analysed for hormones and co-factors. This ought to demonstrate some of the limiting factors in root initiation.

The final aspect of research to be done will be a study of the metabolism and breakdown of IAA within the two rootstocks. This will be achieved by using radioactive IAA, which allows easy tracing of breakdown products of IAA. Since 'M.M. 106' roots more readily than 'E.M. 12' we might expect a difference in the metabolism of IAA to occur. A recent research report on this type of study on plum cuttings has suggested that synthetic auxin IBA, when applied as a rooting hormone, does not act as an auxin itself but acts as a protector of IAA and directs IAA to form certain compounds which could be used in the formation of roots. This effect will be investigated to see if a similar system is operating in apple cuttings. If this effect does prove to operate in apples then the importance of IAA levels within the cutting will be highly significant in terms of the ability to form roots. In conjunction with this work, it is hoped to use radioactive IBA to study the influence of this auxin on the system above and to compare the metabolism of IBA and IAA in the cutting base.

RESEARCH ON THE NUTRITION OF CONTAINER-GROWN PROTEACEAE PLANTS AND OTHER NURSERY STOCK

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Abstract. The nutrition of six species of plants was examined using peat: perlite (1:1) mixes and slow-release fertilisers in factorial experiments. Most plants responded strongly to nitrogen while there was little response to phosphorus. Medium phosphorus levels proved fatal for *Protea repens* and depressed the growth of *Grevillea rosmarinifolia* particularly when accompanied by high nitrogen. Tomatoes responded to very much higher fertiliser levels than proteaceoks and other shrubs and there was a very strong N x K interaction with tomatoes even though they were grown in winter.

REVIEW OF LITERATURE

Gardeners and nurserymen alike have often found plants in the Proteaceae difficult to grow unless certain requirements are met. Plants may die early and can be particularly difficult to grow in containers; a comparison of their growth response with other nursery plants like camellia, erica and tomato will give an insight into their relative nutritional requirements.

Various reasons have been put forward for losses of proteaceous plants including disease and faults with general culture. Hewett (18) states that attack by the fungus *Phytophthora* *cinnamomi* is perhaps the greatest destroyer of plants in the Proteaceae and that it is spread through infected nursery plants or soil.

Many proteaceous plants prefer acid soils and high levels of calcium may result in toxicity (24). Higgs (19) found that the planting depth in containers is important and that the survival of *Grevillea rosmarinifolia* rooted cuttings was severely reduced by planting at 5 cm. depth rather than 1 cm. Plant size and the aerial environment such as temperature regime, relative humidity, and air circulation may also influence plant losses in nurseries.

Nutrition and fertiliser problems are probably the greatest single cause of difficulties in the nursery culture of the Proteaceae. Many of the cultivated Proteaceae come from the Australian Heathlands and the slopes of the coastal mountains of South Africa. The growth of proteaceous plants in their native habitat gives a good indication of their cultural requirements. The distribution and evolution along with cultural implications was reviewed by Hocking and Thomas (2). Soil fertility is a key aspect in the distribution of proteaceous plants in Australia. The plants grow in moist coastal areas on extremely impoverished acid to neutral soils which are very low in P,N,K and Ca, and many trace elements (34, 37, 41). Phosphate has been shown to be the key factor since it influences organic matter levels and protects the healthland species against invasion by competitive plants which need more fertile soils than the Proteaceae (41). Proteaceous plants have adapted to a low P and N requirement (5, 7, 24, 33); for example, some can take up phosphate in the spring and store it until it is required in the growing season (35). Proteoid roots are a further adaptation and are dense clusters of rootlets of limited growth along a lateral root (32) and have been found on a wide range or proteaceous species from Australia (23, 24, 25, 26, 32) and South African species (2). Proteoid roots do not appear to be mycorrhizal (4, 33) and are primarily an adaptation to low fertility soils (6).

Hodge (22) reported that fertilisers high in phosphate have been responsible for the death of many grevilleas. Iron chelates and sulphate of ammonia were recommended to correct chlorosis. Higgs (19) in nursery container trials found that *Grevillea rosmarinifolia* developed chlorotic foliage with full strength fertiliser treatments at normal depths of planting. He found that as time passed growth was inhibited and the lack of vigour became noticeable compared with the healthy appearance of plants grown in the half strength and nil fertiliser treatments. Hockings (21) states that, in general, grevilleas prefer a soil with definite acid reaction but that there are two quite well known exceptions, namely *Grevillea robusta* and *G. striata*, both of which can thrive in alkaline soils. *Grevillea robusta* grown in containers will respond to increasing levels of nitrogen especially at high levels of potassium (27, 28).

Van Staden (38) and Parvin, et al (31) observed and described deficiency symptoms in proteas and found that nitrogen deficiency in *Protea cynaroides* will reduce the dry weight yield of leaves and roots, while potassium and calcium deficiencies will give a general reduction of growth. Low levels of N, K, Ca, Fe in the potting mix will reduce the level of iron in the plant and lead to foliar chlorosis (38). Vogts (39) warned against the use of manure for proteas while Stevens (36), in contrast, recommended liberal applications. Watson and Parvin (40) state that the premature death of proteas is common at any age and most common at the end of a dry season or after over-watering and they attribute this to a serious outbreak of soil-borne fungi. They point out that observations indicate that proteas respond to standard fertiliser programmes.

Camellias respond to supplementary nitrogen feeding when grown in John Innes and U.C. mixes (3). Nitrogen is the major nutrient that needs to be added to sustain growth of camellias (8, 13, 14, 29) while phosphorus, potassium and sulphur are needed in lesser amounts (8, 29). An N. P. K. ratio of 3:2:3 appeared to give optimum growth (13, 14).

Gray (16) reports that light-weight soil-less media are of value for the production of container-grown ericaceous plants and that these plants should be induced to make growth early in the season. Alvey (1) recommended that "flowers of sulphur" should be substituted for chalk in John Innes mixes in order to improve growth and overcome chlorosis which occurs due to lime-induced iron deficiency. Potting mix and feeding trials on *Erica carnea* 'Springwood White' in England showed that this plant established poorly in loamless mixes, appeared chlorotic and was a poorer quality as fertiliser rates increased (2, 11). It was found that these plants grew better in JIP II and were much larger than those in loamless mixes and concluded that a low rate of feeding is needed with loamless mixes.

High fertiliser levels can reduce the growth of container grown tomatoes in winter when light levels are low in Europe (10, 42). This was most severe where high rates of N and Ca were combined with low rates of P (10). It was also found that the peat/sand mixture was deficient in available nitrogen but that increased N levels were more likely to reduce growth in peat/sand in winter than when a loam mix is used. In summer the position was reversed and there was a positive response to each increment of N in the peat-sand mix and growth was significantly better than the growth of tomatoes grown in a loam compost.

MATERIALS AND METHODS

This article reports on the first six of a series of separate trials carred out at various times with different nursery plants in containers. The intention was to standardize materials and methods as much as possible and follow New Zealand commercial practice while still retaining an adequate level of scientific "technique." All trials were based on a N. P. K. 2^3 factorial using randomised blocks and analysed for analysis of variance and Duncan's Test. The physical part of the mix was peat-lite mix B (9) which has the advantage of being relatively inert and chemically uniform (30) and is used by commercial nurserymen. Slow release fertilisers are used where possible.

All trials were based on the following:

Physical Ingredients: 50% Dipton sphagnum peat; 50% horticultural grade perlite (Perloam)

Chemical Ingredients:

	Fertiliser			*Nutrients* g/m^3		
	kg/m^3	lb/yd^3		N	P	K
A base of:-	0.25	0.42	Osmocote NPK 18/ 2.6/10	45	30	25
plus:-	4.5	6.74	dolomite lime			
	1.5	2.53	carbonate of lime			
	0.075	0.136	iron chelate (Sequestrene Na/Fe)			
	0.150	0.253	Trace element mix (Sporumix) - approx. 10% Mg. 1% Cu, 1% Bo, 5% Mn, 0.1% Mo)			

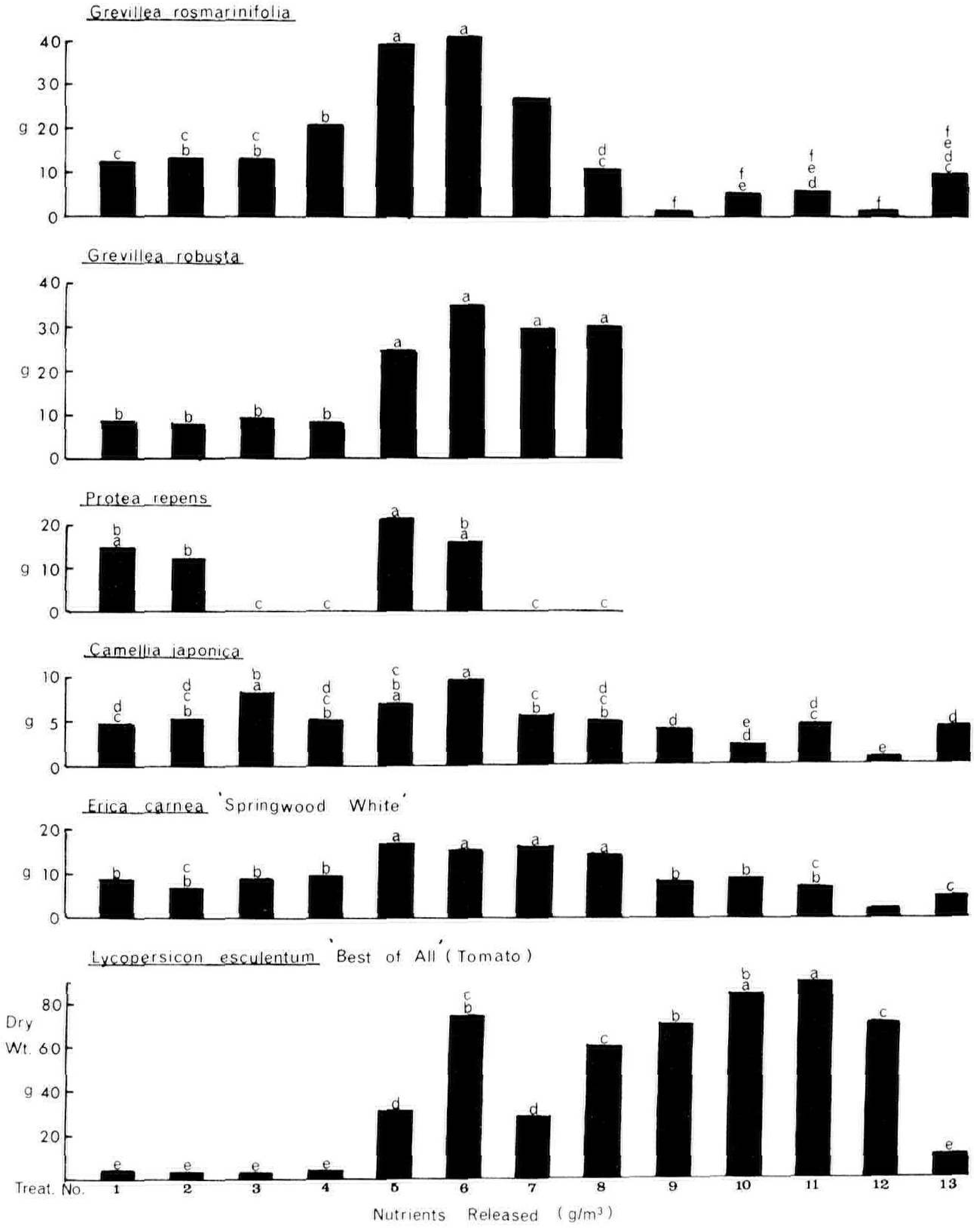
(Note the above 5 ingredients constitutes treatment 1 in all 6 trials)

Further treatments were made up by adding some or all of three fertilisers; for example, with treatment 8 in all the trials:

	Fertiliser		*Nutrients* g/m^3		
	kg/m^3	lb/yd^3	N	P	K
Osmocote 26%N	1.558	2.63	405		
Superphosphate 9%P	3.000	5.06		270	
Sulphate of potash 39%K	0.577	0.97			225
plus base fertilisers			45	30	25
Total NPK nutrients			450 :	300	: 250

No soil disinfection was carried out and black plastic PB5 (3 litres approx. capacity) planter bags were used in each case. Yields were assessed by cutting off the above ground parts of the plant at soil level and then obtaining the oven-dry weight of each foliage sample. Statistical analyses including F Test and analysis of variance; factor interactions and Duncan's test on the data were obtained by computer analysis. Visual ratings were carried out during the running of the trials and statistically analysed in the same manner as dry weights (Results of ratings are not shown).

The 13 treatments (Fig. 1) were the same in each trial, except that



N	45	45	45	45	450	450	450	450	900	450	450	900	0
P	30	30	300	300	30	30	300	300	300	600	300	600	0
K	25	250	25	250	25	250	25	250	250	250	500	500	0

Figure 1. The dry weight growth response of the various species to different levels of N. P. and K. (Levels of significance can only be compared within one species — with small letters in common above the columns there is no significant difference at the 5% level using Duncan's test).

with *Grevillea robusta* and *Protea repens*, the last 5 treatments were omitted. The trials were based on two levels of each of N. P. & K.; i.e. at 2^3 factorial plus five additional treatments (except *Protea repens* and *Grevillea robusta* expts.). All were carried out in a heated glasshouse equipped with automatic fan ventilation.

Table 1: Details of Individual Trials

Plant species lifted	No. of treatments	Reps. (plants per treat.)	plants grown from	Date Bagged	Date Lifted
Grevillea rosmarinifolia	13	24	cuttings	22.9.72	2.5.73
Grevillea robusta	8	10	seed	14.12.73	6.8.74
Protea repens	8	15	cuttings	26.3.73	10.6.74
Camellia japonica	13	25	seed	25.9.72	25.9.73
Erica carnea 'Springwood White'	13	25	cuttings	27.12.72	24.10.73
Lycoperscion esculentum 'Best of All' (Tomato)	13	15	seed	14.6.73	24.8.73

RESULTS

Grevillea rosmarinifolia Experiments: Visual ratings during the early stages (data not given), showed that mild toxicity occurred in varying amounts in treatments 7-12. Analysis of the interactions (not shown) revealed that there was a significant N x P interaction; i.e. these two elements acted to depress growth more than if either one was at high levels on its own.

The dry weights (Fig. 1) indicated the prominent influence of nitrogen in the growth response. Additional potassium was not beneficial while additional phosphate significantly depressed yields

Figure 3 is designed to illustrate the interactions between any two elements. Relative dry weight figures are plotted on a square base and shown by the vertical height above each of the four points. In the N.K. figure for *Grevillea rosmarinifolia*, the lowest point of the box design is low N + low K and the greatest yield is at N + low K. An alternative way to show this second diagram would be as vertical columns representing the yield in g of dry weight (Fig. 2):

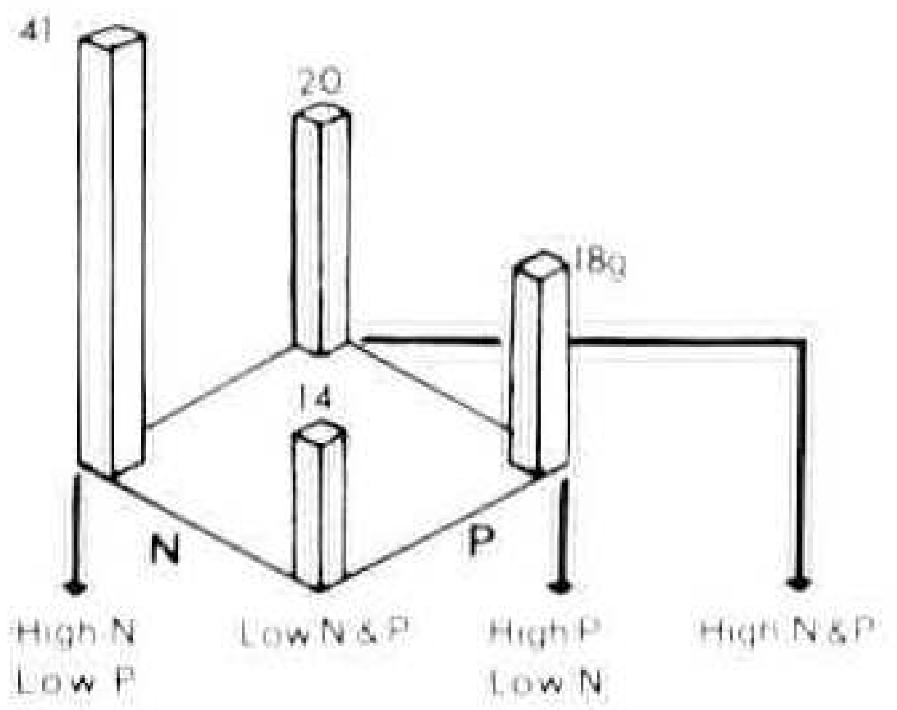


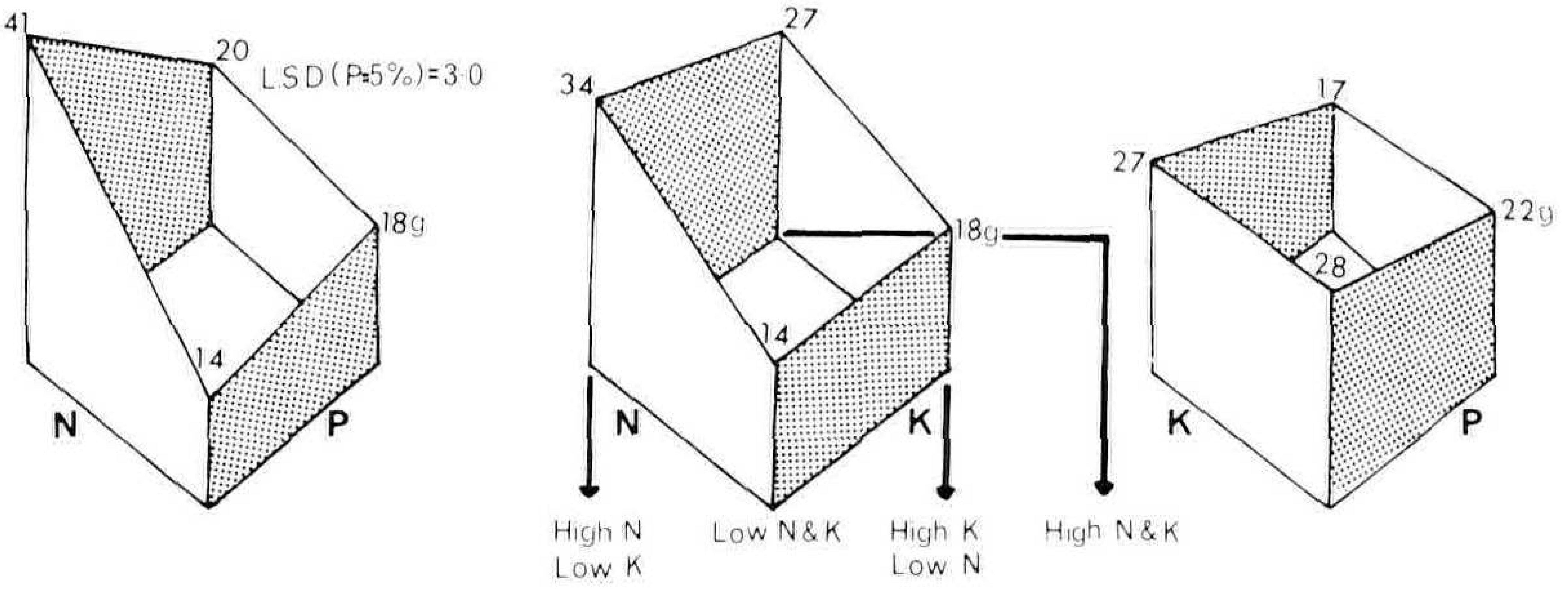
Figure 2. Interactions between any two elements.

Comparisons can only be made within one box using the least significant difference figure (5%); i.e. differences are only significant if greater than the LSD figure.

G. rosmarinifolia in Figure 3 illustrates the significant interactions of N with P and N with K and to a lesser extent P with K where growth was depressed. The main response was to nitrogen while there was a very small response to P and K on their own.

Grevillea robusta Experiments. There were no visual ratings and in Figure 1 the results divide between those treatments where plants grew vigorously with nitrogen and those with small yields due to having only 45 g of N/m^3 supplied. Figure 3 shows that there was a N x K interaction but no N x P or P x K interactions. Plants responded strongly to the main effect of N.

Grevillea rosmarinifolia



Grevillea robusta

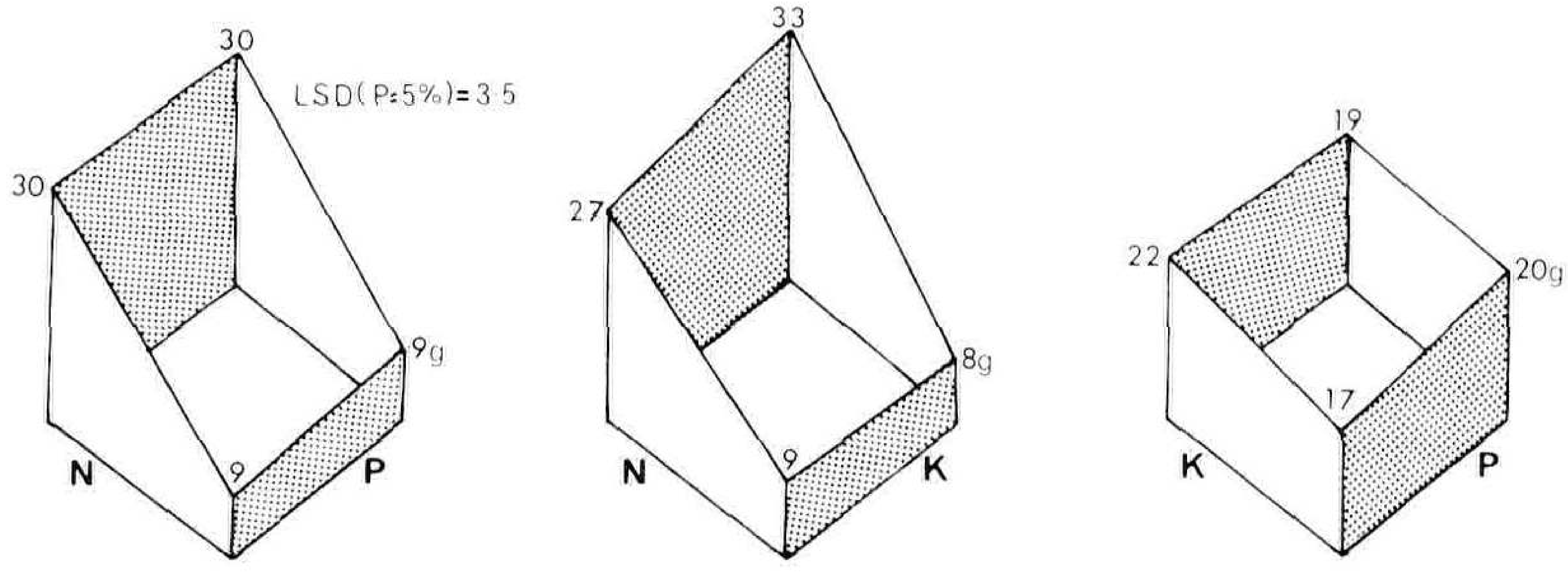
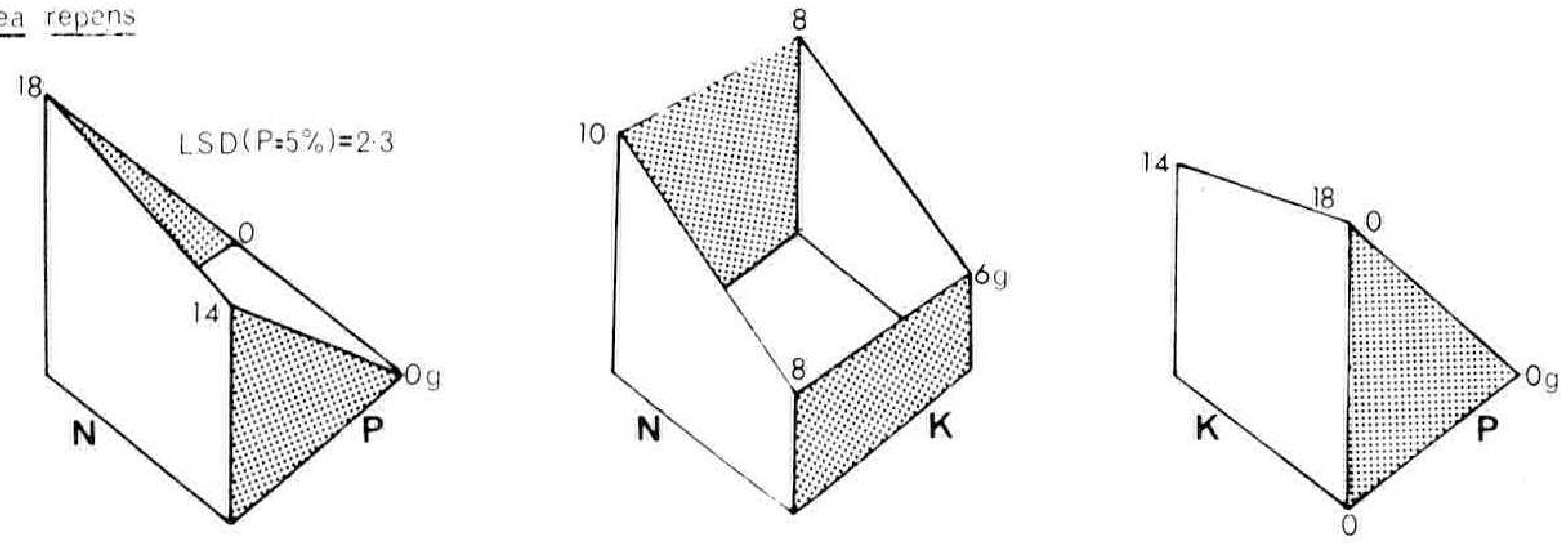
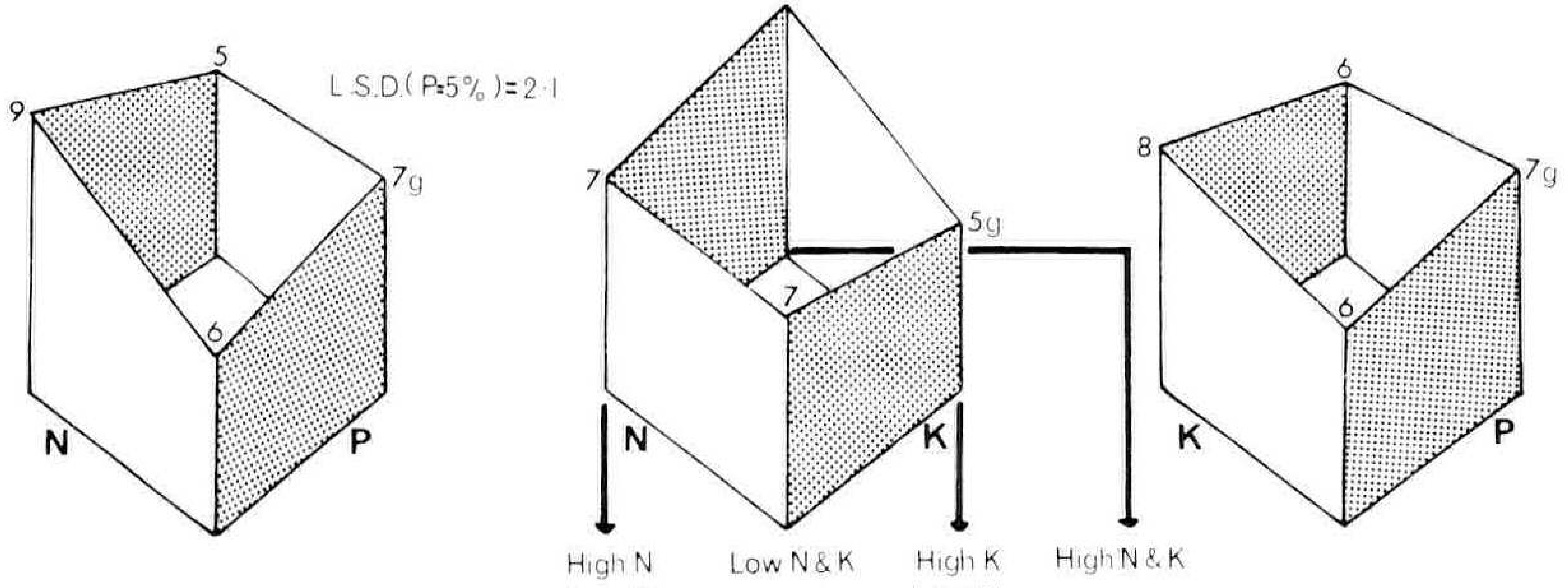


Figure 3. Three dimensional figures depicting the growth response (Dry wt. tops in g.) of container - grown shrubs to N.P.K. and the interactions involved.

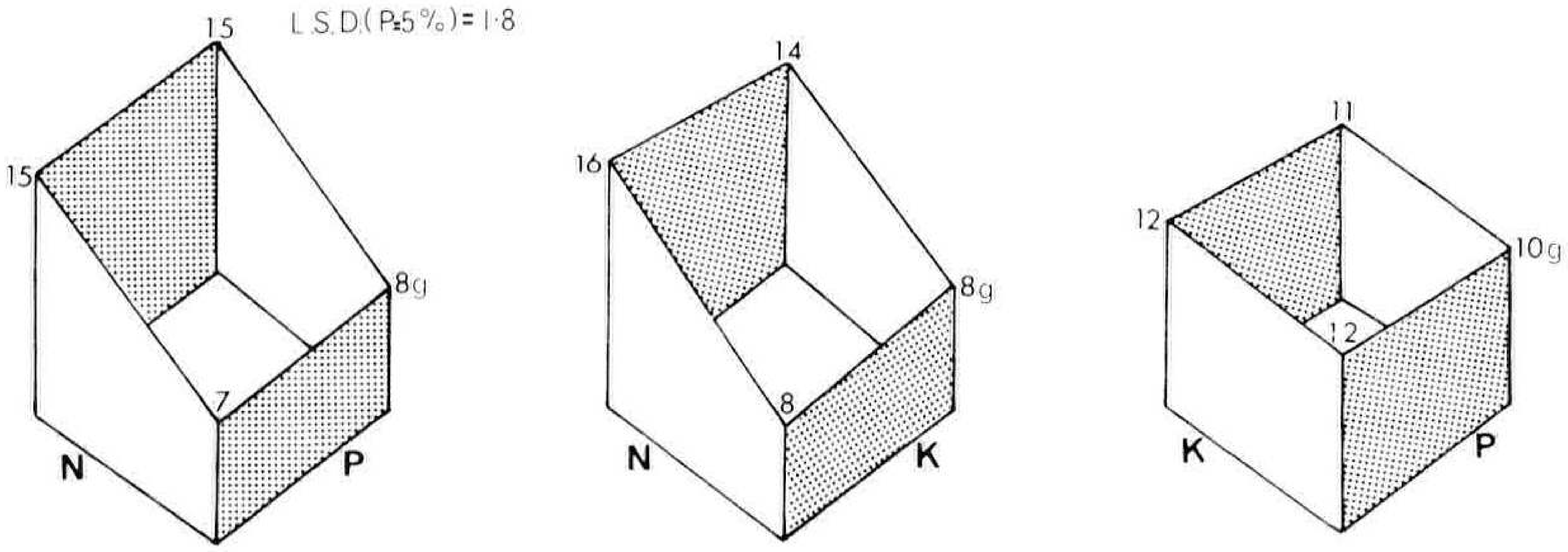
Protea repens



Camellia japonica



Erica carnea "Springwood White"



Lycopersicon esculentum "Best of All" (Tomato)

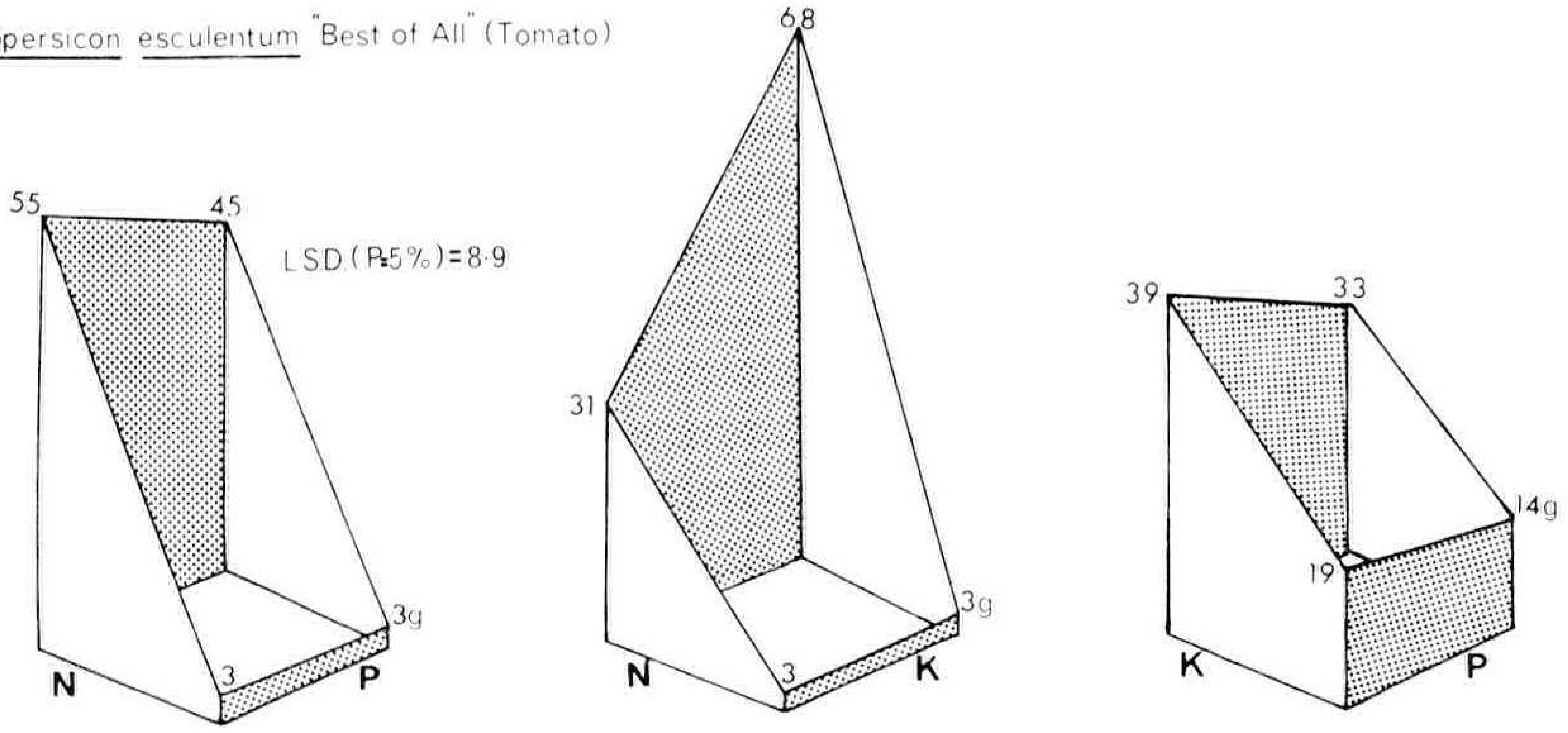


Figure 3 (cont.)

Protea repens Experiments. Visual ratings indicated a steady decline in those plants with 300g P/m^3 and there was a significant N x P interaction. The highest dry weight (Figure 1) was found in those plants supplied with 450:30:25 g/m^3 of N:P:K. respectively while the N.K. (6) and the low NPK (1) treatments were next highest.

Toxic effects of medium and high phosphate show clearly in Figure 3. Growth was mildly depressed by the N x K interaction. There was a mild response to nitrogen and a small depression of growth with high K levels. Plants were observed to show light to strong N toxicity symptoms (treatments 5 and 6) in the early stages of the experiment.

Camellia japonica Experiment. Plants with medium N (5), medium NK (6) and medium P (3) were significantly larger than those with other treatments (Figure 1). The next highest treatments were those with NP (7), NPK (8), PK (4) and K (2).

The interaction of N x P involved a slight depression in growth and the only other significant effect illustrated in Figure 3 was a fairly strong N response (left-hand diagram).

Erica carnea 'Springwood White' *Experiment.* There was a strong and significant response to nitrogen shown by treatments of 6 to 9. The latter was at a high rate of N plus medium P and K (900:300:250 g of NPK per m^3). The dominant main effect of nitrogen was shown in Figure 3 while there were no significant interactions or response to P or K.

Lycoperscion esculentum 'Best of All' (tomato) *Experiment.* All treatments with 450 and 900 g N/m^3 were significantly above all others (Figure 1). Treatment 11 and 10 with NPK in g/m^3 of 450/300/500 and 450/600/250 were the largest plants while treatment 6 with 450/30/250 were not significantly different from the latter.

The extremely strong N x K interaction is clearly shown in figure 3 where relative plant response at medium N and low K is doubled by having medium levels of N and K together. There was a slight depression with the N x P interaction and a strong response to the main effect of N and K.

DISCUSSION

The response to nitrogen was a common and major factor in the growth of all six groups of plants tested and, in all but tomatoes, treatment 5 with a N:P:K of 450:30:25 grew plants which were the largest in the trials (or not significantly different from the largest). It is indeed surprising that medium to high levels of N and other nutrients plus only very small levels of P and K grew good quality ericas, camellias and proteaceous shrubs.

Grevillea rosmarinifolia

Camellia japonica

Grevillea robusta

Erica carnea 'Springwood White'

Protea repens

Lycopersicon esculentum 'Best of All'

Figure 4. **The comparative growth response of the test species with three different treatments, giving some indication of the N.P., N.K., and P.K. interactions.**

Left to right		**High N & P**	**High N & K**	**High P & K**
g/m³ of	N	450	450	45
potting	P	300	30	300
mix	K	25	250	250

High phosphate levels have been observed to cause severe losses with commercially grown nursery plants in the Proteaceae. In this work *Protea repens* did not survive in mixes with 300 g P/m^3 (approx. 3 kg/m^3 or 5 lb/yd^3 superphosphate) while growth of *Grevillea rosmarinifolia* was significantly reduced by similar P levels (Figure 4). The growth of the camellias and tomatoes was also significantly reduced as a result of an unfavourable N x P interaction. Therefore, with four species the response to nitrogen was depressed by the presence of medium levels of phosphate. In contrast, *Grevillea robusta* and the *Erica* 'Springwood White' grew well in mixes with NPK's of 450:300:25 g/m^3. *G. robusta* is native to the moist forested areas of Queensland while *G. rosmarinifolia* comes from the low fertility soils of the heathlands of Australia. The difference in habctat and soils probably accounts for the differing response of these two species and the fact that phosphate toxicity occurred with *G. rosmarinifolia* but not *G. robusta*. Other proteaceous plants may also tolerate medium phosphate levels; for example, macadamia is reported to respond to phosphate side dressings (12).

The difference in nutritional requirements between the two grevilleas is also shown by the fact that there was an unfavourable N x K interaction for *G. rosmarinifolia* while *G. robusta* responded where N and K were high together. The N x K interaction was a dominant feature in the nutritional response of tomatoes and the largest plants were those in treatment 12 with an N.P.K. of 900:600:500 g/m^3.

The proteas and, to a lesser extent, camellias were those plants which grew reasonably well at low and nil rates of N.P.K., probably because of their relatively slow growth rates. Standard fertiliser rates for proteas, suggested by Watson and Parvin (40), would appear to be undesirable because phosphate levels should be low. Proteas may be a low fertility plant but the two grevilleas responded strongly to nitrogen and grew poorly with low levels of this element. Although the *G. rosmarinifolia* is distributed on low fertility soils in its native habitat it appeared to have an even greater requirement for nitrogen than camellia. This may be due to the high potential for rapid growth of *G. rosmarinifolia*.

The tomato trial was started in mid-winter but this plant grew extremely rapidly and responded to medium N coupled with high K and also high P (Figure 1). This is in contrast to the growth supression with high nutrient level reported from England by Woods, et al (42) and Bunt (10). Higher light levels in winter in New Zealand than England may accoknt for the difference in findings and point to the need for caution when considering Northern hemisphere research in New Zealand.

There appears to be quite widely differing nutritional requirements both within the Proteaceae and between other plants.

It can be concluded that nurserymen should maintain at least medium levels of nitrogen with these types of plants grown in soil-less media, while phosphate levels should be minimised for certain Proteaceae, particularly while plants are young (17). This work re-enforces Furuta's (15) comments concerning the importance of quantitative research on such aspects as potting media and the prime importance of interactions when examining the nutrition of container-grown nursery stock.

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ACKNOWLEDGEMENTS

I wish to acknowledge the financial support of N.Z. Perlite Ltd. and the N.Z. Nurserymen's Association and technical assistance from B. Conaglen, M. Spurway and Mrs. P. Moon. Thanks go to Duncan and Davies Ltd. for donating plants.