
Border	S5S4	S4S1	S1S2	S2S3	S3S5
	0.89	-0.38	-1.02	-0.13	0.64
SE			±0.44		
	Grass	1	2	3	
Borders					
S5S4		0.38	-0.25	-0.13	
S4S1		0.30	-0.40	0.10	
S1S2		-0.27	-0.26	0.53	
S2S3		-0.73	0.89	-0.16	
S3S5		0.32	0.02	-0.34	
SE			±0.39		
Grand mean		4.71			

SE= Estimated standard error

Table 3. Estimates of shrub effects and interaction with grasses

	Shrub S j	Effects ψ_j
	S1	-0.759
	S2	-0.265
	S3	0.132
	S4	0.383
	S5	0.509
SE		±0.493

Grass i	Shrub Sj	Interaction δ_{ij}
1	S1	0.351
	S2	-0.617
	S3	-0.109
	S4	-0.051
	S5	0.427
2	S1	-0.643
	S2	0.381
	S3	0.51
	S4	0.245
	S5	-0.492
3	S1	0.293
	S2	0.236
	S3	-0.401
	S4	-0.193
	S5	0.065
SE		±0.486

SE= Estimated standard error

Table 4. Mean of 100 simulations of estimates of shrub effects and interaction with grasses

A. Shrub Effects

	Shrub S j	True value (ψ_j)	Average of 100 simulations
	S1	-1.0	-0.997
	S2	-0.5	-0.518
	S3	1.0	1.068
	S4	0.5	0.478
	S5	0.0	-0.031
SE			±0.325

B. Shrub x Grass interaction

Grass i	Shrub Sj	True value (δ_{ij})	Average of 100 simulations
1	S1	0.2	0.230
	S2	-0.4	-0.447
	S3	-0.2	-0.200
	S4	0	-0.018
	S5	0.4	0.435
2	S1	-0.3	-0.344
	S2	0.2	0.248
	S3	0.4	0.372
	S4	0.1	0.122
	S5	-0.4	-0.399
3	S1	0.1	0.114
	S2	0.2	0.199
	S3	-0.2	-0.172
	S4	-0.1	-0.104
	S5	0.0	-0.037
SE			±0.455

SE= Estimated standard error

Appendices

A1. Genstat Codes for generating randomized plan for Design 1 (Self-borders and grasses combinations in RCBD) and statistical analysis

Let NGrass, NShrub and NRep be the number of grasses, shrubs and replications respectively. The codes for generating such a design are:

```
Scal NRep, NGrass, NShrub,NGxNS, NPlots; 4, 3, 4,* , *
Calc NPlots=NRep*NGrass*NShrub
Calc NGxNS=NGrass*NShrub
Unit[NPlots]
Factor[Levels=NRep] Rep  : &[Levels=NGrass] Grass : &[Levels=NShrub]Shrub
Generate Rep, Grass, Shrub
Fact[levels=NGxNS] GrassShrub
Calc GrassShrub = Shrub+NShrub*(Grass-1)

Randomize[Block=Rep/GrassShrub; Seed=13057] Grass, Shrub
Prin Rep, Grass, Shrub
```

Let Yield be the vector of plot yields. The codes for statistical analysis of variance and estimation of means, effects and interaction are:

```
Block Rep/Shrub.Grass
Treat Shrub*Grass
Anova[print=a,%cv,eff,mean; pse=m; fpro=y]Yield
```

A2. Genstat Codes for generating randomized plan for Design 2 (Self-borders in main-plots and grasses in subplots in RCBD) and statistical analysis

Let NGrass, NShrub and NRep be the number of grasses, shrubs and replications respectively. The codes for generating such a design are:

```
Scal NRep, NGrass, NShrub, NPlots; 4, 3, 4, *
Calc NPlots=NRep*NGrass*NShrub
Unit[NPlots]
Factor[Levels=NRep] Rep  : &[Levels=NGrass] Grass : &[Levels=NShrub]Shrub
Generate Rep,  Shrub, Grass
Randomize[Block=Rep/Shrub/Grass; Seed=17034] Shrub, Grass
Prin Rep,  Shrub, Grass
```

Let Yield be the vector of plot yields. The codes for statistical analysis of variance and estimation of means, effects and interaction are:

```
Block Rep/Shrub/Grass
Treat Shrub*Grass
Anova[print=a,%cv,eff,mean; pse=m; fpro=y]Yield
```

A3. For Design 3, use a partial diallel crosses to form the two borders and obtain the randomized design using codes in A1. For the analysis use the ANOVA codes of A1 and use rest of the codes given in A4 for Design 4.

Design 3 codes for generation

```
"Generate Design 3:"
Scal NRep, NGrass, NBorder, NGxNB, NPlots; 3, 3, 5,* , *
Calc NPlots=NRep*NGrass*NBorder
Calc NGxNB=NGrass*NBorder

Unit[NPlots]
Factor[Levels=NRep] Rep  : &[Levels=NGrass] Grass : &[Levels=NBorder;
labels=!t('S5S4', 'S4S1', 'S1S2','S2S3', 'S3S5')]Border
Generate Rep, Grass, Border
Fact[levels=NGxNB] GrassBorder
Calc GrassBorder = Border+NBorder*(Grass-1)

Randomize[Block=Rep/GrassBorder; Seed=130571] Grass, Border
Prin Rep, Grass, Border
```

Design 4 Codes for generation

```
"Generate Design 4.............. Diallel-borders in main-plots of a split
plot design"
Scal NRep, NGrass, NBorder, NPlots; 3, 3, 5,*
Calc NPlots=NRep*NGrass*NBorder

Unit[NPlots]
Factor[Levels=NRep] Rep  : &[Levels=NGrass] Grass : &[Levels=NBorder;
labels=!t('S5S4', 'S4S1', 'S1S2','S2S3', 'S3S5')]Border
Generate Rep,  Border, Grass

Randomize[Block=Rep/Border/Grass; Seed=130572] Border, Grass
Prin Rep,  Border, Grass
```

A5 Genstat Codes for generating random data for a given design

```
"For the experimental design in Table 1, this section is gives the Genstat
codes generate the random data using the following set of parameters. The
data generated is also given in Table 1"

"-------------------------------------------"
Scal NGrass, NShr, NBorder, NRep, NRepNBorder, NPlots; 3, 5, 5, 3, 15, 45

"Generate Design"
Calc NPlots=NRep*NGrass*NBorder

Factor[Levels=NRep; Nvalues=NPlots] Rep  : &[Levels=NGrass; Nvalues=NPlots]
Grass : &[Levels=NBorder; labels=!t('S5S4', 'S4S1', 'S1S2','S2S3',
```

```
'S3S5')]Border
Generate Rep,  Border, Grass
Randomize[Block=Rep/Border/Grass; Seed=170534] Border, Grass
Prin Rep,  Border, Grass


"Simulate 1 run "
Scal mu;5
Vari[Values= -1.0, -0.5, 1.5] BlkEff
Vari[values=-1.5,0, 1.5 ]GrassEff
Vari[Values=-1.,-.5, 1., 0.5, 0.]ShrEff
Matrix[Rows=3; Colu=5]ShXGrInt ; Values =!(0.2,-0.4,-0.2,0,0.4,  -
0.3,0.2,0.4,0.1,-0.4,  0.1,0.2,-0.2,-0.1,0.)

Scal %CVBorder, %CVGrass ; 10, 15
"---------------------------------------------"

Vari[Nvalues=NPlots]Yield, BEff,ShLEff, ShREff,GEff,SxGInt
Prin ShXGrInt


"for Borders: S5S4, S4S1, S1S2,S2S3, S3S5"

Vari[Values=5,4,1,2,3]LeftB
Vari[Values=4,1,2,3,5]RightB
Scal left, right

Calc  Yield = mu

"Add blocks effects"
For L=1...NRep
Calc Yield=Yield+ BlkEff$[L]*(Rep==L)
Endf

"Add shrubs effects"

For j=1...NBorder  "for Borders: S5S4, S4S1, S1S2,S2S3, S3S5"
Calc left = LeftB$[j]
Calc right=RightB$[j]

Calc Yield=Yield + ( ShrEff$[left] + ShrEff$[right]  )*(Border==j)
Endf

"Add grasses effects"

For i=1...NGrass
Calc Yield = Yield  + GrassEff$[i]*(Grass==i)
Endf


"Add Shrub X Grass interactions"

For j=1...NBorder  "for Borders: 'S2S4','S4S1','S1S3','S3S2'"
Calc left = LeftB$[j]
Calc right=RightB$[j]
```

```
For i=1...NGrass
delete[rede=y]inter : scal inter
Calc inter=ShXGrInt$[i;left] +  ShXGrInt$[i;right]
Calc Yield = Yield  +  inter*(Grass==i.and.Border==j)

Endf
Endf


"Generate experimental errors"

"Add main plot errors"
Vari[Nvalue=NRepNBorder]BorderErr

Calc BorderErr= NED(Urand(390741; NRepNBorder))*%CVBorder*mu/100

Scal count; 0
For L=1...NRep "for Borders: 'S2S4','S4S1','S1S3','S3S2'"
For j=1...NBorder
Calc count=count+1

Rest Yield; Rep==L.and.Border==j
Calc Yield= Yield+ (BorderErr$[count])

Rest Yield
Endf
Endf

"Add sub-plot errors"
Vari[Nvalues=NPlots]GrassErr
Calc GrassErr= NED(Urand(17058; NPlots))*%CVGrass*mu/100


Calc Yield =Yield + GrassErr


Print Rep, Border, Grass, Yield ; field=6
```

A6C. For Design 4 type designs (see Table 1), use a partial diallel crosses to form the two borders and obtain the randomized design using codes in A4. Use the following codes for analysis of such designs. These based on Genstat's ANOVA and linear model fitting directives.

```
"............................. Analysis part............."

"Genstat codes for estimating the effects and interactions using ANOVA and
linear model fitting directives
............................. Analysis part............."

"Stage 1: Estimate borders [shrub combinations] and grasses effect and their
interactions"
```

```
Dele[rede=y] Borders0, LeftBorder0, RightBorder0,Grass0,Sh[1...NShr], yMeans,
Weight, tbEff, yEff,tbMn, tbSeMn

        Block Rep/Border/Grass
        Treat Border*Grass
        Anova[print=a,%cv, eff, mean;pse=m;fpro=y]Yield


"Get the Grasses effects from above or below: Gammas"
        Akeep  Grass; means=tbMn ; SEmeans=tbSe; Effect=tbEff

Prin tbMn, tbEff, tbSe


 "Stage 2:...............To get direct effect of Shrubs (saai s) on grasses"

        Akeep  Border; means=tbMn ; SEmeans=tbSe; Effect=tbEff



" Get error mean squre, weight of means "

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff; Class=!P(Borders0)

Vari  [nval=NShr]Sh[1...NShr], Weight
Calc Weight=1/ySeMn**2

"Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3,
S3S5"

Vari[Values=5,4,1,2,3]LeftB
Vari[Values=4,1,2,3,5]RightB

For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftB.eq.i.or.RightB.eq.i)
Endf

"Print Borders0, LeftB, RightB,Sh[1...NShr], yMeans, ySeMn,yEff, Weight;
field=6"

" Regression Model/Fit to estimate Shrub direct effects: saai s "

Print '    ***** Saai s and their standard errors for shrubs *****'

Model[Weight=Weight; disp=1] yEff
Terms [Full=Y] Sh[1...NShr]
Fit[Prin=m,s,e; cons=o; fpro=y; tpro=y] Sh[1...NShr]


"Estimate Shrub X Grass interaction delta s"
Dele[rede=y] GrassBorders0, GrassLeftBorder0,
GrassRightBorder0,Grass0,Sh[1...NShr], yMeans, Weight, tbMn, tbSe,tbEff, yEff
        Akeep  Grass.Border; means=tbMn ; SEmeans=tbSe; Effects=tbEff
```

```
" Get error mean squre, weight of means "

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff;
Class=!P(Grass0,Borders0)


Scal NGrassXNShrub : Calc NGrassXNShrub=NShr*NGrass
Scal NGrassXNBorder : Calc NGrassXNBorder=NBorder*NGrass

Vari [nval=NGrassXNBorder]Sh[1...NShr], Grs[1...NGrass], Weight
Calc Weight=1/ySeMn**2

" Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3,
S3S5 for each grass

Borders0  Boders and grasses:
  G1      G1       G1  G1    G1      / G2      G2       G2      G2   G2   / G3     G3
G3       G3       G3
 S5S4, S4S1, S1S2,S2S3, S3S5     S5S4, S4S1, S1S2,S2S3, S3S5     S5S4, S4S1,
S1S2,S2S3, S3S5

"

Vari[Values=(5,4,1,2,3)3]LeftBG
Vari[Values=(4,1,2,3,5)3]RightBG


For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftBG.eq.i.or.RightBG.eq.i)
Endf

For i=1...NGrass; dd=Grs[1...NGrass]
   Calc dd=(Grass0==i)
Endf


Print Grass0, Borders0, LeftBG, RightBG,Sh[1...NShr], Grs[1...NGrass],yMeans,
ySeMn,yEff, Weight ; field=6

" Shrubs x Grass interaction: deltas and SE for each grass"
For i=1...NGrass
Print '   ***** Deltas and their standard errors for Grass = ', i, '  *****'
Rest Sh[1...NShr], yEff ; Grass0==i
Model[Weight=Weight; disp=1] yEff
Terms [Full=Y] Sh[1...NShr]
Fit[Prin=m,s,e; cons=o; fpro=y; tpro=y] Sh[1...NShr]
Rest Sh[1...NShr], yEff
Endf
 STOP
```

A6O. Output from codes in A5C (using ANOVA and linear model fitting directives)

```
"Genstat codes for estimating the effects and interactions using ANOVA and linear model fitting directives
 ............................. Analysis part............."

"Stage 1: Estimate borders [shrub combinations] and grasses effect and their interactions"

Dele[rede=y] Borders0, LeftBorder0, RightBorder0,Grass0,Sh[1...NShr], yMeans, Weight, tbEff, yEff,tbMn, tbSeMn

      Block Rep/Border/Grass
      Treat Border*Grass
      Anova[print=a,%cv, eff, mean;pse=m;fpro=y]Yield
```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	37.7542	18.8771	10.81	
Rep.Border stratum					
Border	4	21.7129	5.4282	3.11	0.081
Residual	8	13.9745	1.7468	3.85	
Rep.Border.Grass stratum					
Grass	2	70.1841	35.0920	77.36	<.001
Border.Grass	8	7.3766	0.9221	2.03	0.095
Residual	20	9.0728	0.4536		
Total	44	160.0750			

Tables of effects

Variate: Yield

Rep.Border stratum

Border effects, e.s.e. 0.441, rep. 9

Border	S5S4	S4S1	S1S2	S2S3	S3S5
	0.89	-0.38	-1.02	-0.13	0.64

Rep.Border.Grass stratum

Grass effects, e.s.e. 0.174, rep. 15

Grass	1	2	3
	-1.38	-0.26	1.64

Border.Grass effects, e.s.e. 0.389, rep. 3

Border	Grass	1	2	3
S5S4		0.38	-0.25	-0.13
S4S1		0.30	-0.40	0.10
S1S2		-0.27	-0.26	0.53
S2S3		-0.73	0.89	-0.16
S3S5		0.32	0.02	-0.34

Tables of means

Variate: Yield

Grand mean 4.71

Border	S5S4	S4S1	S1S2	S2S3	S3S5
	5.60	4.34	3.69	4.58	5.35

Grass	1	2	3
	3.33	4.45	6.36

Border	Grass	1	2	3
S5S4		4.60	5.09	7.12
S4S1		3.25	3.68	6.08
S1S2		2.04	3.16	5.86
S2S3		2.47	5.21	6.06
S3S5		4.29	5.11	6.66

Standard errors of means

Table	Border	Grass	Border Grass
rep.	9	15	3
e.s.e.	0.441	0.174	0.543
d.f.	8	20	16.67
Except when comparing means with the same level(s) of Border			0.389
d.f.			20

Stratum standard errors and coefficients of variation

Variate: Yield

Stratum	d.f.	s.e.	cv%
Rep	2	1.122	23.8
Rep.Border	8	0.763	16.2
Rep.Border.Grass	20	0.674	14.3

```


"Get the Grasses effects from above or below: Gammas"
```

```
      Akeep  Grass; means=tbMn ; SEmeans=tbSe; Effect=tbEff

Prin tbMn, tbEff, tbSe
```

	tbMn	tbEff	tbSe
Grass			
1	3.331	-1.382	0.1739
2	4.450	-0.262	0.1739
3	6.356	1.644	0.1739

```


 "Stage 2:...............To get direct effect of Shrubs (saai s) on grasses"

Akeep  Border; means=tbMn ; SEmeans=tbSe; Effect=tbEff



" Get error mean squre, weight of means "

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff; Class=!P(Borders0)

Vari [nval=NShr]Sh[1...NShr], Weight
Calc Weight=1/ySeMn**2

"Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3, S3S5"

Vari[Values=5,4,1,2,3]LeftB
Vari[Values=4,1,2,3,5]RightB

For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftB.eq.i.or.RightB.eq.i)
Endf

"Print Borders0, LeftB, RightB,Sh[1...NShr], yMeans, ySeMn,yEff, Weight; field=6"

" Regression Model/Fit to estimate Shrub direct effects: saai s "

Print '   ***** Saai s and their standard errors for shrubs *****'
```

***** Saai s and their standard errors for shrubs *****

```

Model[Weight=Weight; disp=1] yEff
Terms [Full=Y] Sh[1...NShr]
Fit[Prin=m,s,e; cons=o; fpro=y; tpro=y] Sh[1...NShr]
```

Regression analysis

Response variate: yEff

Weight variate: Weight
Fitted terms: Sh[1], Sh[2], Sh[3], Sh[4], Sh[5]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	chi pr
Regression	5	12.43	2.486	2.49	0.029
Residual	0	0.00	*		
Total	5	12.43	2.486		

Standard error of observations is fixed at 1.00.

Message: deviance ratios are based on dispersion parameter with value 1.

Message: the following units have high leverage.

Unit	Response	Leverage
1	0.89	1.00
2	-0.38	1.00
3	-1.02	1.00
4	-0.13	1.00
5	0.64	1.00

Estimates of parameters

Parameter	estimate	s.e.	t(*)	t pr.
Sh[1]	-0.759	0.493	-1.54	0.124
Sh[2]	-0.265	0.493	-0.54	0.590
Sh[3]	0.132	0.493	0.27	0.789
Sh[4]	0.383	0.493	0.78	0.436
Sh[5]	0.509	0.493	1.03	0.302

Message: s.e.s are based on dispersion parameter with value 1.

```
"Estimate Shrub X Grass interaction delta s"
Dele[rede=y] GrassBorders0, GrassLeftBorder0,
GrassRightBorder0,Grass0,Sh[1...NShr], yMeans, Weight, tbMn, tbSe,tbEff, yEff
      Akeep  Grass.Border; means=tbMn ; SEmeans=tbSe; Effects=tbEff


" Get error mean squre, weight of means "

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff;
Class=!P(Grass0,Borders0)


Scal NGrassXNShrub : Calc NGrassXNShrub=NShr*NGrass
Scal NGrassXNBorder : Calc NGrassXNBorder=NBorder*NGrass

Vari [nval=NGrassXNBorder]Sh[1...NShr], Grs[1...NGrass], Weight
```

```
Calc Weight=1/ySeMn**2

" Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3, S3S5 for each grass

Borders0  Boders and grasses:
  G1   G1    G1 G1       G1   / G2   G2    G2   G2  G2      / G3  G3 G3     G3    G3
 S5S4, S4S1, S1S2,S2S3, S3S5   S5S4, S4S1, S1S2,S2S3, S3S5   S5S4, S4S1, S1S2,S2S3, S3S5

"

Vari[Values=(5,4,1,2,3)3]LeftBG
Vari[Values=(4,1,2,3,5)3]RightBG


For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftBG.eq.i.or.RightBG.eq.i)
Endf

For i=1...NGrass; dd=Grs[1...NGrass]
   Calc dd=(Grass0==i)
Endf


Print Grass0, Borders0, LeftBG, RightBG,Sh[1...NShr], Grs[1...NGrass],yMeans, ySeMn,yEff, Weight ; field=6
```

Grass0	Borders0	LeftBG	RightBG	Sh[1]	Sh[2]	Sh[3]	Sh[4]	Sh[5]	Grs[1]	Grs[2]	Grs[3]
1	S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	0.0000
1	S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.0000
1	S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
1	S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000
1	S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	1.0000	0.0000	0.0000
2	S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000	1.0000	0.0000
2	S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000	0.0000
2	S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
2	S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000
2	S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
3	S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000	0.0000	1.0000
3	S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	1.0000
3	S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
3	S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	1.0000
3	S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.0000	1.0000

yMeans	ySeMn	yEff	Weight
4.598	0.5430	0.3755	3.391
3.255	0.5430	0.2992	3.391
2.041	0.5430	-0.2662	3.391
2.471	0.5430	-0.7261	3.391
4.289	0.5430	0.3177	3.391
5.094	0.5430	-0.2477	3.391
3.676	0.5430	-0.3987	3.391
3.164	0.5430	-0.2625	3.391

5.207	0.5430	0.8911	3.391
5.108	0.5430	0.0179	3.391
7.120	0.5430	-0.1278	3.391
6.080	0.5430	0.0995	3.391
5.861	0.5430	0.5287	3.391
6.057	0.5430	-0.1650	3.391
6.661	0.5430	-0.3355	3.391

```

" Shrubs x Grass interaction: deltas and SE for each grass"
For i=1...NGrass
Print '    ***** Deltas and their standard errors for Grass = ', i, '
*****'
Rest Sh[1...NShr], yEff ; Grass0==i
Model[Weight=Weight; disp=1] yEff
Terms [Full=Y] Sh[1...NShr]
Fit[Prin=m,s,e; cons=o; fpro=y; tpro=y] Sh[1...NShr]
Rest Sh[1...NShr], yEff
Endf
```

***** Deltas and their standard errors for Grass = 1.000 *****

Regression analysis

Response variate: yEff
Weight variate: Weight
Fitted terms: Sh[1], Sh[2], Sh[3], Sh[4], Sh[5]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	chi pr
Regression	5	3.152	0.6304	0.63	0.677
Residual	0	0.000	*		
Total	5	3.152	0.6304		

Standard error of observations is fixed at 1.00.

Message: deviance ratios are based on dispersion parameter with value 1.

Message: the following units have high leverage.

Unit	Response	Leverage
1	0.38	1.00
2	0.30	1.00
3	-0.27	1.00
4	-0.73	1.00
5	0.32	1.00

Estimates of parameters

Parameter	estimate	s.e.	t(*)	t pr.

Sh[1]	0.351	0.607	0.58	0.564
Sh[2]	-0.617	0.607	-1.02	0.310
Sh[3]	-0.109	0.607	-0.18	0.857
Sh[4]	-0.051	0.607	-0.08	0.932
Sh[5]	0.427	0.607	0.70	0.482

Message: s.e.s are based on dispersion parameter with value 1.

***** Deltas and their standard errors for Grass = 2.000 *****

Regression analysis

Response variate: yEff
Weight variate: Weight
Fitted terms: Sh[1], Sh[2], Sh[3], Sh[4], Sh[5]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	chi pr
Regression	5	3.675	0.7349	0.73	0.597
Residual	0	0.000	*		
Total	5	3.675	0.7349		

Standard error of observations is fixed at 1.00.

Message: deviance ratios are based on dispersion parameter with value 1.

Message: the following units have high leverage.

Unit	Response	Leverage
6	-0.25	1.00
7	-0.40	1.00
8	-0.26	1.00
9	0.89	1.00
10	0.02	1.00

Estimates of parameters

Parameter	estimate	s.e.	t(*)	t pr.
Sh[1]	-0.643	0.607	-1.06	0.289
Sh[2]	0.381	0.607	0.63	0.530
Sh[3]	0.510	0.607	0.84	0.401
Sh[4]	0.245	0.607	0.40	0.687
Sh[5]	-0.492	0.607	-0.81	0.417

Message: s.e.s are based on dispersion parameter with value 1.

***** Deltas and their standard errors for Grass = 3.000 *****

Regression analysis

Response variate: yEff
Weight variate: Weight
Fitted terms: Sh[1], Sh[2], Sh[3], Sh[4], Sh[5]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	chi pr
Regression	5	1.511	0.3022	0.30	0.912
Residual	0	0.000	*		
Total	5	1.511	0.3022		

Standard error of observations is fixed at 1.00.

Message: deviance ratios are based on dispersion parameter with value 1.

Message: the following units have high leverage.

Unit	Response	Leverage
11	-0.13	1.00
12	0.10	1.00
13	0.53	1.00
14	-0.16	1.00
15	-0.34	1.00

Estimates of parameters

Parameter	estimate	s.e.	t(*)	t pr.
Sh[1]	0.293	0.607	0.48	0.630
Sh[2]	0.236	0.607	0.39	0.697
Sh[3]	-0.401	0.607	-0.66	0.509
Sh[4]	-0.193	0.607	-0.32	0.750
Sh[5]	0.065	0.607	0.11	0.914

Message: s.e.s are based on dispersion parameter with value 1.

A7C. Genstat codes for analysis of designs of type Design 4. These are based on Genstat's ANOVA and matrices directives.

```
"Genstat codes for estimating the effects and interactions using ANOVA and
matrices directives”
“.............................. Analysis part............."

"Stage 1: Estimate borders [shrub combinations] and grasses effect and their
interactions"
```

```
Dele[rede=y] Borders0, LeftBorder0, RightBorder0,Grass0,Sh[1...NShr], yMeans,
tbEff, yEff,tbMn, tbSeMn

        Block Rep/Border/Grass
        Treat Border*Grass
        Anova[print=a,%cv, eff, mean;pse=m;fpro=y]Yield


"Get the Grasses effects from above or below: Gammas"
        Akeep  Grass; means=tbMn ; SEmeans=tbSe; Effect=tbEff

Prin tbMn, tbEff, tbSe


 "Stage 2:...............To get direct effect of Shrubs (saai s) on grasses"

        Akeep  Border; means=tbMn ; SEmeans=tbSe; Effect=tbEff

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff; Class=!P(Borders0)


"Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3,
S3S5"

Vari[Values=5,4,1,2,3]LeftB
Vari[Values=4,1,2,3,5]RightB

For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftB.eq.i.or.RightB.eq.i)
Endf

Print Borders0, LeftB, RightB,Sh[1...NShr], yMeans, ySeMn,yEff; field=6


"Do matrix calculation and GLM estimation of Saai s"
Matr[Rows=NBorder; Colu=NShr; Modi=y] Xmat
Calc Xmat$[*;1...NShr] = Sh[1...NShr]
"Prin Xmat"

Matr[Rows=NShr; Colu=1] Saai, SeSaai "beta=(X'X)-X'Y; (X'X)-Sig2 "
Matr[Rows=NShr; Colu=NShr]CInvShrub
Calc CInvShrub=GInv( Prod(Tran(Xmat);Xmat))
"Prin CInvShrub"

Calc Saai=Prod(CInvShrub; Prod(Tran(Xmat);yEff))
Calc SeSaai=Prod(sqrt(diag(CInvShrub));ySeMn)
Prin '  ***** Estimates of saai s and standard errors *****'
Prin Saai, SeSaai


"Estimate Shrub X Grass interaction delta s"
Dele[rede=y] GrassBorders0, GrassLeftBorder0,
GrassRightBorder0,Grass0,Sh[1...NShr], yMeans, tbMn, tbSe, yEff
        Akeep  Grass.Border; means=tbMn ; SEmeans=tbSe; Effects=tbEff
"Prin tbMn, tbEff, tbSe"
```

```
Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff;
Class=!P(Grass0,Borders0)

Scal NGrassXNShrub : Calc NGrassXNShrub=NShr*NGrass
Scal NGrassXNBorder : Calc NGrassXNBorder=NBorder*NGrass


" Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3,
S3S5 for each grass

Borders0  Boders and grasses:
  G1     G1      G1 G1   G1     / G2     G2      G2     G2  G2  / G3    G3
G3       G3      G3
 S5S4, S4S1, S1S2,S2S3, S3S5     S5S4, S4S1, S1S2,S2S3, S3S5     S5S4, S4S1,
S1S2,S2S3, S3S5

"

Vari[Values=(5,4,1,2,3)3]LeftBG
Vari[Values=(4,1,2,3,5)3]RightBG


For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftBG.eq.i.or.RightBG.eq.i)
Endf

For i=1...NGrass; dd=Grs[1...NGrass]
   Calc dd=(Grass0==i)
Endf


Print Grass0, Borders0, LeftBG, RightBG,Sh[1...NShr], Grs[1...NGrass],yMeans,
ySeMn,yEff ; field=6

Calc yMn_Mu =yMeans - mean(yMeans)

Scal NParam : Calc NParam=NGrass+NShr  "Eastimates of gammas:grasses followed
by saai:shrubs"
Matr[Rows=NGrassXNBorder; Colu=NParam; Modi=y] Xmat
Calc Xmat$[*;1...NParam] =Grs[1...NGrass], Sh[1...NShr]
"Prin Xmat"

Matr[Rows=NParam; Colu=1] GammaSaai, SeGammaSaai, Q "incl. mu, beta=(X'X)-
X'Y; (X'X)-Sig2 ; assume constant variance or weight;;;; QPRODUCT(x;y)"
Matr[Rows=NParam; Colu=NParam]Smat, CInvGammaSaai
Diag[Rows=NGrassXNBorder]SIGMA, InvSIGMA  "Variance covariance of yMean"
Calc SIGMA=ySeMn**2
Calc InvSIGMA=Inv(SIGMA)
Calc Smat= QPROD(Tran(Xmat); InvSIGMA)
Calc CInvGammaSaai=GInv(Smat)
Prin CInvGammaSaai
Calc Q= Prod(Prod(Tran(Xmat); InvSIGMA);yMn_Mu)            "yEff, yMn_Mu"
```

```
"Print SIGMA: & InvSIGMA: & Smat : & CInvGammaSaai :& Q "

Vari[Values=#NParam(1)] Jvec

Calc GammaSaai=Prod(CInvGammaSaai;Q)
Calc SeGammaSaai=Prod(sqrt(diag(CInvGammaSaai));Jvec)

Prin GammaSaai, SeGammaSaai

"Get estimates of delta s"
Matr[Rows=NGrassXNBorder; Colu=1] GrsBorderEff  " two-way table with Graas &
border effects= delta(ij) + delts(ik) combined"
Vari[Values=#NGrassXNBorder(1)] Jvec2

Calc GrsBorderEff =yMn_Mu - Prod(Xmat;GammaSaai)               "yEff, yMn_Mu"
Calc XSinvXT=Prod( Prod(Xmat;CInvGammaSaai); Tran(Xmat))
Calc varGrsBorderEff  = SIGMA - XSinvXT
Calc SeGrsBorderEff =Prod(sqrt(diag(varGrsBorderEff ));Jvec2)

Prin  GrsBorderEff , SeGrsBorderEff

"Now invert the matrix... to estimate REAL deltas"
"Create new Z variables: Grass1 (Sh1...5)+Gras2 (Shr1...5).."
Scal NParam1 : Calc NParam1=NGrass*NShr  "Eastimates of gammas:grasses
followed by saai:shrubs"
Matr[Rows=NGrassXNBorder; Colu=NParam1; Modi=y] Zmat
Scal count ; 0
For i=1...NGrass
For j=1...NShr
Calc count=count+1
Calc Zmat$[*;count] = Grs[i]*Sh[j]
Endf
Endf
"Prin Zmat"
"Prin NParam1"

Matr[Rows=NParam1; Colu=1;Modi=y] Delta, SeDelta
Matr[Rows=NGrassXNBorder; Colu=NGrassXNBorder]InvSigmaStar
Vari[Values=#NParam1(1)] Jvec3, QDelta

Calc InvSigmaStar=Ginv(varGrsBorderEff)
Calc QDelta= Prod(Prod(Tran(Zmat); InvSigmaStar);GrsBorderEff)

Calc ZTSigStarInvZ=Prod( Prod(Tran(Zmat);InvSigmaStar); Zmat)
Calc varDelta=Ginv(ZTSigStarInvZ)

Calc Delta=Prod(varDelta; QDelta)
Calc SeDelta =Prod(sqrt(diag(varDelta));Jvec3)

Prin Delta, SeDelta

STOP
```

A7O. Output from A6C

```
"Genstat codes for estimating the effects and interactions using ANOVA and matrices directives”
‶ ............................. Analysis part............."

"Stage 1: Estimate borders [shrub combinations] and grasses effect and their interactions"

Dele[rede=y] Borders0, LeftBorder0, RightBorder0,Grass0,Sh[1...NShr], yMeans, tbEff, yEff,tbMn, tbSeMn

      Block Rep/Border/Grass
      Treat Border*Grass
      Anova[print=a,%cv, eff, mean;pse=m;fpro=y]Yield
```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	37.7542	18.8771	10.81	
Rep.Border stratum					
Border	4	21.7129	5.4282	3.11	0.081
Residual	8	13.9745	1.7468	3.85	
Rep.Border.Grass stratum					
Grass	2	70.1841	35.0920	77.36	<.001
Border.Grass	8	7.3766	0.9221	2.03	0.095
Residual	20	9.0728	0.4536		
Total	44	160.0750			

Tables of effects

Variate: Yield

Rep.Border stratum

Border effects, e.s.e. 0.441, rep. 9

Border	S5S4	S4S1	S1S2	S2S3	S3S5
	0.89	-0.38	-1.02	-0.13	0.64

Rep.Border.Grass stratum

Grass effects, e.s.e. 0.174, rep. 15

Grass	1	2	3
	-1.38	-0.26	1.64

Border.Grass effects, e.s.e. 0.389, rep. 3

Border	Grass	1	2	3
S5S4		0.38	-0.25	-0.13
S4S1		0.30	-0.40	0.10
S1S2		-0.27	-0.26	0.53
S2S3		-0.73	0.89	-0.16
S3S5		0.32	0.02	-0.34

Tables of means

Variate: Yield

Grand mean 4.71

Border	S5S4	S4S1	S1S2	S2S3	S3S5
	5.60	4.34	3.69	4.58	5.35

Grass	1	2	3
	3.33	4.45	6.36

Border	Grass	1	2	3
S5S4		4.60	5.09	7.12
S4S1		3.25	3.68	6.08
S1S2		2.04	3.16	5.86
S2S3		2.47	5.21	6.06
S3S5		4.29	5.11	6.66

Standard errors of means

Table	Border	Grass	Border Grass
rep.	9	15	3
e.s.e.	0.441	0.174	0.543
d.f.	8	20	16.67
Except when comparing means with the same level(s) of			
Border			0.389
d.f.			20

Stratum standard errors and coefficients of variation

Variate: Yield

Stratum	d.f.	s.e.	cv%
Rep	2	1.122	23.8
Rep.Border	8	0.763	16.2
Rep.Border.Grass	20	0.674	14.3

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```
"Get the Grasses effects from above or below: Gammas"
      Akeep  Grass; means=tbMn ; SEmeans=tbSe; Effect=tbEff

Prin tbMn, tbEff, tbSe
```

Grass	tbMn	tbEff	tbSe
1	3.331	-1.382	0.1739
2	4.450	-0.262	0.1739
3	6.356	1.644	0.1739

```


 "Stage 2:...............To get direct effect of Shrubs (saai s) on grasses"

Akeep  Border; means=tbMn ; SEmeans=tbSe; Effect=tbEff

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff; Class=!P(Borders0)


"Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3, S3S5"

Vari[Values=5,4,1,2,3]LeftB
Vari[Values=4,1,2,3,5]RightB

For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftB.eq.i.or.RightB.eq.i)
Endf

Print Borders0, LeftB, RightB,Sh[1...NShr], yMeans, ySeMn,yEff; field=6
```

Borders0	LeftB	RightB	Sh[1]	Sh[2]	Sh[3]	Sh[4]	Sh[5]	yMeans	ySeMn	yEff
S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	5.604	0.4406	0.8922
S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	4.337	0.4406	-0.3752
S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	3.688	0.4406	-1.0237
S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	4.578	0.4406	-0.1336
S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	5.352	0.4406	0.6403

```


"Do matrix calculation and GLM estimation of Saai s"
Matr[Rows=NBorder; Colu=NShr; Modi=y] Xmat
Calc Xmat$[*;1...NShr] = Sh[1...NShr]
"Prin Xmat"

Matr[Rows=NShr; Colu=1] Saai, SeSaai "beta=(X'X)-X'Y; (X'X)-Sig2 "
Matr[Rows=NShr; Colu=NShr]CInvShrub
Calc CInvShrub=GInv( Prod(Tran(Xmat);Xmat))
"Prin CInvShrub"

```

```
Calc Saai=Prod(CInvShrub; Prod(Tran(Xmat);yEff))
Calc SeSaai=Prod(sqrt(diag(CInvShrub));ySeMn)
Prin '  ***** Estimates of saai s and standard errors *****'
```

***** Estimates of saai s and standard errors *****

```
Prin Saai, SeSaai
```

	Saai	SeSaai
	1	1
1	-0.7585	0.4926
2	-0.2652	0.4926
3	0.1315	0.4926
4	0.3833	0.4926
5	0.5088	0.4926

```
" Estimate Shrub X Grass interaction delta s"
Dele[rede=y] GrassBorders0, GrassLeftBorder0, GrassRightBorder0,Grass0,Sh[1...NShr], yMeans, tbMn, tbSe, yEff
Akeep  Grass.Border; means=tbMn ; SEmeans=tbSe; Effects=tbEff
"Prin tbMn, tbEff, tbSe"

Vtable Table=tbMn, tbSe, tbEff; Vari=yMeans, ySeMn, yEff; Class=!P(Grass0,Borders0)

Scal NGrassXNShrub : Calc NGrassXNShrub=NShr*NGrass
Scal NGrassXNBorder : Calc NGrassXNBorder=NBorder*NGrass

" Decode Borders into left and right border shrubs: S5S4, S4S1, S1S2,S2S3, S3S5 for each grass
Borders0  Boders and grasses:
  G1 G1      G1 G1          G1       / G2    G2     G2    G2   G2       / G3   G3  G3          G3          G3
 S5S4, S4S1, S1S2,S2S3, S3S5 S5S4, S4S1, S1S2,S2S3, S3S5     S5S4, S4S1, S1S2,S2S3, S3S5

"

Vari[Values=(5,4,1,2,3)3]LeftBG
Vari[Values=(4,1,2,3,5)3]RightBG

For i=1...NShr;dd=Sh[1...NShr]
   Calc dd=(LeftBG.eq.i.or.RightBG.eq.i)
Endf

For i=1...NGrass; dd=Grs[1...NGrass]
   Calc dd=(Grass0==i)
```

```
Endf


Print Grass0, Borders0, LeftBG, RightBG,Sh[1...NShr],
Grs[1...NGrass],yMeans, ySeMn,yEff ; field=6
```

Grass0	Borders0	LeftBG	RightBG	Sh[1]	Sh[2]	Sh[3]	Sh[4]	Sh[5]	Grs[1]	Grs[2]	Grs[3]
1	S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	0.0000
1	S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.0000
1	S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
1	S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000
1	S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	1.0000	0.0000	0.0000
2	S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000	1.0000	0.0000
2	S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000	0.0000
2	S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
2	S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	0.0000
2	S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
3	S5S4	5.000	4.000	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000	0.0000	1.0000
3	S4S1	4.000	1.000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	1.0000
3	S1S2	1.000	2.000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
3	S2S3	2.000	3.000	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	1.0000
3	S3S5	3.000	5.000	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.0000	1.0000

yMeans	ySeMn	yEff
4.598	0.5430	0.3755
3.255	0.5430	0.2992
2.041	0.5430	-0.2662
2.471	0.5430	-0.7261
4.289	0.5430	0.3177
5.094	0.5430	-0.2477
3.676	0.5430	-0.3987
3.164	0.5430	-0.2625
5.207	0.5430	0.8911
5.108	0.5430	0.0179
7.120	0.5430	-0.1278
6.080	0.5430	0.0995
5.861	0.5430	0.5287
6.057	0.5430	-0.1650
6.661	0.5430	-0.3355

```

Calc yMn_Mu =yMeans - mean(yMeans)

Scal NParam : Calc NParam=NGrass+NShr  "Eastimates of gammas:grasses
followed by saai:shrubs"
Matr[Rows=NGrassXNBorder; Colu=NParam; Modi=y] Xmat
Calc Xmat$[*;1...NParam] =Grs[1...NGrass], Sh[1...NShr]
"Prin Xmat"

Matr[Rows=NParam; Colu=1] GammaSaai, SeGammaSaai, Q "incl. mu,
beta=(X'X)-X'Y; (X'X)-Sig2 ; assume constant variance or weight;;;;
QPRODUCT(x;y)"
Matr[Rows=NParam; Colu=NParam]Smat, CInvGammaSaai
Diag[Rows=NGrassXNBorder]SIGMA, InvSIGMA  "Variance covariance of
yMean"
```

```
Calc SIGMA=ySeMn**2
Calc InvSIGMA=Inv(SIGMA)
Calc Smat= QPROD(Tran(Xmat); InvSIGMA)
Calc CInvGammaSaai=GInv(Smat)
Prin CInvGammaSaai
```

CInvGammaSaai

	1	2	3	4	5
1	0.04102	-0.01796	-0.01796	0.00204	0.00204
2	-0.01796	0.04102	-0.01796	0.00204	0.00204
3	-0.01796	-0.01796	0.04102	0.00204	0.00204
4	0.00204	0.00204	0.00204	0.12041	-0.07619
5	0.00204	0.00204	0.00204	-0.07619	0.12041
6	0.00204	0.00204	0.00204	0.02211	-0.07619
7	0.00204	0.00204	0.00204	-0.07619	0.02211
8	0.00204	0.00204	0.00204	0.02211	0.02211

	6	7	8
1	0.00204	0.00204	0.00204
2	0.00204	0.00204	0.00204
3	0.00204	0.00204	0.00204
4	0.02211	-0.07619	0.02211
5	-0.07619	0.02211	0.02211
6	0.12041	0.02211	-0.07619
7	0.02211	0.12041	-0.07619
8	-0.07619	-0.07619	0.12041

```
Calc Q= Prod(Prod(Tran(Xmat); InvSIGMA);yMn_Mu)              "yEff, yMn_Mu"

"Print SIGMA: & InvSIGMA: & Smat : & CInvGammaSaai :& Q "

Vari[Values=#NParam(1)] Jvec

Calc GammaSaai=Prod(CInvGammaSaai;Q)
Calc SeGammaSaai=Prod(sqrt(diag(CInvGammaSaai));Jvec)

Prin GammaSaai, SeGammaSaai
```

	GammaSaai 1	SeGammaSaai 1
1	-1.3815	0.2025
2	-0.2622	0.2025
3	1.6437	0.2025
4	-0.7585	0.3470
5	-0.2652	0.3470
6	0.1315	0.3470
7	0.3833	0.3470
8	0.5088	0.3470

```

"Get estimates of delta s"
Matr[Rows=NGrassXNBorder; Colu=1] GrsBorderEff  " two-way table with Graas & border effects= delta(ij) + delts(ik) combined"
Vari[Values=#NGrassXNBorder(1)] Jvec2
```

```

Calc GrsBorderEff =yMn_Mu - Prod(Xmat;GammaSaai)               "yEff, yMn_Mu"
Calc XSinvXT=Prod( Prod(Xmat;CInvGammaSaai); Tran(Xmat))
Calc varGrsBorderEff  = SIGMA - XSinvXT
Calc SeGrsBorderEff =Prod(sqrt(diag(varGrsBorderEff ));Jvec2)

Prin  GrsBorderEff , SeGrsBorderEff
```

	GrsBorderEff	SeGrsBorderEff
	1	1
1	0.3755	0.3966
2	0.2992	0.3966
3	-0.2662	0.3966
4	-0.7261	0.3966
5	0.3177	0.3966
6	-0.2477	0.3966
7	-0.3987	0.3966
8	-0.2625	0.3966
9	0.8911	0.3966
10	0.0179	0.3966
11	-0.1278	0.3966
12	0.0995	0.3966
13	0.5287	0.3966
14	-0.1650	0.3966
15	-0.3355	0.3966

```

"Now invert the matrix... to estimate REAL deltas"
"Create new Z variables: Grass1 (Sh1...5)+Gras2 (Shr1...5).."
Scal NParam1 : Calc NParam1=NGrass*NShr  "Eastimates of gammas:grasses followed by saai:shrubs"
Matr[Rows=NGrassXNBorder; Colu=NParam1; Modi=y] Zmat
Scal count ; 0
For i=1...NGrass
For j=1...NShr
Calc count=count+1
Calc Zmat$[*;count] = Grs[i]*Sh[j]
Endf
Endf
"Prin Zmat"
"Prin NParam1"

Matr[Rows=NParam1; Colu=1;Modi=y] Delta, SeDelta
Matr[Rows=NGrassXNBorder; Colu=NGrassXNBorder]InvSigmaStar
Vari[Values=#NParam1(1)] Jvec3, QDelta

Calc InvSigmaStar=Ginv(varGrsBorderEff)
Calc QDelta= Prod(Prod(Tran(Zmat); InvSigmaStar);GrsBorderEff)

Calc ZTSigStarInvZ=Prod( Prod(Tran(Zmat);InvSigmaStar); Zmat)
Calc varDelta=Ginv(ZTSigStarInvZ)

Calc Delta=Prod(varDelta; QDelta)
Calc SeDelta =Prod(sqrt(diag(varDelta));Jvec3)
```

```
Prin Delta, SeDelta
```

	Delta	SeDelta
	1	1
1	0.3506	0.4857
2	-0.6169	0.4857
3	-0.1093	0.4857
4	-0.0514	0.4857
5	0.4269	0.4857
6	-0.6434	0.4857
7	0.3808	0.4857
8	0.5103	0.4857
9	0.2446	0.4857
10	-0.4924	0.4857
11	0.2927	0.4857
12	0.2360	0.4857
13	-0.4010	0.4857
14	-0.1932	0.4857
15	0.0655	0.4857

```
STOP
```