CONCLUSION

South African propagators and other nurserymen must take note of the trends in the marketing of plants in the rest of the world and be prepared to adapt to the changing needs of customers. Much can be accomplished by liaison with the Australian nursery industry, we can learn such things as nursery hygiene and marketing. International Plant Propagators' Society and South African Nurserymen's Association each have a different role to play, and gardening writers play a special role.

The Use of Taguchi Methods to Analyze Variables

Dudley Wilson
Hadeco, PO Box 7, Maraisburg, 1700, South Africa

Taguchi methods offer plant propagators an opportunity to develop optimal methods or conditions in a cost-effective way. An example used in our tissue culture laboratory is discussed and Internet addresses to find more information are given.

INTRODUCTION

Propagators often face the situation where a new method has to be developed, or an existing one optimized. Usually more than one factor affects the processes of growth, for example: temperature, age of the plant, season, light intensity, day length, growth regulators, etc. To complicate matters, one or more of these critical factors may have a more profound effect on the process than others. Even worse is that two or more of these factors may interact with each other. More often than not, limited amounts of material are available for experimentation and the propagator has little time for experimentation.

The conventional method of investigating all possible combinations and conditions in an experiment is known as a factorial design. It is based on the theory that for a full factorial design, all possible combinations are tested, obviously at great cost and time, with a statistical analysis of results. In contrast to the factorial design, Taguchi's robust design method provides the propagator with a systematic and efficient approach to determine the near optimum conditions. In this paper the method is briefly discussed and an example where I used it successfully is given.

TAGUCHI AND ROBUST DESIGN METHODS

Taguchi methods are a system of cost-driven quality engineering that emphasizes the effective application of engineering strategies, rather than advanced statistical methods. Taguchi methods are known as Robust Design methods in the U.S.A. The approach allows for experiments to be performed and prototypes tested on multiple factors at once so that the process becomes insensitive to experimental conditions and other uncontrollable factors. Dr. Genichi Taguchi developed his philosophy on quality engineering over a period of 30 years after he was recruited to repair Japan's telephone system. Not satisfied with trial and error methods, he developed his own method to design experiments. One of Taguchi's key ideas is the upstream optimi-

zation of the process. In general, the further upstream the optimal conditions are applied, the greater the effect on the successful outcome of the process and the more it reduces cost. Taguchi Methods employ design experiments using specially constructed tables, know as Orthogonal Arrays (OA). Orthogonal Arrays are not unique and they were discovered in the 1930s by Fisher and Tippet in England. Taguchi has simplified their use by providing tabulated sets of orthogonal designs and their corresponding linear graphs to fit a specific project.

AN APPLICATION OF TAGUCHI METHODS

I was faced with the challenge to find a method to regenerate bulbs from *Nerine* callus in vitro. Seven factors were investigated, each at a high and low level:

Macro-nutrient formulation: Schenk and Hildebrandt (L) vs.
Murashige and Skoog (H)
Sucrose: 12.5 g liter^{-1} (L) vs 50 g liter^{-1} (H)
Maltose: 5 g liter^{-1} (L) vs 20 g liter^{-1} (H)
Casein AH: 0 (L) vs 1 g liter^{-1} (H)
Citrate: 0 (L) vs 20 mM (H)
Plant growth regulators (PGRs): None (L) vs usual mix (H)
Charcoal: 0 (L) vs 2 g liter^{-1} (H)

The experiment was laid out using the L8 OA as guide (Table 1).

If a factorial design was used, no less than 128 different media would have to be prepared compared to the 8 used in this experiment. After 3 months, the growth was ranked from 0 to 3, with 0 being the poorest and 3 the best. In this case, the higher the score, the better. To analyze the results, a table was constructed where scores of the main effects were summarized (Table 2).

Table 1. Experimental layout according to Taguchi's method.

	Medium number							
	1	2	3	4	5	6	7	8
Macronutrient formulation	L	L	L	L	H	H	H	H
Sucrose	L	L	H	H	L	L	H	H
Maltose	L	L	H	H	H	H	L	L
Casein AH	L	H	L	H	L	H	L	H
Citrate	L	H	L	H	H	L	H	L
PGRs	L	H	H	L	L	H	H	L
Charcoal	L	H	H	L	H	L	L	H

The scores in the table were calculated as follows:

The score (0.75) for salts at a low level (Table 2), is the average for the media in Table 1 where salts were used at low concentration namely: 1, 2, 3, and 4.

The score (1.5) for salt at a high level (Table 2), is the average for the media where salts were used at the high concentration namely: 5, 6, 7, and 8.

The score for charcoal at a high level, is the average for media 2, 3, 5, and 8.

The conclusion that can be made from the results in Table 2 is that the optimal

medium for bulb formation is one which contain a high level of salts, sucrose, maltose, and charcoal together with a low level of casein, citrate, and PGRs. It can also be seen that charcoal was probably the most important variable in this experiment. It is possible to find interactions between the different factors but one must study them with care.

Table 2. Summary of results of seven factors tested for bulb formation on *Nerine*.

Variable	Low level (L)	High level (H)
Salts	0.75	1.5
Sucrose	1	1.25
Maltose	1	1.25
Casein AH	1.25	1
Citrate	1.25	1
PGRs	1.5	0.75
Charcoal	0	2.25

FURTHER INFORMATION

- Two sites on the Internet that may be of use and provide other references are:
  http://www.amsup.com/TAGUCHI
  http://garcia1.larc.nasa.gov/dfca/dfc/tm.html
- Bibliography.
  http://www.quality.org/Bookstore/Taguchi.html
- A free demonstration software application for designing and running Taguchi experiments is available from: http://www.wnet/~rkroy/wp-q4.html