CHAPTER 3

Effects of temperature and fertiliser on mungbean (*Vigna radiata* L. Wilczek.) growth, phenological development and yield.

3.1. INTRODUCTION

Adequate nutrition is an important factor limiting all plant growth and yield potential; depending on soil nitrogen levels, nitrogen fertiliser can increase soybean yield from 33% to 40% (Brevedan et al., 1978). Phosphorus fertiliser also increased mungbean yield from 27% to 125% over the control (Sadaphal, 1988) and potash increased pea yields by between 9% and 19% (Bhangoo and Albritton, 1972). The application of fertilisers, in combination with inoculum, may be necessary to sustain vegetative dry matter production and also to increase total seed yield in mungbean (Lawn and Ahn, 1985). However, all such responses will depend on soil nutrient status and the plant's ability to grow without other limiting factors (e.g. soil moisture).

Optimum temperature also enhances the plants capability to fix nitrogen and increase dry matter and hence grain yield. The aim of this initial experiment was to compare possible interaction effects of temperature and fertiliser application on mungbean (*Vigna radiata* L.). In earlier work with Vigna spp., at Armidale (Jessop, unpublished data), considerable variation in growth occurred which suggested the need for some preliminary work to establish suitable temperature conditions and likely responses to nutrient status. Fertiliser treatments which included nitrogen were used to allow the determination of optimal rates of application which removed the plants reliance on rhizobial N_2 fixation.

3.2. MATERIALS AND METHODS

Site

This study was conducted in July, 199? in both a 'tropical' (Figure 3.1) and a 'temperate' (Figure 3.2) glasshouse of the Department of Agronomy and Soil Science, University of New England, Armidale, New South Wales, Australia.

Experimental design

The experiment was a randomised split-plot design with three soil fertiliser applications as the main plot treatments and two foliar fertiliser applications as sub treatments, with three replications. The soil used for the experiment was a sandy loam mixed with peat and sand in a 3:1:1 ratio. The basal fertiliser (NPK) was applied in the form of urea (46% N), triple super phosphate (45% P) and muriate of potash (60% K) at the rates of 40N-60P-40K kg ha^{-1}. Five seeds of an unknown cultivar of mungbean (*Vigna radiata* L. Wilczek.) were sown into each 30 cm diameter plastic pot containing the soil mixture and thinned to two plants per pot after germination. Two sets of this experiment were set up: one set was kept in the tropical glasshouse and the other set was maintained under temperate glasshouse conditions.

Fertiliser treatments

Aquasol* soluble fertiliser was used for both the soil and the foliar fertiliser applications which started seven days after germination. Aquasol was applied to the soil at rates designated, low (2g), normal (4g) and high (8g) dissolved in 5L of water. These solutions were applied at 500 ml per pot, to the soil at seven day intervals.

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*Aquasol; aquasol is a readily soluble fertiliser containing N (23%), P (4%) and K (18%) and the percentage of trace elements was Zn as $ZnSO_4$ (0.05%), $CuSO_4$ (0.06%), $NaMo_4$ (0.0013%),

$MnSO_4$ (0.15%), Fe (0.06% as Fe E.D.T.A), $NaBO_4$ (0.011%).

For the foliar application, aquasol was applied every alternate day at the rates of nil and $1.6gL^{-1}$ of water. The aquasol was applied to the vegetative parts of the plants on both the dorsal and ventral surfaces of the leaves (until the leaves were thoroughly wetted). Before foliar application, the soil surface and untreated plants were covered with polythene to avoid contamination. Both soil and foliar applications continued until the pods reached physiological maturity ie. when the pods started changing colour from green to yellow.

Temperature

Temperatures in the glasshouses were recorded at hourly intervals with a Campbell Scientific Data Logger throughout the growth period. Minimum and maximum day and average night temperatures were recorded daily and used to calculate weekly averages. Mean temperatures from sowing to harvest were calculated as

$$T = \sum_{i=n}^{m} \frac{(Ti + ti)}{2} \Big/ (m - n),$$

where Ti and ti are daily maximum and minimum temperatures respectively and n and m are the number of days after the commencement of the study to the beginning and end of the growing period respectively.

Measurements

During growth and at the end of the experiment, plant growth and yield parameters were recorded. These were phenological development, plant height, flower number and distribution, percentage of pods set, seed yield and percentage of protein content in the seeds and plant fractions (stems and leaves). The seeds stems and leaves were dried for 48 hours in a fan forced oven at 85°C and then weighed. Nitrogen content of seeds, stems and leaves was measured directly by the Dumas type catalytic combustion method and a mass spectrometer detection system. The equipment consisted of a Carlo Erba NA1500 carbon and nitrogen analysis coupled

to Europa trace mass isotope ratio mass spectrometer. The percentage protein content was estimated by multiplying the percentage nitrogen in the sample by a correction factor N x 6.25 (Norton et al., 1985). Due to insufficient seed production from plants grown under temperate conditions, the analysis of seed protein could not be undertaken.

Phenology

The stages of phenological development were recorded as vegetative (days from seedling emergence to flower bud emergence), flowering (flower bud emergence to opening of flowers), grain filling (from pod set to pod colour change to yellow) and harvest maturity (total days from seedling emergence to harvest).

Data analysis

The experimental data were analysed by analysis of variance to determine significant treatment effects ($P<0.05$, 0.01, 0.001%) using the Genstat and NEVA computerised statistical packages; where necessary, data was converted into Square Root and Log transformations. Statistical differences within the treatments was assessed by the Duncan's Multiple Range Test (DMRT) or least significant difference (lsd). Only treatment means which were statistically different at a probability of at least 5% ($P<0.05$) have been discussed in the text of all chapters unless otherwise stated.

3.3. RESULTS

3.3.1. Temperatures

Tropical glasshouse

Under tropical glasshouse conditions, seeds germinated five days after sowing and plants were harvested 72 days after sowing. The average day temperature in the tropical glasshouse was 27°-32°C maximum, 15°-22°C minimum with an average night temperature of 18°-22°C. Due to the breakdown of the temperature data logger, no temperature data could be collected between

weeks 2 and 5. Figure 3.1 shows the weekly maximum, minimum, and average maximum, minimum and night temperatures in the tropical glasshouse.

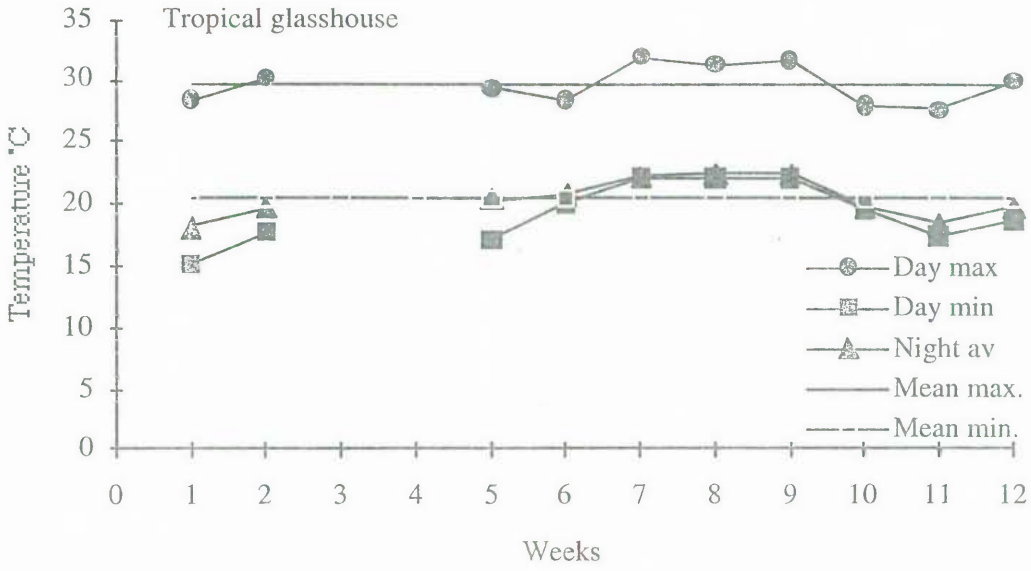

Figure 3.1 Weekly mean maximum and minimum day temperatures and average maximum, minimum and night temperatures during the growing period in the tropical glasshouse (July, 1992-Oct., 1992).

Temperate glasshouse

Under the temperate glasshouse conditions, seeds germinated 12 days after sowing and subsequent growth and development were very slow and stunted; plants developed symptoms such as chlorotic and crinkled leaves. The average mean day temperatures ranged from 24°-27°C maximum, 9°-16°C minimum and 12°-16°C for the average night temperatures (Figure 3.2). There were a few nights when temperatures went down to 4°-6°C.

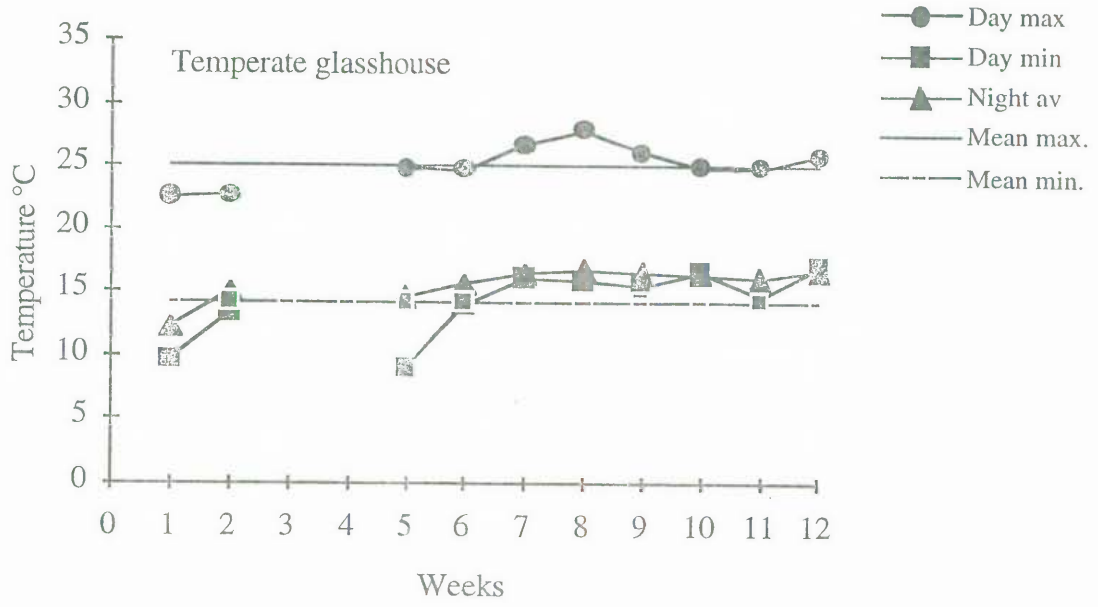

Figure 3.2 Weekly mean maximum and minimum daily temperatures and average maximum, minimum and night temperatures during the growing period in the temperate glasshouse (July, 1992-Oct., 1992).

3.3.2. Phenological development

Data on the length of three phenological stages (vegetative, flowering and grain filling) under tropical and temperate glasshouse conditions, have been presented in Figure 3.3. All three stages of phenological development were shorter under tropical glasshouse conditions than in the temperate glasshouse. Under tropical conditions, the vegetative, flowering and grain filling stages, and total days to harvest were 21, 9, 16 and 56 days earlier respectively than under temperate glasshouse conditions.

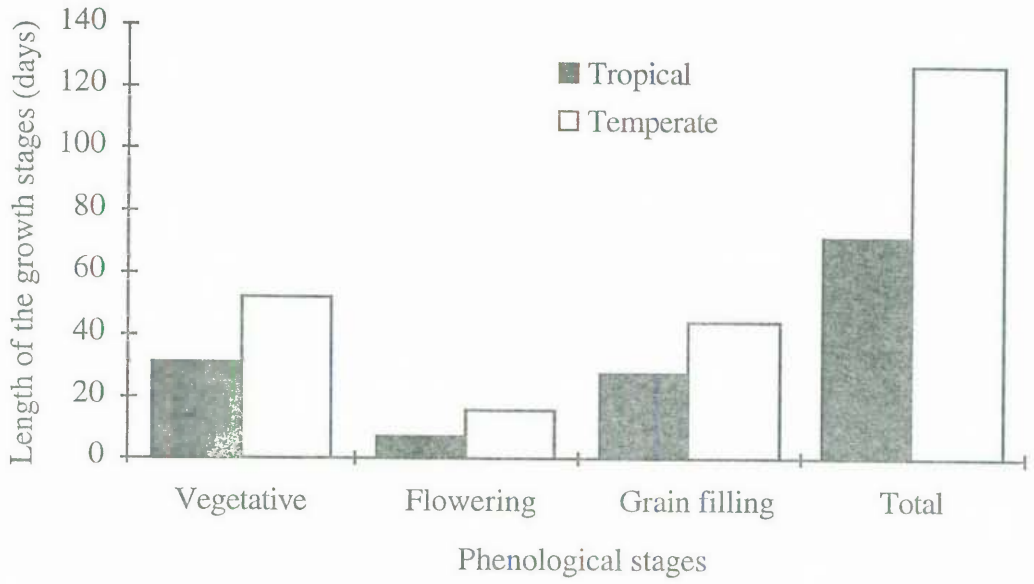

Figure 3.3 Comparison of the length of phenological stages in mungbean under tropical and temperate glasshouse conditions.

Under temperate conditions, different rates of fertiliser application did not cause any variation in the phenological development of mungbean (data not presented). Under tropical conditions (Figure 3.4), there was no difference between 8g and 4g fertiliser concentrations but these two treatments were earlier than 2g ($P<0.001$) by 13 and 10 days in the total growing period as a result of shorter vegetative stage and grain filling periods. Under tropical conditions the length of the flowering period was not affected by fertiliser treatment.

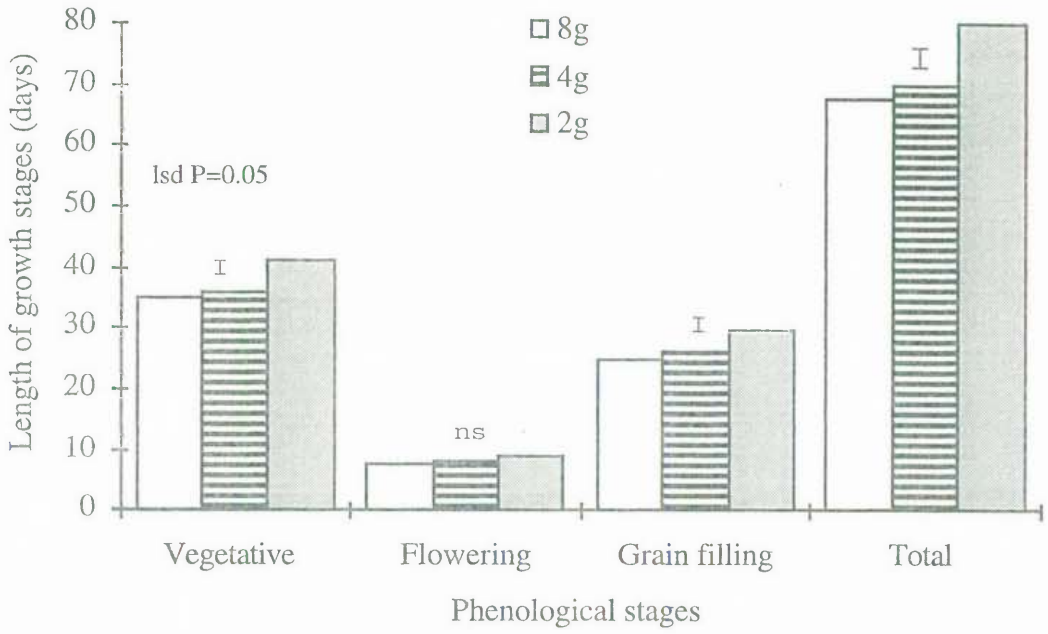

Figure 3.4 Length of phenological stages in *Vigna radiata* L. under tropical glasshouse conditions with three fertiliser concentration treatments.

3.3.3. Plant height

Plant heights in the 8g and 4g treatments were similar under tropical conditions but both were greater than the 2g fertiliser treatment ($P<0.001$) (Figure 3.5). The foliar application (+F) increased ($P<0.01$) plant heights in the tropical glasshouse conditions when the data was log transformed. Under temperate glasshouse conditions; there were no differences in plant height; however plant height was much less for all temperate treatments compared to those under tropical conditions.

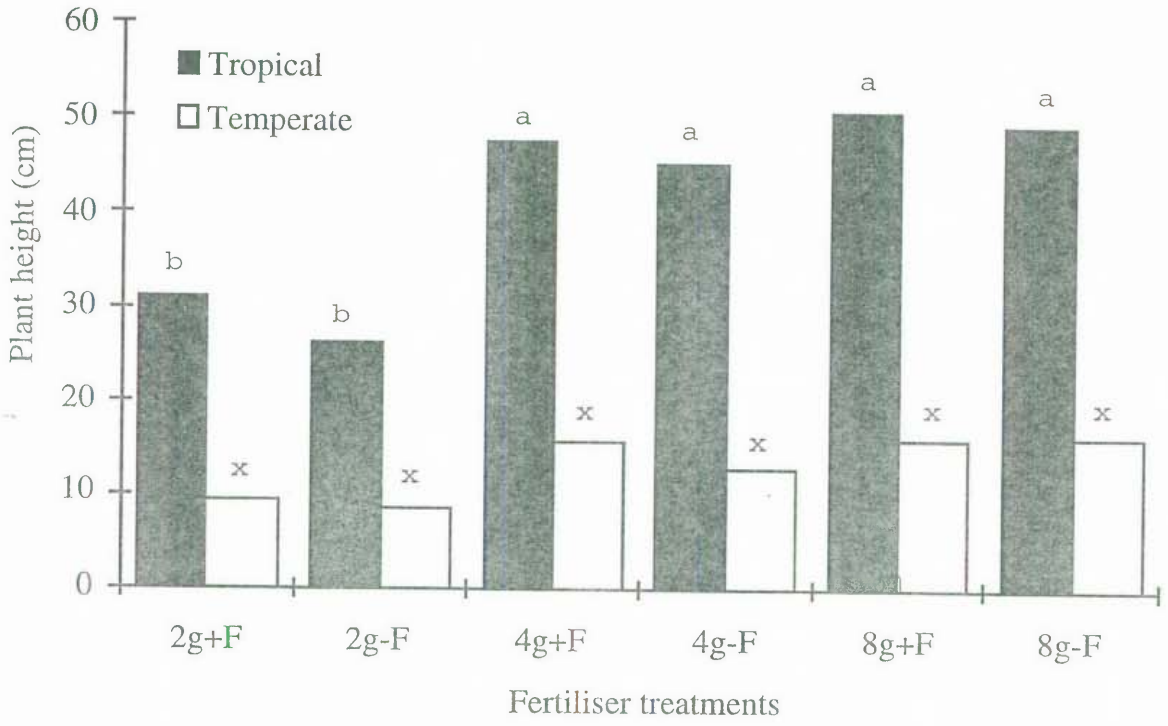

Figure 3.5 Plant height (cm) of mungbean (*Vigna radiata* L.) at three levels of fertiliser treatments in tropical and temperate glasshouse conditions. The abbreviations used in the figures are different concentrations of aquasol (2g, 4g and 8g of aquasol /5L of water). F= foliar aquasol application. Within the temperature treatments, fertiliser treatments with the same letter were not different (P=0.05, DMRT).

3.3.4. Distribution of flowers in mungbean plants

Flower distribution at nodal positions under tropical and temperate glasshouse conditions is shown in Figure 3.6 and Figure 3.7 respectively. Generally there were more flowers at each node and flowering continued at higher internodes under tropical conditions. Flower buds may develop at almost all the nodes, but pod setting (data not presented) was found to be limited mostly to the apical region of the plants. It was observed in all the treatments that when early flowers set and formed pods, the remaining flowers at those nodes abscised. Foliar fertiliser application appeared to promote flowering on the later developed nodes (Figure 3.6) under warm growing conditions. There was no clear response to fertiliser levels.

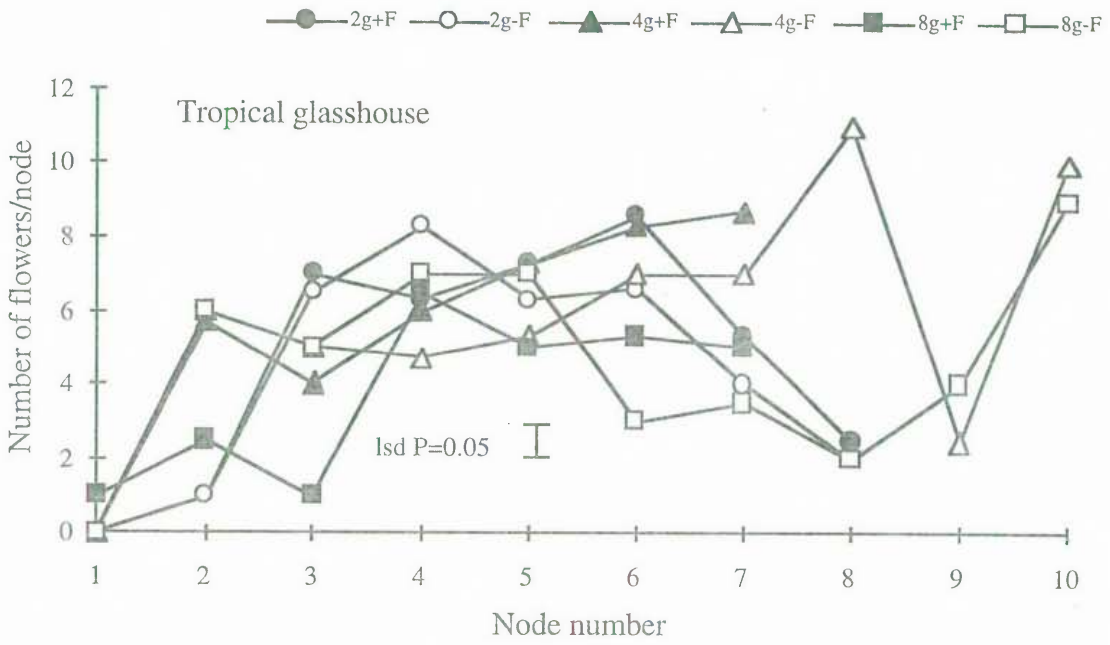

Figure 3.6 Number of open flowers produced at different nodes under tropical glasshouse conditions. Closed symbols are for the foliar, and open symbols are for the non foliar fertiliser application treatments. The lsd is for differences in flower numbers at each node.

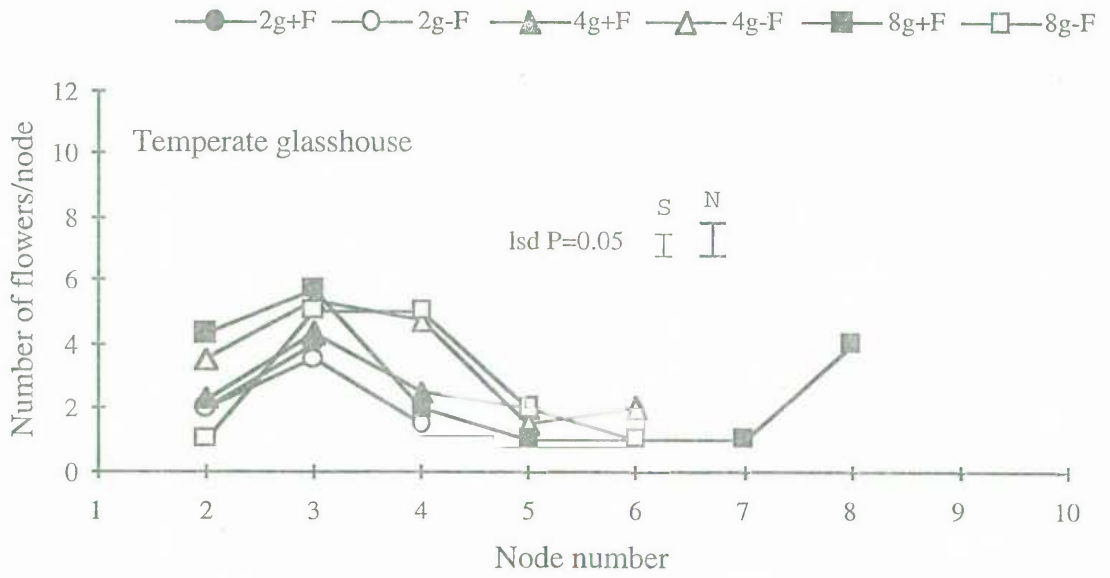

Figure 3.7 Number of open flowers produced at different nodes under temperate glasshouse conditions. Closed symbols are for the foliar and open symbols are for the non foliar fertiliser application treatments. The lsd's are for differences of each node between flower numbers and treatments. The abbreviations used for lsd are S for fertiliser treatments and N for nodes.

3.3.5. Flower and pod number

There were no differences between treatments under tropical conditions in flower number, but at

lower temperatures higher fertility induced an increase in flower numbers (Table 3.1). The data suggest however that under tropical conditions flower number was higher with the intermediate level (4g) of fertiliser application whereas under temperate conditions, flower number appeared greatest at the highest application (8g) rate (Table 3.1). Pod number was greatest with added fertiliser (Table 3.2) in both the tropical and temperate conditions. There was no response to foliar aquasol.

Table 3.1 Total number of open flowers produced per plant under tropical and temperate glasshouse conditions.

Conditions	Treatments/ Foliar treats.	2g	4g	8g	Mean	lsd P=0.05
Tropical	+F	31.7	40.0	20.7	30.8	
	-F	27.0	33.0	27.0	29.0	
	mean	29.4	36.5	23.9		ns
Temperate	+F	7.0	14.0	19.0	13.3	
	-F	6.0	11.0	15.0	10.7	
	mean	6.5	12.5	17.0		** (3.1)

Values within the parenthesis are lsd at P=0.05.

Table 3.2 Total number of pods per plant in tropical and temperate glasshouses.

Conditions	Treatments/ Foliar treats.	2g	4g	8g	Mean	lsd P=0.05
Tropical	+F	11.5	15.0	17.9	12.8	
	-F	9.2	9.2	12.0	12.1	
	mean	10.4	12.1	14.9		*(2.2)
Temperate	+F	4.0	6.7	8.8	6.5	
	-F	4.0	5.7	7.8	5.8	
	mean	4.0	6.2	8.3		**(2.3)

Values within the parenthesis are lsd at P=0.05.

3.3.6. Percentage pod set

The percentage of flowers which set pods generally increased with increasing fertiliser application under tropical conditions but decreased under temperate conditions (Figure 3.8).

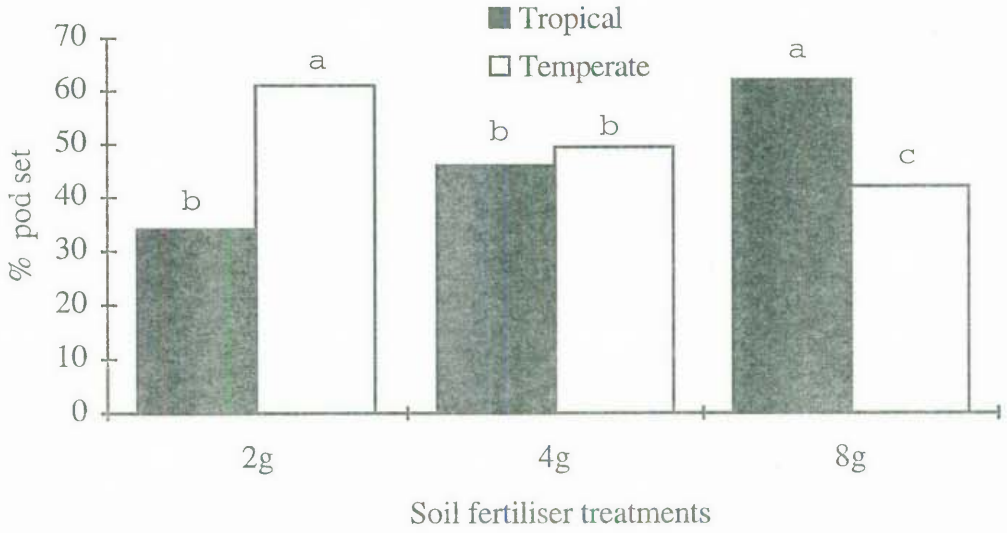

Figure 3.8 Percentage of flowers which set pods in three fertiliser treatments under tropical and temperate glasshouse conditions. Within the temperature treatments, fertiliser treatments with the same letter was not different (P=0.05, DMRT).

3.3.7. Yields per plant

Under tropical conditions yields from the 8g fertiliser treatment were higher ($P<0.01$) than from the other two fertiliser treatments (4g and 2g, Figure 3.9). The fertiliser response patterns were similar under temperate conditions. Yields per plant were much higher under tropical than under temperate conditions.

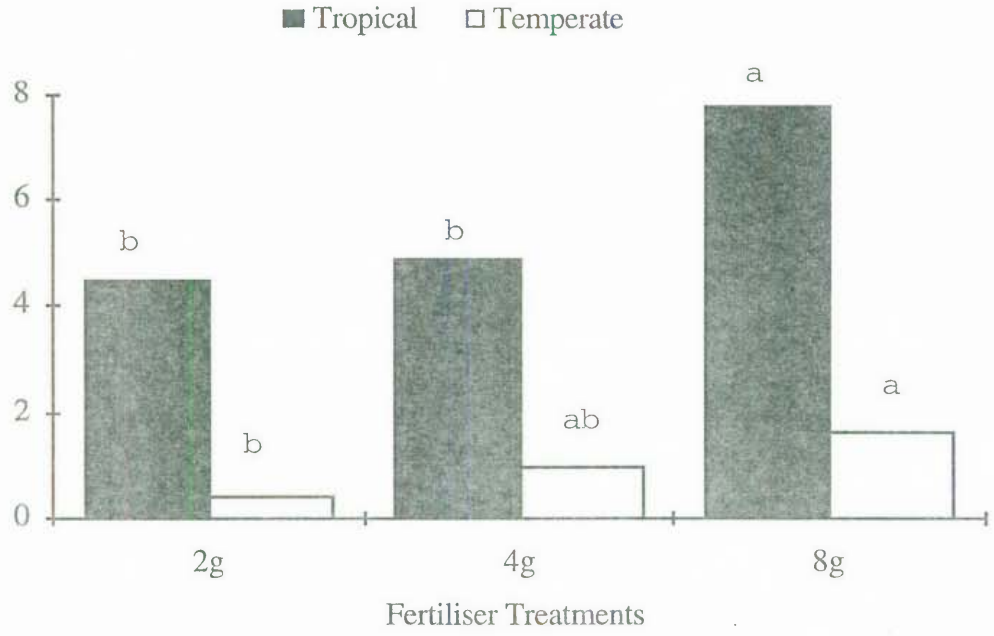

Figure 3.9 Seed yield at three fertiliser concentration treatments in tropical and temperate glasshouse conditions. Within temperature treatments, fertiliser treatments with the same letter were similar (P=0.05, DMRT).

Due to the adverse effects of low temperatures on the growth and development of seedlings under the temperate glasshouse conditions, grain yield and all other yield parameters were drastically reduced, and a few plants produced no seeds (Table 3.3).

Table 3.3 Summary of yield affecting characters of mungbean growth under temperate glasshouse conditions.

Treatments Characters /plant	2g+F	2g-F	4g+F	4g-F	8g+F	8g-F	lsd P=0.05
Plant ht. (cm)	13.7	12.3	14.7	13.7	12.0	11.0	ns
Node no.	5.0	5.0	3.7	4.3	5.3	5.3	ns
Flower no.	7	6	14	11	19	15	**(3.1)
Pod no.	4	4	6.7	5.7	7.3	7.0	**(2.3)
Seed no.	8.6	9.6	30.3	20.0	27.3	18.3	*(10.9)
Seed wt. (g)	0.4	0.3	1.2	0.8	2.0	1.2	*(0.5)

** P<0.01, *<0.05 and ns =not significant. Values within the parenthesis are lsd at P=0.05.

Table 3.4 Summary of yield affecting characters of mungbean grown under tropical glasshouse conditions.

Treatments Characters/plant	2g+F	2g-F	4g+F	4g-F	8g+F	8g-F	lsd
Plant ht. (cm)	31.2	26.1	47.6	45.4	51.0	49.0	***(3.51)
Node no.	9.5	8.8	8.8	8.1	8.8	8.1	*(0.8)
Flower no.	31.7	27.0	40.0	33.0	27.0	20.7	ns
Pod no.	11.5	9.2	15.0	9.2	17.9	12.0	*(2.2)
Seed no.	81.0	73.0	112.0	109.0	160.0	120.0	ns
Seed wt. (g)	4.3	4.0	5.8	4.7	8.4	7.2	**(0.6)

***P<0.001, **P<0.01 and *P<0.05, ns = not significant. Values within the parenthesis are lsd at P=0.05.

The yield (seed weight/ plant) and yield contributing characters in Table 3.3 and 3.4 indicate that the increased yields with higher rate of fertiliser application might be the cumulative result of increases in seed and pod number. Proportionally, increased fertiliser gave much greater overall increases in seed weight per plant under cooler temperate conditions; however the yields under these conditions were so low that this had little effect compared to the high yields under tropical conditions.

3.3.8. Protein measurement

Protein content in stem, leaves and seed

The protein contents of stem and leaves were not affected by fertiliser rates of application or by the temperature treatments (Table 3.5).

Under tropical conditions the higher fertiliser (8g and 4g) treatments had a higher (P<0.05) protein content in the seed than the lower fertiliser rate. Due to the low yield from the treatments under temperate glasshouse conditions, there were insufficient seeds for the determination of seed protein content.

Table 3.5 Protein content (% D.M.) in stems, leaves and seeds of mungbean grown under tropical and temperate glasshouse conditions.

Conditions	Tropical glasshouse			Temperate glasshouse		
Treatments Plant component	2g	4g	8g	2g	4g	8g
Stems	7.1	6.8	6.9	6.7	7.3	6.8
Leaves	7.1	7.0	6.6	7.1	7.1	7.1
Seed	19.5b	22.4a	23.5a	-	-	-

In percentage seed protein content, treatments with the same letter are not different at P=0.05, DMRT.

3.4. DISCUSSION

This initial experiment examined possible nutrient level by temperature interactions with a view to establishing optimal temperature and nutrient conditions for good mungbean growth.

3.4.1. Germination and early growth

Germination and growth were completed more quickly in the warmer treatment with additional fertiliser application increasing plant growth only under the tropical conditions. Other workers (Angus et. al., 1981; Searle et al., 1980; Lawn and Ahn, 1985; Raison and Chapman, 1976) have also shown slowed germination and reduced growth of mungbean at temperatures lower than 14°C.

The minimum temperature in the temperate glasshouse (Figure 3.2) during plant growth occasionally dropped to 4°C. The overall maximum and minimum temperatures during the growing period were lower than the reported optimum (28°-30°C) temperatures (Lawn and Ahn, 1985). Mean minimum temperatures were generally below 15°C during the first five weeks; this may account for the marked reduction in growth.

The length of the phenological development stages of mungbean were also shorter in tropical

conditions (Figure 3.3); under temperate conditions, increased fertiliser concentrations did not induce any variations in the phasic development pattern of mungbean which was set by low atmospheric temperatures. Under tropical conditions, plants in 8g and 4g fertiliser treatments matured 13 and 10 days earlier respectively than from 2g. These findings are different to those of Buttery et al. (1987) who, working with white bean under field conditions, reported that maturity was delayed by the application of high rates (112 to 336 kg N/ha) of N fertiliser.

3.4.2. Plant height

The taller plants under tropical conditions suggest that mungbean has a relatively high temperature requirement. The differences in plant height between fertiliser treatments under tropical conditions suggest that mungbean also need a higher level of fertility of which is in agreement with the reports of (Edje et al., 1975; Brady, 1978; Brevedan et. al., 1978; Sinha et. al., 1988 and Mitra et. al., 1988).

The lack of response to fertiliser treatments under the temperate conditions (Figure 3.5) may be due to the slowing down of physiological process at these lower temperatures. Thus the response to applied fertiliser depends on temperature.

3.4.3. Flower number and its distribution

The number of flower bearing nodes under tropical conditions (Figure 3.6) was higher than that under temperate conditions (Figure 3.7). The total number of flowers under tropical conditions was also higher than under temperate conditions, but there was no difference between the fertiliser treatments. These results suggest that flower number and their distribution were directly related to temperature during the flowering stage.

Walsh (1991) suggested that flower and pod production and retention were widely distributed throughout the mungbean plant (from the first to eleventh node) but the maximum retention was at nodes 3 to 7; this is similar to the present results under tropical conditions (Figure 3.6).

Mitra et al., (1988) showed that % pod survival increased with a 1% foliar application of urea in a

range of mungbean cultivars under the field conditions. The % increased from 14% to 42% over the control and the highest response occurred when the foliar fertiliser was applied early (36 to 46 days after sowing) rather than later (40 to 47 days after sowing). However, in this experiment fertiliser was applied throughout the growing period up to the end of the grain filling phase. Under the temperate condition % pod set decreased with increased fertiliser application; this suggests a temperature / nutritional status interaction in pod set levels.

The percentage pod set relied on the number of flowers produced. The percentage increased under temperate conditions but these were related to the very small number of flowers produced.

3.4.4. Seed yield

Seed yield was related to the rate of applied fertiliser under both temperature treatments; high temperature greatly increased seed yield (Figure 3.9). Other researchers also reported that increased application of N to soybean during the vegetative and flowering stages increased pod number, seed size and seed yield (Hanway and Weaver, 1971; Brevedan et. al., 1978; Scarisbrick et. al., 1982; Ashour and Thalooth, 1983).

Both increased soil N, and symbiotic N increased seed yield in soybean (Harper, 1974) and 1% foliar fertiliser application improved the assimilation of carbon (Mitra et al., 1988) and increased yield by 14% to 39%. Additional application of fertiliser increased pod set, possibly through better carbon assimilation, and might have increased the export of assimilates to the sinks thus contributing to higher yield per plant under the tropical temperature conditions. Under temperate conditions, plant were unable to utilise the applied nutrients resulting in the development of deformed and parthenocarpic seeds.

3.4.5. Seed protein

Under tropical conditions the percentage seed protein produced under 8g and 4g fertiliser treatments were respectively 21% and 16% higher than that under the 2g treatment. This might be attributed to the higher rate of fertiliser utilisation under high temperature conditions and the

consequent increased nitrogen content of seeds. The higher protein content may also be associated with the active remobilisation of protein or amino acid from leaves and pod walls to the seed under tropical conditions. This is in agreement with the findings of Brevedan et. al. (1978) and Ashour and Thalooth, (1983) who also reported an increase of seed protein content from 38% to 42% due to increased application of N fertiliser in soybean.

3.5. CONCLUSIONS

Rates of growth and phenological development of mungbean have been found to depend on temperature and to a lesser extent on the rate of fertiliser application. Under tropical conditions, plant growth and development were excellent and mungbean yields increased with higher fertiliser rates. On the other hand, poor plant growth, reduced flower production, deformed pods, reduced seed set and poor per plant yield were obtained from plants grown under temperate conditions. Thus there was an interaction between temperature and plant response to fertiliser application.

This initial experiment suggested major temperature effects on growth, floral development and grain filling in mungbean; these were proportionally larger than nutritional effects. Further experimental studies examined the comparative temperature responses of a range of genotypes with a view to the possible extension of mungbean production into the cooler Tableland environment.