Tropical Agricultural Research Vol. 5 1993

# Analysis of Growth and Indirect Selection for Environmental Sensitivity in *Nicotiana rustica*

A.T.L. Thalib, M.J. Kearsey[1], H.S.P. Pooni[1], and R.O. Thattil

Department of Crop Science
Faculty of Agriculture
University of Peradeniya
Peradeniya

**ABSTRACT.** *There has been a growing body of evidence that the genetic control of plant growth is related to macro-environmental sensitivity in Nicotiana rustica. Repeatedly measured heights obtained from the triple test cross families, inbred lines and the basic generations of the V2 x V12 cross was used in this study. Growth analysis combined with multivariate analyses were used to find the best indirect measures to select for the environmental sensitivity which cannot be objectively measured. The selection index formed by stepwise regression showed the highest correlation with the sensitivity. The linear and cubic components of the growth were found to be the most important determinants of the indirect measure.*

## INTRODUCTION

Genotype (G) - environmental (E) interactions have long been known to contribute a significant proportion of the variation of many polygenically controlled characters (Jinks, 1976). G x E interactions occur when genotypes differ in their responses to environmental changes. Genotypes may interact with environments at two levels, *viz.* macro and micro. Genotype x macro-environmental interactions represent the differential responses of genotypes between environments while genotype x micro-environmental effects are known to occur when genotypic response differs within the same macro-environment. Clearly, varieties that exhibit a high degree of stability for any uncontrollable environmental factors are mostly at advantage.

Finlay and Wilkinson (1963) defined favourable genotypes as those that possess both high or desirable levels of mean performance and high

---

[1] Faculty of Science, University of Birmingham, United Kingdom.

stability over a wide range of environments. Perkins and Jinks (1971) extended this definition to one combining a suitable mean performance with low sensitivity or high stability to uncontrollable effects and high sensitivity or responsiveness to controllable environmental effects.

The generations derived from crossing varieties 2 and 12 of *Nicotiana rustica* were lately identified to be ideal for studying G x E interactions (Boughey, 1978). These two varieties are not only the extremes for mean performance of important traits such as flowering time and final height, among the Birmingham collection, but they also differ in their reactions to environmental differences (Jinks and Mather, 1955).

Selection for a desired level of environmental sensitivity became possible as it was shown to be under genetic control by several workers using various *Nicotiana rustica* lines (Perkins and Jinks, 1968, Jinks and Perkins, 1970). Perkins and Jinks (1971, 1973) showed that mean performance and sensitivity to macro-environmental variables were, at least in part, under independent genetic control in a number of *Nicotiana rustica* crosses. Brumpton, Boughey and Jinks (1977) further showed that the positive correlation between mean performance and environmental sensitivity could be broken and even reversed. However, to measure and select for different levels of sensitivity in segregating materials, it is essential that the experimental materials are grown in a number of contrasting environments. Therefore, any method by which differences in sensitivity can be identified from materials grown in one single environment will have great practical advantages.

If sensitivity is highly correlated with another easily measurable phenotypic character, it might be possible to use this character to select indirectly for environmental sensitivity. Evidence of the relationship between the differences in environmental sensitivity of *Nicotiana rustica* genotypes and the differences in their growth habits was first presented by Perkins and Jinks (1968). Further evidences were presented by Perkins (1974) and Boughey and Jinks (1978) who showed that growth pattern is a major determinant of sensitivity for final plant height (FH). The possibility of indirect selection for sensitivity using growth parameters was further examined by Boughey *et al.*, (1978). Consequently, Al-Banna and Jinks (1984) have practiced indirect selection for macro-environmental sensitivity of FH using the proportion of FH achieved by the middle of the growing season.

The main objectives of the present study were as follows:

i. to evaluate the potential of using multivariate compound characters as indirect measures of environmental sensitivity opposed to the univariate characters that have been considered by the previous workers, and

ii. to explore further the possibility of forming an index of compound characters objectively involving many characters both univariates and multivariates of growth and non-growth traits to select for the environmental sensitivity with increased precision and to testify whether the growth components are reliable measures of indirect selection of sensitivity.

## MATERIALS AND METHODS

The experiment consisted of triple test cross (TTC) families, inbred lines and basic generations derived from the cross between varieties V2 and V12 of *Nicotiana rustica*. Perkins and Jinks extracted 60 pure breeding lines (named as 60 D lines) from the F2 generation of this cross by single seed descent (Jinks, Jayasekara and Boughey. 1977). These 60 D lines were selfed and crossed to V2, V12 and their F1 (V2 x V12) during the summer of 1991, in the main field of the School of Biological Sciences at Birmingham to produce L1, L2 and L3 families, respectively, of the TTC programme. The 180 families thus produced together with the 60 inbred lines were grown during the summer of 1992. Ten replicate plants were raised for each of these families. Sixteen families of the basic generations (P1, P2, F1, F2, BC1 and BC2) of this cross were also raised in the same experimental plot, randomised individually, together with the TTC families and inbred lines.

Many characters were scored on the various stages of the plant growth, on an individual plant basis. However, only fourteen characters are relevant to this paper. They included plant heights measured weekly beginning at 3 weeks after planting until the end of the season (nine consecutive height measurements were scored in cm and abbreviated as H1 to H9) and final height (FH) taken at the end of the season. Flowering time (FT) (number of days taken for the opening of the first flower), height at flowering (HFT) (the height of the plant measured in cm at the time of the first flowering), maximum length (LL) and width (LW) of the fully expanded largest leaf in cms were the other characters measured.

Independent macro-environmental sensitivity scores required in this study to correlate the phenotypic mean performances were obtained from an earlier experiment that was conducted in 1972 by Jinks, Jayasekara and Boughey (1977). The experiment consisted of eight environments of 4 sowing dates and 2 planting densities in which the inbred lines of the V2 x V12 cross were grown. The macro-environmental sensitivity was then measured by performing a one way analysis of variance for each inbred family and partitioning the total variation in FH into components, between environments, $s^2_b$ and within environments component, $s^2_w$. The $s_b$ was preferred over the linear regression co-efficient (1+b) as it incorporated both the linear and non-linear components of macro environmental sensitivity. However, this measure was available for the 59 out of 60 inbred lines and hence the present study relates the mean performances and the environmental sensitivities of these lines only. The genetic control of the growth components that were found to be related to the environmental sensitivity, on the other hand were analyzed using the full set of data from the TTC families and the basic generations.

The following variables were evaluated as potential indirect measures of macro-environmental sensitivity, by correlating them with the independent measure of environmental sensitivity:

i. all 14 variables measured on the material,

ii. orthogonal polynomial components of successive height measurements, as growth parameters (orthogonal polynomial components were preferred over other growth model parameters as they would provide independent growth components related to various stages of growth),

iii. ratios obtained by dividing (a) each height by FH (denoted as RH's), (b) each height by HFT (denoted as QH's) and (c) HFT by FH,

iv. the principal component scores, the factor scores and the canonical variates obtained from the analysis of all the 14 variables scored on the inbred lines and

v. selection indices that were chosen objectively using multiple regression involving all the above mentioned variables.

## RESULTS AND DISCUSSION

ANOVA carried out on all the univariate characters considered have shown highly significant variability between families in all the generations. Analysis of variance carried out separately on the polynomial growth coefficients of inbred lines, L1, L2 and L3 families also indicated that families differed very significantly for all first five polynomial coefficients. The variability of multivariate compound characters, principal components, factors and canonical variates has also been identified to be significant (detailed analyses are given in Thalib, 1993). All univariate and compound characters differed significantly between families and thus are appropriate to be investigated as potential indirect selection measures of environmental sensitivity.

Pearson's linear correlations between the macro-environmental sensitivity scores of the 59 inbred lines and the family mean score of all the variables described above are given in Table 1. The FT, first six heights, last two heights, HFT, LL and LW, the summary ratios of growth (except, RH9, QH9 and HF/FH), linear and quadratic components of orthogonal polynomials and the first canonical variates, first two principal components, and the first two factors were significantly correlated to the macro-environmental scores.

The first canonical variate had the highest correlation of 0.49 while the quadratic polynomial had the second highest of correlation of 0.47. Next in order were the correlations with FT (0.45) and the summary ratios RH3-RH6 and QH3-QH6 (-0.43 to -0.45). However, if the canonical variate is to be used in practice as an indirect measure of selection then all fourteen variables scored in this study have to be measured. This is certainly a disadvantage which often occur with the use of multivariate or compound characters.

Single characters, ratios of two characters or the multivariate dimensions have been considered as the potential measures for selection. However, if a compound index is formed using a combination of some of the variables correlated to sensitivity achieving an increased correlation, then such an index can be used as an indirect measure.

**Table 1.** **Correlation between the environmental sensitivity scores and the other variables of the 59 inbred lines (d.f.=58).**

Original variables

| | | | | | | |
|---|---|---|---|---|---|---|
| H1 | H2 | H3 | H4 | H5 | H6 | H7 |
| -0.31* | -0.32* | -0.32* | -0.31* | -0.29* | -0.22* | -0.03 |
| H8 | H9 | FH | FT | HFT | LL | LW |
| 0.15 | 0.40** | 0.41** | 0.45*** | 0.38** | 0.45*** | 0.37** |

Summary ratios

| | | | | |
|---|---|---|---|---|
| RH1. | RH2 | RH3 | RH4 | RH5 |
| -0.42** | -0.43*** | -0.44*** | -0.44*** | -0.45*** |
| RH6 | RH7 | RH8 | RH9 | |
| 0.44*** | -0.41** | -0.32* | 0.02 | |
| QH1 | QH2 | QH3 | QH4 | QH5 |
| -0.41** | -0.42** | -0.43*** | -0.43*** | -0.43*** |
| QH6 | QH7 | QH8 | QH9 | |
| -0.42** | -0.37** | -0.30* | -0.16 | |

Growth components

| Linear | Quadratic | Cubic | Quartic | Quintic |
|---|---|---|---|---|
| 0.32* | 0.47*** | 0.20 | -0.25 | -0.09 |

Multivariate components

| Can1 | Can2 | Prin1 | Prin2 | Factor1 | Factor2 |
|---|---|---|---|---|---|
| 0.49*** | 0.15 | -0.36** | 0.35** | -0.37** | 0.36** |

Stepwise multiple regression involving all the above variables was therefore, used as an objective way of forming an index that had the highest correlation with environmental sensitivity. The results were promising as the best selected ($P<0.05$) model included only the linear and the cubic components of the growth polynomials alone, implying that only 4 height measurements are necessary for the estimation. The estimated equation is given by

$$ES = 0.642 \times (\text{linear}) + 5.454 \times (\text{cubic})$$

This equation explained about 94% of the variability for environmental sensitivity. This is the highest $r^2$ achieved between the mean performance of any single or compound character and environmental sensitivity of FH, even higher than the first canonical variate which was identified to be the best in this study as a single measure for indirect selection.

If the polynomial components (especially the linear and the cubic) were to be used as indirect measures for the selection of environmental sensitivity, understanding their genetic control and inheritance is vital to determine the efficiency of selection. The results of the genetic analysis on these growth components will be presented in a separate paper to be published soon.

## CONCLUSIONS

Mean performances of the growth components were, undoubtedly, found to be related to the macro-environmental sensitivity of FH in *Nicotiana rustica* and further confirmed the findings of the previous workers. Moreover, the linear and the cubic components of the growth curve were found to be tightly related to the environmental sensitivity. The use of multivariate compound characters as well as the indices formed by multiple regression were found to be better measures than the univariate measures that have been used in the previous studies.

The linear and cubic orthogonal growth polynomials are alone sufficient to form an index that will enable the selection of macro environmental sensitivity. However, further studies designed to practically evaluate the efficiency of indirect selection for sensitivity using the index formed (with linear and quadratic components) would be the natural extension of this study to prove the efficiency of this method.

## ACKNOWLEDGEMENTS

This work being a component of the Ph.D. programme, the author is grateful to the ODA/British Council for the financial support provided as a scholarship to pursue the postgraduate studies at the University of Birmingham, U.K.

## REFERENCES

Al-Banna, M.K.S. and Jinks, J.L. (1984). Indirect selection for environmental sensitivity in *Nicotiana rustica*. Heredity, 52: 297-301.

Boughey, H.J. (1978). Competitive ability and environmental sensitivity in *Nicotiana rustica*. Ph.D. thesis, University of Birmingham, U.K.

Boughey, H.J and Jinks, J.L. (1978). Joint selection for both extremes of mean performance and sensitivity to a macro-environmental variable III. The determinants of sensitivity. Heredity, 40: 363-369.

Boughey, H.J., Jinks, J.L., Coombs, D. and Shufflebotham, W. (1978). Joint selection for both extremes of mean performance and of sensitivity to a macro-environmental variable IV. Growth pattern and sensitivity. Heredity, 41: 175-183.

Brumpton, R.J., Boughey, H.J. and Jinks J.L. (1977). Joint selection for both extremes of mean performance and of sensitivity to a macro-environmental variable 1. Family selection. Heredity, 38: 219-226.

Finlay, K.W. and Wilkinson, G.N. (1963). The analysis of adaptation in a plant breeding programme. Aust. J. Agric. Res., 114: 742-754.

Jinks, J.L. (1976). The impact of genotype-environment interaction on plant breeding. Definitions and genetical analysis. Plant Science Committee meeting, University of Birmingham, U.K.

Jinks, J.L. and Mather, K. (1955). Stability in the development of heterozygotes and homozygotes. Proc. Roy. Soc. B, 143: 561-578.

Jinks. J.L. and Perkins, J.M. (1970). Environmental and genotype-environmental components of variability VII. Simultaneous prediction across environments and generations. Heredity, 25: 475-480.

Jinks, J.L., Jayasekara, N.E.M. and Boughey, H. (1977). Joint selection for both extremes of mean performance and of sensitivity to a macro-environmental variable II. Single seed descent. Heredity, 39: 345-355.

Perkins, J.M. (1974). Orthogonal and principal components analysis of genotype-environmental interactions for multiplemetrical traits. Heredity, 32: 189-209.

Perkins, J.M. and Jinks, J.L. (1968). Environmental and genotype-environmental components of variability IV. Non-linear interactions for multiple inbred lines. Heredity, 23: 525-535.

Perkins, J.M. and Jinks, J.L. (1971). Specificity of the interaction of genotypes with contrasting environments. Heredity, 26: 203-209.

Perkins, J.M. and Jinks, J.L. (1973). The assessment and specificity of environmental and genotype-environmental components of variability. Heredity, 30: 111-126.

Thalib, A.T.L. (1993). Biometrical analysis of *Nicotiana* and Sunflower. Ph.D. Thesis, (Unpublished). University of Birmingham, U.K.