EFFECTS OF SINK-SOURCE MANIPULATIONS AND WATER STRESS ON FLOWER - AND POD-ABSCISSION, YIELD AND YIELD COMPONENTS OF PIGEONPEAS (Cajanus cajan L. Millsp.)

by
SOLOMON IGOSANGWA SHIBAIRO

This thesis is submitted to the University of Nairobi, in partial fulfilment of the requirement for
MASTER OF SCIENCE
IN
AGRONOMY
FACULTY OF AGRICULTURE

1988.

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signed S. Shibairo Date 21st June, 1988

Solomon Igosangwa Shibairo

This thesis has been submitted for examination with our approval as University supervisors.

Signed J. Nyabundi Date 21/6/88

Dr. J.O. Nyabundi

Signed P.Kimani Date 29/7/88

Dr. P.M. Kimani

DEDICATION

I dedicate this work to my father Javan Shibairo, mother Dina Shibairo and my son Murira Igosangwa.

ACKNOWLEDGEMENTS

A large number of people have been of assistance in preparation to this thesis. I would like to acknowledge my indebtness to Dr. J.O. Nyabundi and Dr. Kimani, P.M. of the Crop Science Department, University of Nairobi for the constructive criticisms, guidance, suggestions, encouragement and advice they offered to me during this study.

My special thanks go to the University of Nairobi for the financial support through which I was able to undertake the course. I will always remember their kindness.

I am also indebted to the technical staff of the Department of Crop Science who helped me during my field work.

Many thanks also go to my wife Philomena Igosangwa for her patience, aspiration and constant encouragement during this study.

I also thank Ms. Jane Njeri Mbugua for typing this thesis.

Last but not least, I extend many thanks to anybody who might have helped me in one way or the other during the time of this study.

S.I. SHIBAIRO, 1988.

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Two greenhouse and one field experiments were carried out at Kabete to determine the effects of sink-source ratio manipulations (deflowering and defoliation) and water stress on flower - and pod-abscission, yield and yield components of pigeonpeas. Three genotypes, 423/60, ICPL 7403 and NPP 670 were used.

In greenhouse experiments, three levels of deflowering: 0, 50 and 75% were enforced in experiment I. In experiment II, 0, 25, 50 and 75% deflowering levels were enforced. Defoliation treatments at similar levels were imposed in parallel concurrent experiments. Two watering levels of 650 mm and 325 mm per season were applied in both experiments but water was applied after 3 days in experiment I and daily in experiment II.

The same deflowering and defoliation treatments as in greenhouse experiment II were imposed in the field experiment where a line source-sprinkler irrigation system was used to apply watering treatments. Water levels in the field experiment were defined as high, medium and low, receiving a total of 219.93, 187.65 and 124.72 mm irrigation water respectively

in addition to rainfall of 412.75 mm.

Deflowering led to; decreased percent abscission, increased number of flowers formed per plant, increased 100-seed weight, and extended flowering and podding duration. Deflowering had no effect on grain yield per plant and number of seeds per pod. Mild defoliation treatments, of 25 and 50%, generally had similar effects as deflowering treatments, while the opposite occurred for the heavy defoliation treatment. 100-seed weight was not affected by defoliation treatments. In all experiments, number of pods per node was distinctly increased by deflowering and decreased by defoliation.

There was an increase in percent abscission, a decrease in number of flowers per plant, yield per plant, number of pods per plant, pods per node, 100-seed weight and a shortened flowering and podding duration in plants under severe water stress treatment of greenhouse experiment I. Mild water stress conditions, in the field experiment, decreased percent abscission while the number of flowers per plant, yield and yield attributes were not affected.

Genotypic differences were noted in the

abscission and yield attributes. Genotypes 423/60 and ICPL 7403 were more drought tolerant than genotype NPP 670. Their drought tolerance was attributed to their indeterminate growth habits.

Plants in the field experiment were larger than those in the greenhouse experiment and this explained the differences between the experiments.

Results of this study indicate that abscission in pigeonpeas may be caused by competition for photoassimilates among developing reproductive sinks. That the number of pods per node is highly responsive to manipulation of sink-source ratio suggests that competition for photosynthates is more intense at local sections surrounding each node.

1. INTRODUCTION

By the year 2000 the population of Kenya is expected to reach about 30 million (McCarthy and Mwangi, 1982). The resulting increase in food demand can be met by intensification of food production in the high rainfall areas and bringing under production more of the arid and semi-arid areas. The arid and semi-arid areas constitute about 82 percent of the land area in Kenya (Kimani, 1987). In the search for crops tolerant to climatic conditions in these marginal areas cereals, cotton and grain legumes have received considerable attention (M'Arimi, 1977). Among the food crops, grain legumes have been found to be capable of giving reasonable grain yields when other crops experience crop failure due to drought (Onim, 1981).

Pigeonpea is the most important grain legume in the marginal areas of Kenya where it is grown on approximately 115000 ha. annually (Anonymous, 1976). It is the second most important grain legume in Kenya after field beans (*Phaseolus vulgaris* L.).

Pigeonpea is generally drought resistant and survives well in areas with rainfall under 600 mm (Purseglove, 1968; Acland, 1972; Sinha, 1981). Drought resistance in pigeonpea has been attributed to its deep taproot and well-developed mass of fibrous roots (Purseglove, 1968; Acland, 1972; Sheldrake and Narayanam, 1979; Natarajan and Willey, 1980).

In ~~common~~ comparison with other grain legumes grown for seed, pigeonpeas form many more flowers than mature fruit (Subhadrabhandhu *et al*., 1978; D'Souza and Coulson, 1985). This is mainly attributed to heavy abscission of flowers and immature pods. If abscission could be prevented or decreased, yield might be increased, provided other physiological limits are not encountered. Unfortunately, the physiological factors controlling abscission are not well understood. Factors such as water stress, high temperatures, lack of or competition for assimilates, low relative humidity, plant diseases and pests and high wind velocities have been reported to enhance flower abscission (Subhadrabhandhu *et al*., 1978; Sheldrake, 1984; D'Souza and Coulson, 1985).

However, these parameters are highly dynamic, strongly influenced by conditions in the environment, and regulated differently by different physiological and genetic factors. Thus the effects of these factors on the rate of abscission are difficult to examine experimentally and this may probably explain the fact that little effort has been directed to this field.

It has been generally observed that the amount of abscission of flowers increases with the flowering period (Subhadrabhandhu et al., 1968; D'Souza and Coulson, 1985; Pandley and Singh, 1981) in pulses. This is attributed to the plants attaining a maximum capacity to maintain flowers and pods and therefore the flowers formed subsequently absciss (Subhadrabhandhu et al., 1968; D'Souza and Coulson, 1985).

Severe water stress during the reproductive period reduces yield of both vegetative and reproductive materials of many crops (Doss et al., 1974; Constable and Hearn, 1978; Keatinge and Hughes, 1981; Sinha, 1981; Akinola and Whiteman, 1974, Reddy et al., 1975). However, the vegetative growth is more sensitive to mild water stress than reproductive growth during the reproductive period (Constable and Hearn, 1978; Sinha, 1981, Kohel and Benedict, 1984; Nyabundi, 1985). Photosynthesis is also less sensitive, to mild water stress than expansive vegetative growth (Bradford and Hsiao, 1982). This implies that photosynthates can be made available for reproductive growth even after vegetative growth has stopped. It has been reported that the proportion of assimilates translocated towards the reproductive organs increases during mild water-stress conditions (Johnson and Moss, 1976; Constable and Hearn, 1978; Kohel and Benedict, 1984; Nyabundi, 1985). It may, therefore, be hypothesized that the increased translocation of assimilates towards the reproductive structures under mild water stress conditions may enhance flower and pod retention. Reduced crop yield frequently observed under such conditions may arise from fewer flower nodes and smaller photosynthetic surface area, both results of inhibited vegetative growth, rather than flower and fruit abscission (Nyabundi, 1985). Although flower abscission has been observed in pigeonpeas, little work has been done to determine the causes, especially under deficient moisture conditions. Therefore this study was carried out:-

(a) To determine the effects of sink-source manipulations on flower - and pod-abscission and grain yield of pigeonpeas.

(b) To examine the effects of water-stress induced reduction in vegetative growth on flower - and pod-abscission and grain yield of pigeonpeas.

(c) To determine whether there are genotypic differences in pigeonpeas for the effects stated in (a) and (b).

2. LITERATURE REVIEW

2.1: Flower - and Pod-abscission in Pigeonpeas and other Legumes.

Flower - and pod-abscission affects the number of pods per plant; which is the most important yield component in grain legumes (Khan and Rachie, 1972; Hicks and Pendleton, 1969; Hammerton, 1972; Akinola and Whiteman, 1974; Rao et al., 1981; Rowden et al., 1981). In beans (Phaseolus vulgaris) 35 to 80 percent flower and immature pod shedding have been reported (Subhandrabhandu, et al., 1978; Binnie and Clifford, 1980; Kamweti and Coulson, 1984; D'Souza and Coulson, 1985). Flower losses of 85 percent in soybean (Glycine max) (Van Schaik and Probst, 1958), 54 percent in cowpeas (Vigna unguiculata) and 34 percent in field peas (Pisum sativum) (Meadley and Milborn, 1970) have also been reported.

Work with pigeonpeas shows that a high proportion of flowers - in the range of 30 to 98 percent-fail to produce harvestable pods (Ariyanayagam, 1975; Narayanam and Sheldrake, 1976; Sheldrake et al., 1979; Tayo, 1980; Pandley and Singh, 1981).

The factors influencing abscission of flowers and immature pods are not well understood. It has been suggested that factors such as water stress high temperatures, low relative humidity, plant diseases and pests may enhance flower and pod-abscission (Egwatu, 1975; Subhadra bhandhu *et al*., 1978; D'Souza and Coulson, 1985; Sheldrake, 1984). Other factors that have been implicated include inadequate pollination, competition from earlier formed pods and other sinks within the plant and hormonal factors (Subhadrabhandhu *et al*., 1978; Binnie and Clifford, 1980; Sheldrake, 1984; D'Souza and Coulson, 1985). It follows, therefore, that the sink-source ratio, may play a big role in the shedding of flowers and pods. Few studies have been undertaken to investigate the effects of sink-source ratio on flower - and pod-abscission of pigeonpeas, and hence the need for such studies.

2.2 Effects of Sink-source Manipulations on Flower - and Pod-abscission and Yield of Pigeonpeas.

2.2.1 Effects of Sink Manipulations (Deflowering).

Flowers and fruits form the most active sinks during reproductive growth (Kramer, 1949; Neales and Incoll, 1968; Donhoff and Shibles, 1970; Ciha and Brun, 1978; Lawn, 1981; Nyabundi, 1985). It therefore follows that competition for assimilates among the flowers and pods may be decreased if some flowers and pods are removed.

Experiments carried out to study effect of floral bud removal on performance of soybeans revealed that upto 1/3 of the floral buds could be removed without affecting yield per plant (Hicks and Pendleton, 1969). Similarly, in field experiments carried out at Hyderabad, India, removal of all flowers and young pods for upto 5 weeks after the beginning of flowering had little or no effect on final yield of pigeonpeas. The flowering period of the deflowered plants was extended but flower removal treatments had little effect on number of seeds per pod or seed weight (Sheldrake *et al.*, 1979). Tayo (1980) reported that pigeonpeas could compensate completely for loss of all developing pods upto two weeks after the beginning of flowering. Pandley and Singh (1981) found that removal of upto two thirds of the flowers throughout the reproductive period had no significant effects on yield and yield components.

These studies suggest that mild flower and pod removal does not result in reduced number of pods per plant. Possibly the natural shedding was reduced in the other sections of the treated plants. If shedding of reproductive structures in pigeonpeas is a result of lack of assimilates within a given node, then translocation must have occurred from the leaves subtended on the section of the plant which had all flowers and pods removed.

Heavy flower and pod removal experiments have resulted in increase in seed size and 100-seed weight, weight per pod and seed weight per pod though the final yield per plant was reduced due to less pods per plant formed from the few flowers that remained after deflowering (Hicks and Pendleton, 1969; Tayo, 1980). This gives further indirect evidence that translocation occurred. In soybean the protein contents of the seed increased with the removal of floral buds while the oil content decreased as bud removal increased (Hicks and Pendleton, (1969).

Lawn and Brun (1974) reported that growth rate of soybean pods at mid pod fill exceeds that of the total tops, possibly indicating mobilization and translocation of previously stored assimilates from other plant parts into pods.

There seems to be genotypic differences on the effects of different sink strengths on assimilate partitioning. Barnett and Pearce (1983) found that the hybrid maize (Zea mays L.), which had the greatest sink strength because of large stalks and ears (more and large kernels), had the largest capacity to store assimilates when compared to inbreds (with low sink strengths). As a result hybrids had the advantage of storing more assimilate when the source-sink ratio was high that is when some ears are removed and remobilizing more assimilate to other sinks when the source-sink ratio was low (on leaf removal). Similarly, in experiments carried out at Hyderabad, it was reported that there was no significant reduction in yield when flowers were removed 1 - 7 weeks in in medium and early cultivars of pigeonpeas. It is not known whether other genotypes would respond in the same way.

2.2.2 Effects of Source Manipulation (Defoliation)

The leaf area on a plant is a measure of its assimilatory (source) capacity (Tayo, 1982; Laffite and Travis, 1984). Wilson (1972) expressed source strength (capacity) as the product of the state variable source size (leaf area) and the rate variable activity (rate of photosynthesis per unit leaf area). The leaf area development in pigeonpeas is known to influence the pattern of growth, development and yield of the plant (Hammerton, 1975; Ciha and Brun, 1978, Barnett and Pearce, 1983; Wilkerson *et al*., 1984).

Simulated experiments on the effects of reduced assimilatory capacity showed similar results. Barnett and Pearce (1983) reported that defoliation resulted in a decrease in the weights of stalks, leaf sheaths, ears and stalk total non-structural carbohydrates in maize. Similarly defoliation resulted in lower stem weight to length ratios and high leaf weights in groundnuts (*Arachis hypogaea*) (Wilkerson *et al*., 1984).

In pigeonpeas, it has been shown that defoliation led to shorter plants, reduced leaf area and number and lower dry matter accumulated in the various parts of the plant. As a consequence of reduced growth, seed yield was reduced in proportion to the amounts of defoliation (Tayo, 1982). Similar results have also been reported by Egli and Leggett (1976), Pandley and Singh (1981); Hammerton (1975) and at Hyderabad, India, (ICRISAT 1975-1976). Yield reductions were almost wholly due to decrease in pod number per plant, seeds per pod and 100-seed weight being little affected. This conforms with what has been reported in defoliation experiments of groundnuts (Wikerson et al., 1984). However, these results contradict what Barnett and Pearce (1983) found in maize where the cob and grain weights and 100-kernel weights were reduced by leaf defoliation.

The effects of defoliation also seem to depend on or vary with the degree of the source reduction. Hammerton (1975) found no significant effect on total number of pods per plant with mild defoliation, suggesting that the leaves removed were photosynthetically ineffective due to ageing and/or mutual shading/or that the plants photosynthetic capacity, due to improved light penetration, exceeded that necessary to sustain the pod-loads. However, severe defoliation did significantly reduce total pod number. Similar results have been obtained at Hyderabad (ICRISAT 1976, 1977) and by Pandley and Singh (1981) in pigeonpeas. Hammerton (1972), Turnipseed (1972) and Egli and Leggett (1976) found similar results when soybeans were subjected to severe defoliation. However, Pandley and Singh (1981) found that the decrease in yield per plant was not proportional to defoliation. This suggests that the plants were able to compensate for the loss of leaf area.

Work done at Hyderabad (ICRISAT 1976, 1977) showed that in some cultivars defoliation during the vegetative phase had little effect on final yield but in other cultivars yield was significantly reduced. Similar experiments with $^{14}CO_2$ fed pigeonpeas have shown that there are cultivar differences in the amounts of ^{14}C fixed in seeds, podwalls and stems (Setter et al., 1984). This suggests that the amount of seed yield per plant and percent abscission may be different in genotypes with different source-sink ratios.

From the above review it is clear that little work has been done to find whether the yield decrease per plant, due to defoliation, is caused by higher rates of flower - and pod-abscission, or lower flower and bud initiation. It is also clear that the reasons for flower - and pod-abscission are primarily physiological. There is, therefore, need for further studies on the effects of sink-source manipulations on flower - and pod-abscission, in different genotypes of pigeonpeas to provide further tests on source limitations theory regarding abscission.

2.3 The Effects of Water stress on Flower - and Pod-abscission.

Availability of water is one ecological factor of major adaptative significance to a long-duration crop such as pigeonpeas, where part or all of the growth cycle may occur during periods of low rainfall. Pigeonpea is comparatively deep rooted and is therefore capable of utilizing stored soil water at depth, even exceeding 150 cm in long-duration cultivars (Sheldrake and Narayanam, 1979). Pigeonpeas can also adapt to drought stress through osmotic adjustment; relative to other pulses substantial adjustment in osmotic potential can occur in response to water stress (Lawn, 1981). The osmotic adjustment delays the ceasation of turgor driven processes such as leaf expansion, stomatal opening, root growth and metabolic processes.

Results of various trials show that severe stress during the reproductive period reduces yield of many crops. Doss et al (1974), and Constable and Hearn (1978) found that severe stress during grain filling stage reduced the yield of soybean. Garrity et al (1984) and Constable and Hearn (1978) reported that severe stress during the reproductive period reduced grain and dry matter yield by as much as 37 percent in sorghum (Sorghum bicolor (L.). However, it is reported that photosynthesis per unit leaf area was not decreased by water stress. The rate of apparent canopy photosynthesis was reduced by 14 to 26 percent but this was solely a result of lower leaf area in the stressed treatments (Garrity et al., 1984). Reduction in leaf area was an important mechanism for transpiration control under drought stress.

In the All-India Coordinated Project on Improvement of Pulses, short duration pigeonpea varieties were tested and the results indicated that the yield varied with location. For example the yield of 'Prabhat' was 1389 kg/ha at Hissar with average rainfall of 398 mm, and 1236 kg/ha at Pantnagar with average rainfall of 1412 mm (Sinha, 1981). It would, therefore, appear that yield of pigeonpea is not related to water availability alone. Probably the distribution of rainfall or temperature or soils could be alternative factors influencing yield. Nevertheless, it has been shown that pigeonpeas suffer damage from both poor availability of water (Lawn, 1981; Keatinge and Hughes, 1981; Nyabundi, 1980; Sinha, 1981), and excess water (Sinha, 1981). Generally in terms of grain yield, water stress is critical to plants at the time when reproductive organs are formed (Salter and Goode, 1967; Kramer, 1949). In a study of the effects of water stress on pigeonpeas, Nyabundi (1980) found that plants bearing buds, flowers and young pods showed signs of wilting before those still in vegetative state. It has been reported that water stress results in smaller plants and reduced yield of both vegetative and reproductive material (Keatinge and Hughes, 1981; Sinha, 1981;

Akinola and Whiteman, 1974 and Reddy *et al.*, 1975).

The effects of water stress on yield components have been reported by several workers. Sinha (1981), reported that increase in yield, due to irrigation, resulted from increase in number of pods, seeds per pod, and seed weight, in pigeonpeas. In the same studies, it was shown that application of 50 to 90 kgs of water per pot between the flowering period and harvesting of the crop resulted in slight decrease of number of seeds and number of pods per plant. This shows that excess water application is detrimental in pigeonpeas.

It has been reported that vegetative growth is more sensitive to water stress than the reproductive growth (Kohel and Benedict, 1984; Constable and Hearn, 1978; Sinha, 1981; Nyabundi, 1985) during the reproductive period. This physiological behaviour can be explained by the observation that flowers and fruits form a major sink during the reproductive growth. Johnson and Moss (1976) reported that the proportion of assimilates translocated to the grain was increased following water stress in wheat. Constable and Hearn (1978), similarly, showed that water stress increased the proportion of dry matter in the seeds of soybean compared to the stem. Kohel and Benedict (1984) showed that water stress resulted in increase in the rate of dry matter accumulation in the seeds and dec- rease in the rate of dry weight accumulation in fibres of cotton (*Gossypium* spp). Nyabundi (1985) found that tomato plants under mild stress conditions exhibited higher fruit biomass than well watered plants early in the fruiting period. Sinha (1981) reported that harvest index (HI) was increased in pigeonpeas under water stress. If abscission is a result of competition among flowers and other plant sinks for limited resources, it may be hypothesized that flower and pod retention may be enhanced by water stress as relatively more assimilates will be translocated to the reproductive structures. Results of flower-tagging experiments in tomatoes (Nyabundi, 1985) showed that non-irrigated plants retained close to 80 percent of the flowers in the first two to three trusses as opposed to 35 percent for the irrigated plants. The above observations suggest that less flower abscission had occurred in the stressed plants over this period. It is not known whether this could be true for pigeonpeas, hence part of the need for this study.

3. MATERIALS AND METHODS

3.1 Location

This study was conducted at Kabete Field Station in the Faculty of Agriculture, University of Nairobi. The altitude of the station is approximately 1940 metres and it lies within latitudes 1° 14' 20" S to 1° 15' 15" S and longitudes 36° 44' to 36° 45' 20 E (Wamburi, 1973). It has a bimodally distributed rainfall, with the long rains starting from late March to June and short rains from late October to December. The mean annual rainfall of the station is 925 mm and the mean potential evapotranspiration is 1363 mm (Brown and Cocheme, 1969).

The soils at the experimental site are deep red eutric nitosols containing 60 percent clay particles. The clay mineral is predominantly kaolin while the parent material is the Kabete trachyte. The pH of the soil ranges between 5.2 and 7.2 for the top soil, and 5.2 and 7.7 for the subsoil (Nyandat and Michieka, 1970).

3.2 Plant Materials

Two glasshouse and one field experiment

were conducted. Pigeonpea genotypes 423/60 and ICPL 7403 were used for greenhouse experiment I. The same genotypes along with genotype NPP 670 were used for greenhouse experiment II and the field experiment.

Genotype 423/60 is early to medium maturing of indeterminate growth habit selected at Katumani dryland research station, Machakos, Kenya. Genotype ICPL 7403 is early maturing with indeterminate growth habit selected at ICRISAT, India. NPP 670 is also an early maturing genotype but with determinate growth habit developed in Kenya by Nairobi University Pigeonpea Project.

3.3.1 Greenhouse Experiment I

The planting medium used was prepared by mixing forest soil, ballast and animal manure in the ratios of 3:1:1 by volume. This ratio had been used successfully for growth of pigeonpeas in pots (Okiror, personal communications). The pots contained 10 kilogrammes of the potting mixture. Prior to planting the pots were watered daily for three days to allow the mixture to settle.

The deflowering and defoliation experiments were run concurrently but separately. Each experiment was laid out in a split-plot design with three replications. Two water treatments were the main plots. The genotypes at three deflowering (or defoliation in the concurrent experiment) levels were in the sub plots, consisting of a pot each.

Eight seeds were planted in each pot on 17th July, 1986. The seeds had earlier been dressed with "benlate" powder to protect against soil pathogens. Thinning to two plants per pot was done three weeks after planting. The plants were watered daily until they reached 95 percent flowering stage (when 95 percent of the plants had at least one open flower). Insect pests (Pod fly, pod borers and sucking insects) were controlled by spraying with 30 ml "Rogor E" (dimethoate 40 percent E.C.) plus 180 ml DDT 25 percent in 16 litres of water every two weeks from the start of flowering.

At 95 percent flowering stage the following treatments were imposed:-

(i) Application of 750 ml of water after every three days (W_1). This is equivalent to 650 mm of rainfall in 120 days and is comparable to field conditions of pigeonpea growing areas.

(ii) Application of 375 ml of water after every three days (W_2) per pot This is equivalent to 325 mm of rainfall in 120 days.

Plants under treatment (i) and (ii) were described as non-stressed and stressed plants respectively.

The deflowering treatments were:-

(i) Control - 0% deflowering (F_1). No flowers were manually removed in these treatments.

(ii) 50% deflowering (F_3). Flower clusters at alternate nodes were removed manually.

(iii) 75% deflowering (F_4). Flower clusters at every second, third and fourth node were manually removed also.

Similarly in the separate concurrent experiment the defoliation treatments were:-

(i) Control - 0% defoliation (D_1). No leaves were manually removed in this treatment.

(ii) 50% defoliation (D_3),

(iii) 75% defoliation (D_4).

The defoliation treatments D_3 and D_4 were carried out by removal of leaves at similar nodes as done in the deflowering experiment.

Both deflowering and defoliation treatments were repeated at weekly intervals until maturity.

3.3.2 Greenhouse Experiment II.

The second set of greenhouse experiment was planted on 22nd November, 1986. The treatments in this experiment were generally similar to those in greenhouse experiment I except for the following modifications:-

(i) Application of 250 ml of water per day (W_1) per pot. This is equivalent to 650 mm of rainfall in 120 days and is comparable to field conditions in pigeonpea growing areas.

(ii) Application of 125 ml of water per

day (W_2) per pot. This is equivalent to 325 mm rainfall. It should be noted that the total amount of water applied was equal to that in the first greenhouse experiment.

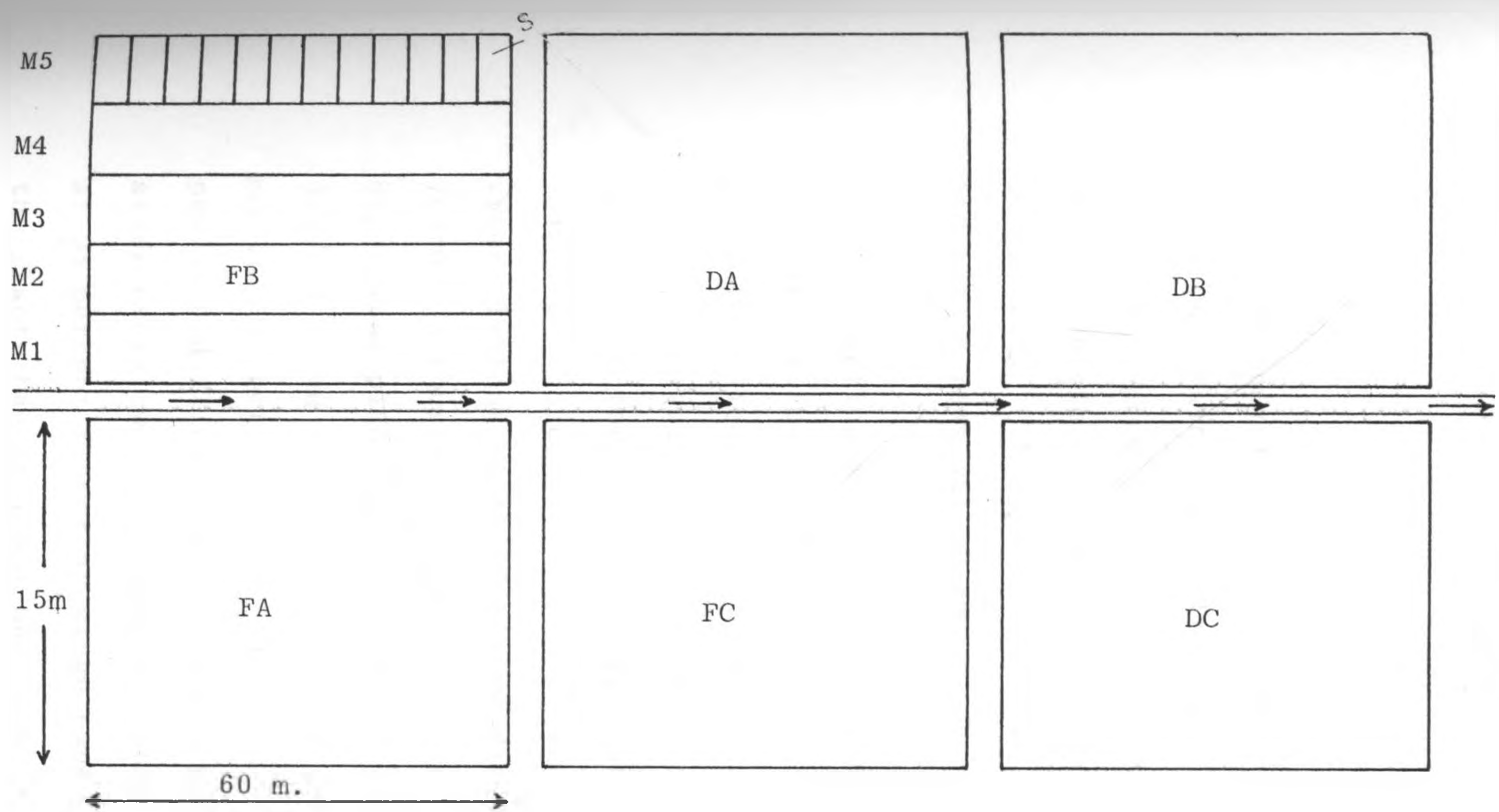
(iii) 25% deflowering (F_2) and 25% defoliation (D_2) (in the concurrent separate experiment) treatments were also included in the sink-source ratio manipulation treatments.

Temperature and sunshine data were recorded at a weather station 0.1 km from the greenhouses where the experiments were conducted (See Appendix 1). Temperature inside the greenhouse was not monitored but the general trend (not individual values) is likely to have been similar to that recorded at the weather station.

3.3.3 The Field Experiment.

The deflowering and defoliation experiments were run concurrently but separately. The experiment was laid out in a split-plot design with three replications (See Fig. I). Five irrigation treatments were arranged in the main plots (Data were

Fig. 1. The Field Experiment Layout



 Main sprinkler line.

FA, FB, FC are replications of the deflowering experiment.

DA, DB, DC are replications of the defoliation experiment.

M1, M2, M3, M4, M5 are the main-plots.

S - A sub-plot.

collected only in the first (M1), third (M3) and fifth (M5) main-plots). Genotypes at four deflowering(or defoliation in the concurrent experiment) levels were in the sub-plots, consisting of four rows each five metres long. The spacing between rows was 75 cm and within rows was 30 cm.

Planting was done on 16th October, 1986 at the rate of three seeds per hole. Diammonium phosphate fertilizer was applied at the rate of 100 kg/ha. The seeds had earlier been dressed in "benlate" powder for protection against soil pathogens. Thinning to one plant per hole was done three weeks after planting on the first weeding. The second, third and fourth weedings were done 56, 104 and 132 days after planting, respectively. The plants were sprayed using a mixture of 30 ml. "Rogor E" and 180 ml. "DDT" 25 percent in 16 litres of water to control insect pests (pod flies, pod borers and pod sucking insects) after every two weeks from the start of flowering. At 95 percent flowering stage (when 95 percent of the plants had at least one open flower), identical sub-plot treatments to those in the second greenhouse experiment were imposed.

A line source sprinkler irrigation system was used to apply irrigation treatments. This consisted of a sprinkler system of 2m risers. A controlled pressure of 1.8 kg/cm^2 on the line schieved consistent water gradient which zeroed at a distance of 15 metres. Catch cans on 75 cm stand were placed in a direction perpendicular to the sprinkler line at a distance of 1.5 m, 7.5 m, 7.5m and 13.5 m from the main sprinkler line. This enabled evaluation of irrigation amounts in main-plots M1, M3 and M5 where the plants were described as under high, medium and low water levels, respectively. Rainfall, pan evaporation, sunshine and atmosphere data were recorded at a weather station 0.8 km. from the experimental site (see Appendix II and III). Evaporation and rainfall data enabled the computation of an approximate water balance which was used as a guide to irrigation dates. Irrigation water was applied when the amount of evapotranspiration exceeded the amount of water applied and/or the amount of rainfall. The amount of irrigation water applied is shown in Table 1 and Figure 2. The water distribution by sprinklers was non-linear so that the amounts received by high and medium watering levels were not noticeably different.

The second irrigation on 13th February was followed by a total of 80 mm rainfall which was recorded in the week that followed. Rain obviated the need for irrigation until the end of

Table 1. Irrigation dates and amount of irrigation water applied for the field experiment - 1986/87.

Main plot	Dates / Water level	Irrigation amounts (mm)					Total (mm)
		29-1-87	13-2-87	25-2-87	4-3-87	11-3-87	
M1	High	28.03	56.06	39.32	53.89	42.63	219.93
M3	Medium	20.59	41.19	34.53	49.75	41.59	187.65
M5	Low	8.98	18.97	28.74	38.11	29.92	124.72

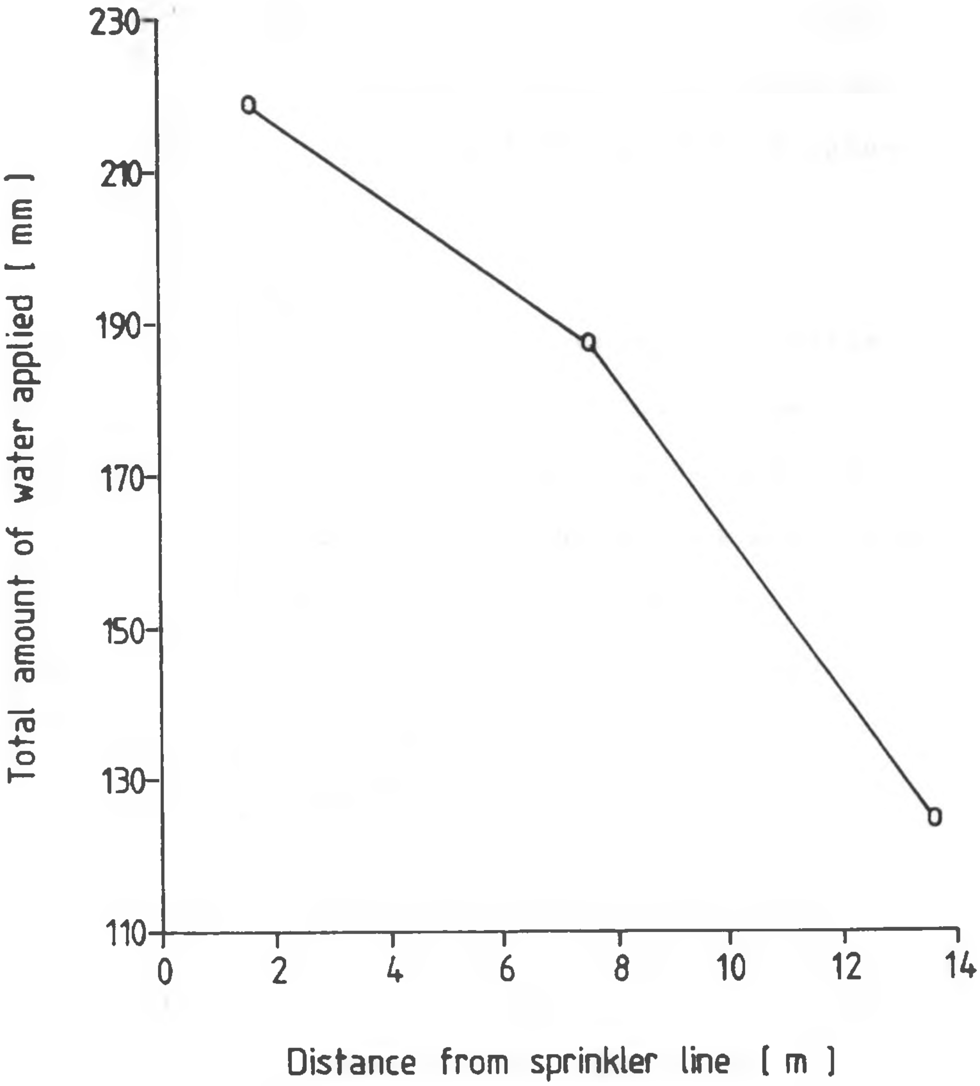


Fig. 2. The total amount of water applied at various points from the sprinkler line. Field experiment - 1986/87.

that month. Consequently the results reported in this study are mainly on water shortage during the month of March which was a grain filling stage for the pigeonpeas. The January to March 533.3 mm pan evaporation exceeded the amount of rainfall by 353.9 mm.

To determine the degree of drought in water levels M_1, M_3 and M_5, soil moisture content was measured by gravimetric method on 11-2-87 and 1-3-87, that is 2 and 3 days before the second and fifth irrigation days, respectively. The soil moisture was then expressed as a percentage of the weight of undried soil sample (Appendix IV).

3.4 Measurement of Parameters.

For both glasshouse and field experiments studies on flower abscission and pod retention were done using the tagging method. In the field experiment, four plants to be tagged had been selected early before the plants flowered in each sub-plot. Flowering and abscission were monitored at every node of the plants. After every five days each node with newly opened flowers was tagged with a tie on tag, and its location recorded. A pod was defined as an ovary whose tip protruded beyond the calyx. By inspecting every five days, the developmental process of each flower was followed while the number of flowers and pods that abscissed were recorded.

Harvesting of the pods was done by hand-picking on 15th April, 1987. The pods were then separated into seeds and pod-walls then oven-dried at 80°C for 48 hours.

The following information was recorded:-

(1) Percent flower - and pod-abscission,

(2) Total number of open flowers per plant,

(3) Total number of pods per plant,

(4) Number of pods per flower node,

(5) Number of seeds per pod,

(6) 95% flowering date,

(7) Time to maturity,

(8) Flowering and podding duration,

(9) Yield per plant and 100-seed weight data were only taken in the second greenhouse and field experiments.

3.5 Analysis of Data

Data from all the experiments were analysed as outlined by Steel and Torrie (1980) for a split-plot experiment.

Data on corrected number of open flowers per plant was computed by the following formula:-

$$C = N \times \frac{100}{100-x}$$

Where C - is the corrected number of open flowers per plant.

N - is the actual number of flowers on the plant.

x - is the number of flowers manually removed from the plant.

Corrected number of open flowers per plant is that which could have formed if abscission and manual removal of flowers did not occur.

4. RESULTS

4.1 Greenhouse experiments - 1986 and 1986/87

Since the data from the greenhouse experiments were generally similar, their results are presented together.

4.1.1 Effects of Sink-source Ratio Manipulations and Water-stress on Flower - and Pod-abscission in Pigeonpeas.

4.1.1.1 Effects on percent flower - and pod-abscission.

Flower removal treatments affected percent flower - and pod-abscission in greenhouse experiment I. Deflowering reduced abscission in non-stressed more than in stressed plants (Table 2 and Figure 3). The decrease in percent abscission was only significant (P = 0.05) at higher deflowering levels (75 % deflowering). In non-stressed plants the effect was more pronounced in genotype 423/60 than genotype ICPL 7403. In stressed plants percent abscission increased at 50 % deflowering then decreased significantly at 75

Table 2. Effects of deflowering and water stress on flower - and
pigeonpea genotypes.

Greenhouse experiment I - 1986.

		Percent deflowering	
Water level	Genotype	0	50
Non-stressed	423/60	79.05a*	83.7a
	ICPL 7403	78.57a	76.33a
	Mean	78.81a	80.02a
Stressed	423/60	84.75b	96.71a
	ICPL 7403	80.45a	81.22a
	Mean	82.6ab	88.97a
Overall mean		80.71a	84.49a

* Means in a row followed by the same letter are not significan
LSD 0.05 between genotypes and deflowering levels = 6.76%
LSD 0.05 between genotypes and deflowering at different water l
CV (a) = 5.13%
CV (b) = 7.21%

CV(a) is the coefficient of variability for main plots.
cv(b) is the coefficient of variability for subplots.

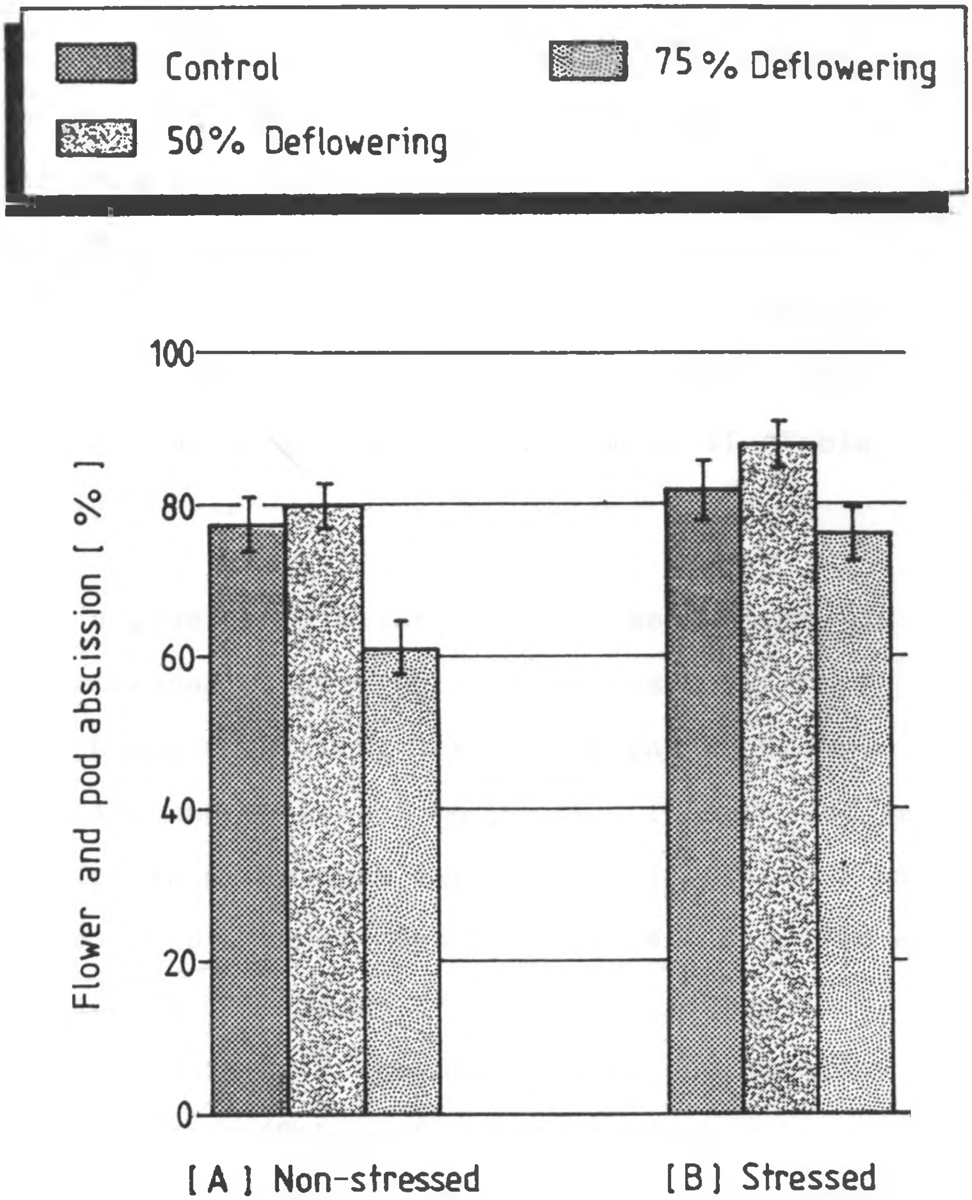


Fig. 3. Effects of deflowering and water stress on percent flower-and pod-abscission in pigeonpeas. Greenhouse experiment I - 1986.

percent deflowering treatment in genotype 423/60, while genotype ICPL 7403 was not affected by deflowering treatments. In general water stress increased abscission in both genotypes in all deflowering treatments. The different treatments had no significant effect on percent flower- and pod-abscission in greenhouse experiment II (Table 3 and Figure 4).

In general defoliation increased abscission in non-stressed plants, but not stressed plants in greenhouse experiment I (Table 4 and Figure 5). Defoliation had no effect on percent flower- and pod-abscission in greenhouse experiment II (Table 5 and Figure 6). As a whole, genotype NPP 670 had a lower abscission in comparison to the other 2 genotypes. This was true in both the deflowering and defoliation experiments (Tables 2, 3, 4 and 5).

4.1.1.2 Number of open flowers per plant.

There was a decrease in the number of open flowers per plant with increase in deflowering in both stressed and non-stressed plants (Tables

Table 3. Effects of deflowering and water stress on flower - and pod-abscission in pigeon-pea genotypes.

Greenhouse experiment II - 1986/87

Water level	Genotype	Percent deflowering				Mean
		0	25	50	75	
Non-stressed	423/60	80.23*	83.3	74.4	71.46	77.35
	ICPL 7403	80.77	74.83	75.83	73.27	76.18
	NPP 670	75.4	69.57	72.8	69.61	71.85
	Mean	78.80	75.9	74.34	71.45	75.12
Stressed	423/60	84.47	81.03	87.21	82.17	83.72
	ICPL 7403	87.73	86.23	77.6	85.37	84.23
	NPP 670	82.53	79.43	81.5	83.07	81.63
	Mean	84.91	82.23	82.1	83.54	83.19
Overall mean		81.86	79.07	78.22	77.49	79.16

Differences between treatments were not significant (P = 0.05)

C.V.(a) = 10.05%

C.V.(b) = 10.42%

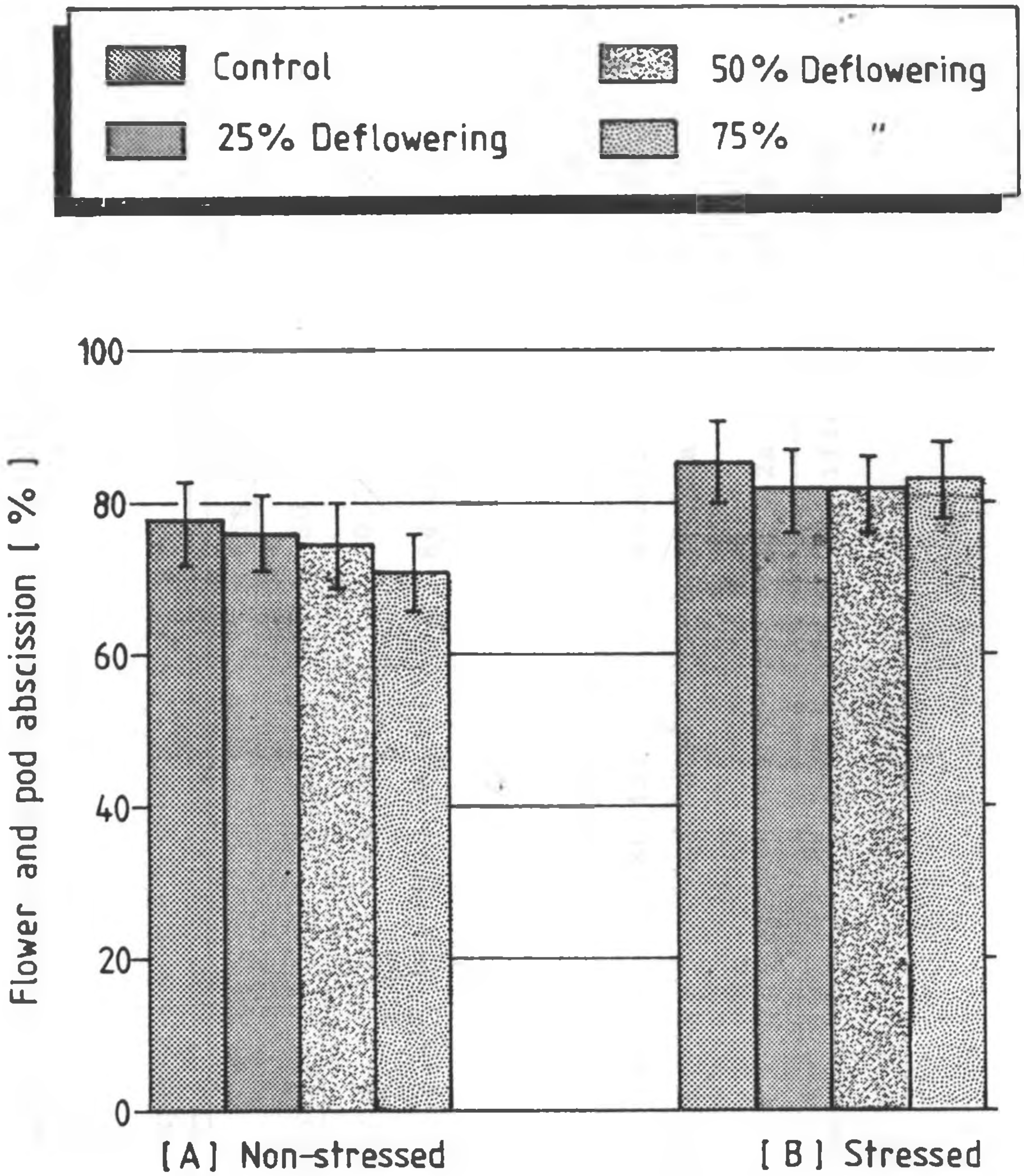


Fig. 4. Effects of deflowering and water stress on flower- and pod-abscission in pigeonpeas. Greenhouse Experiment II - 1986/87.

Table 4. Effects of defoliation and water stress on flower - and pod-abscission of pigeon-pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent defoliation 0	50	75	Mean
Non-stressed	423/60	79.05b*	80.71ab	87.98a	82.58
	ICPL 7403	78.57b	84.85 ab	86.83a	83.42
	Mean	78.81b	82.78 ab	87.41a	83.00
Stressed	423/60	84.75b	91.88a	85.82a	87.48
	ICPL 7403	80.45a	83.05a	84.52a	82.67
	Mean	82.6a	87.47a	85.17a	85.08
Overall mean		80.71a	85.12a	86.29a	84.04

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between defoliation treatments = 6.18%

C.V.(a) = 4.71%

C.V.(b) = 6.11%

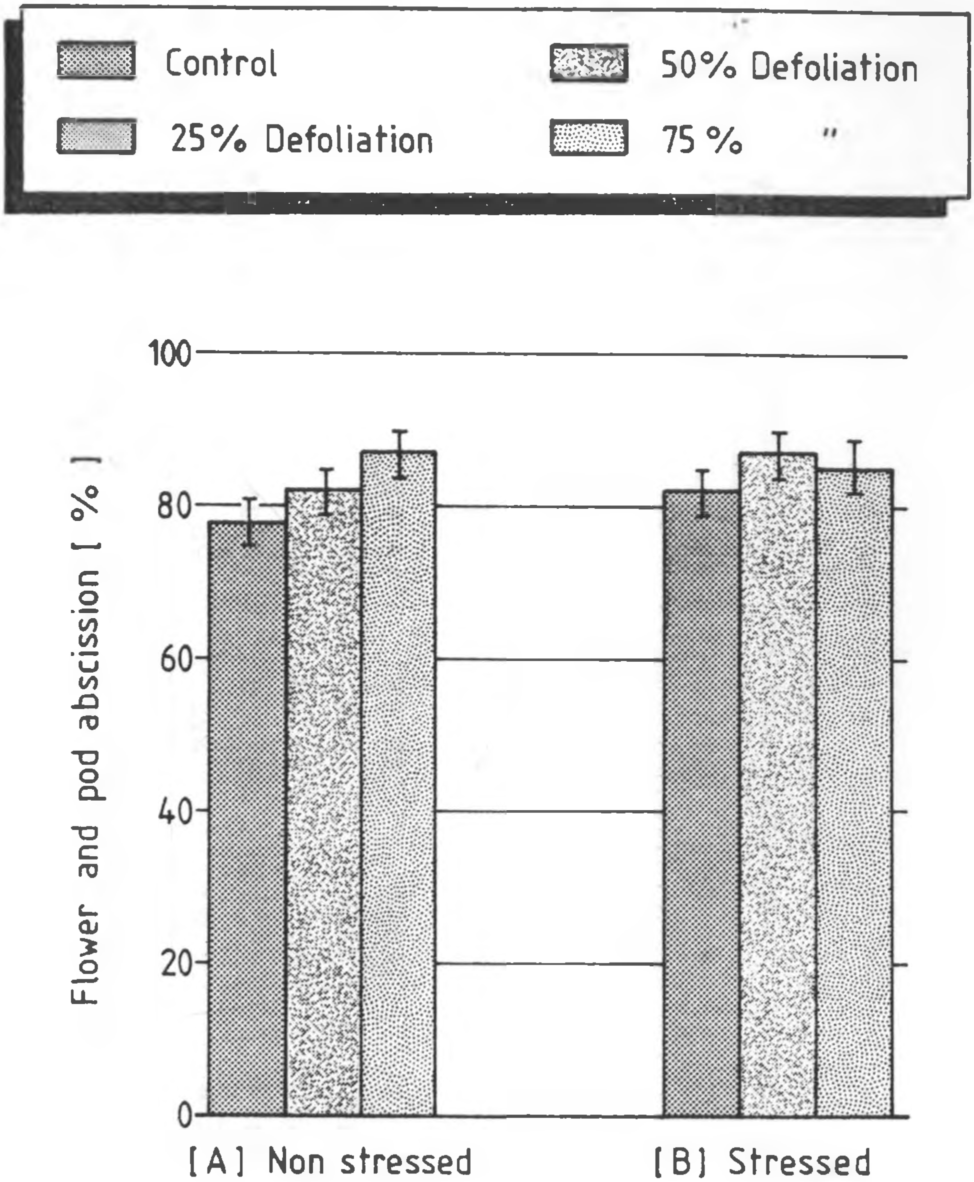


Fig. 5. Effects of defoliation and water stress on percent flower - and pod-abscission of pigeonpeas. Greenhouse experiment 1 - 1986.

Table 5. Effects of defoliation and water stress on flower - and pod-abscission in pigeon-pea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent defoliation				Mean
		0	25	50	75	
Non-stressed	423/60	80.23*	87.23	80.37	87.63	83.86
	ICPL 7403	80.77	83.00	80.73	87.93	83.11
	NPP 670	75.4	71.8	78.43	77.37	75.83
	Mean	78.8	80.68	79.84	84.31	80.93
Stressed	423/60	84.47	82.5	87.5	81.6	84.02
	ICPL 7403	87.73	84.23	90.1	86.4	87.12
	NPP 670	82.53	78.57	80.67	88.6	82.59
	Mean	84.91	81.77	86.09	85.53	84.58
Overall mean		81.86	81.22	82.97	84.92	82.76

*Differences between defoliation treatments were not significant (P = 0.05)

LSD 0.05 between genotypes = 6.61%

C.V.(a) = 8.59%

C.V.(b) = 6.85%

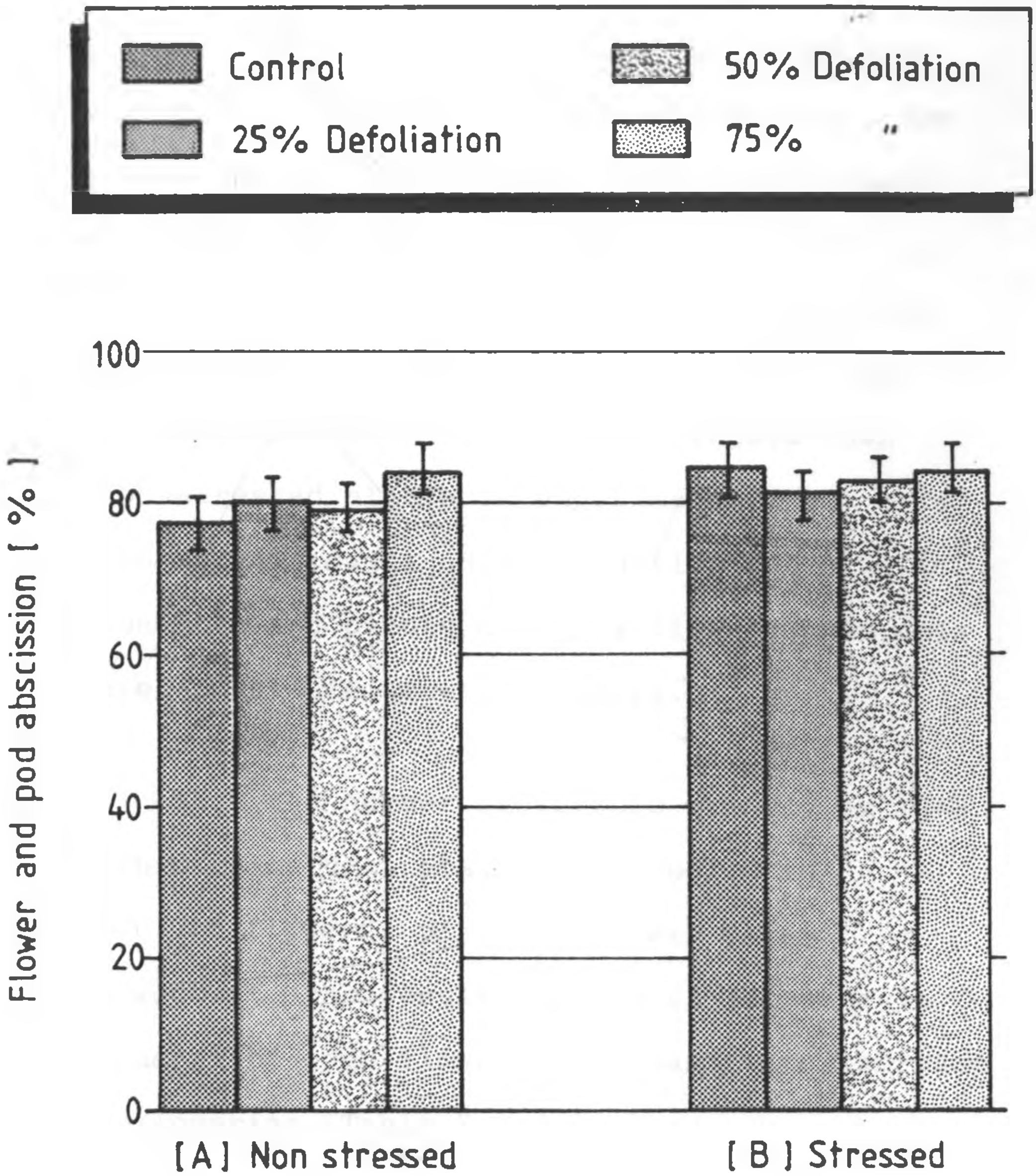


Fig. 6. Effects of defoliation and water stress on flower - and pod-abscission of pigeonpeas. Greenhouse experiment II - 1986/87.

6 and 7). However, the decrease was proportionately less than expected from deflowering. The decrease was more in stressed than non-stressed plants in greenhouse experiment II. Comparing the genotypes, the decrease was more pronounced in genotype NPP 670 than the other 2 genotypes. The control had more flowers in stressed than in non-stressed plants in experiment II but this was not significant. However, deflowered plants in non-stressed plants had more flowers than deflowered plants in stressed plants.

When the number of flowers removed by hand and through natural abscission (corrected number of flowers per plant) was taken into account, the results showed an increase in the number of open flowers per plant with increase in deflowering (Table 8 and 9).

Water stress decreased the number of flowers per plant in all genotypes. Genotype 423/60 had more open flowers per plant than genotype ICPL 7403 in non-stressed plants, while the opposite occurred in stressed plants. Overall genotype NPP 670 had the lowest number compared to the other two genotypes.

Table 6. Effects of deflowering and water stress on number of open flowers per plant in pigeonpea genotypes.

Greenhouse experiment I - 1986

Water level	Genotype	Percent deflowering 0	50	75	Mean
Non-stressed	423/60	184.42a*	114.0b	104.5b	134.31
	ICPL7403	114.25a	74.0b	49.83c	79.36
	Mean	149.34a	94.0b	77.17b	106.84
Stressed	423/60	74.72a	50.0b	41.0b	55.24
	ICPL 7403	85.75a	55.0b	45.5b	62.08
	Mean	80.24a	52.5b	43.25b	58.66
Overall mean		114.79a	73.25b	60.21b	82.75

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and deflowering 22.13 flowers.

LSD 0.05 between genotypes and deflowering at different water levels = 32.65 flowers

C.V.(a) = 8.33%

C.V.(b) = 20.9%

Table 7. Effects of deflowering and water stress on number of open flowers per plant in pigeonpea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering				Mean
		0	25	50	75	
Non-stressed	423/60	139.0a*	148.33a	140.67a	131.5a	139.88
	ICPL 7403	100.77a	136.0a	99.33a	105.9a	110.5
	NPP 670	183.17a	130.83b	114.1b	118.83b	136.73
	Mean	140.98a	138.39a	118.03a	118.74a	129.04
Stressed	423/60	154.03a	122.67ab	104.67b	88.23b	117.4
	ICPL 7403	193.77a	148.17b	110.33b	130.0b	145.57
	NPP 670	171.67a	65.28b	64.00b	73.34b	93.58
	Mean	173.16a	112.04b	93.0b	97.19b	118.85
Overall mean		157.07a	125.21a	105.52b	107.96b	123.94

*Means in a row followed by the same letter are not significantly different (P = =.05)

LSD 0.05 between deflowering levels = 40.95 flowers

LSD 0.05 between deflowering and genotypes at different water levels = 59.83 flowers.

C.V.(a) = 12.08%

C.V.(b) = 28.31%

Table 8. The effects of deflowering and water stress on corrected number of open flowers per plant in pigeonpea genotypes.

Greenhouse experiment I-1986.

Water level	Genotype	Percent deflowering 0	50	75	Mean
Non-stressed	423/60	188.42b*	228ab	418a	276.81
	ICPL 7403	114.30b	148b	199.33a	153.88
	Mean	149.36b	188b	308.67a	215.34
Stressed	423/60	74.72b	100b	164a	112.91
	ICPL 7403	85.75b	110b	182a	125.92
	Mean	80.24b	105b	173a	119.41
Overall mean		114.79b	146.5b	240.84a	167.38

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between water levels = 61.92 flowers.

LSD 0.05 between genotypes and deflowering = 62.27 flowers.

LSD 0.05 between genotypes at different water levels = 96.98 flowers.

C.V. (a) = 50.2%

C.V. (b) = 50.1%

Table 9. The effects of deflowering and water stress on corrected number of open flowers per plant in pigeonpea genotypes.

Greenhouse experiment II - 1986/87

Water level	Genotype	Percent deflowering				Mean
		0	25	50	75	
Non-stressed	423/60	139c*	197.5b	281.3b	526.0a	285.95
	ICPL 7403	100.77c	181.1bc	251.7b	422.7a	239.07
	NPP 670	183.20b	174.4b	228.2b	475.33a	265.28
	Mean	140.99b	184.33b	253.73b	474.68a	263.43
Stressed	423/60	154.03b	163.2b	209.33b	352.91a	219.87
	ICPL 7403	193.8b	197.5b	220.7b	520a	283.00
	NPP 670	171.7b	86.95b	128.0b	293.0a	169.91
	Mean	173.18b	149.22b	186.01b	388.64a	224.26
Overall mean		157.08b	166.77b	219.87b	431.66a	243.85

*Means in a row followed by the same letter are not significantly different (P = 0.05)

LSD 0.05 between deflowering levels = 111.7 flowers

LSD 0.05 between genotypes at different water levels = 315.2 flowers.

C.V. (a) = 14.24%

C.V. (b) = 38.04%

There was a decrease in number of open flowers per plant with increase in defoliation in genotype 423/60 in non-stressed plants of greenhouse experiment I (Table 10). However, defoliation had no effect on the number in both genotypes in stressed plants. Increase in defoliation decreased the number of open flowers per plant in stressed than in non-stressed plants in greenhouse experiment II (Table 11). The number of open flowers per plant increased with increase in defoliation treatments of upto 50% but decreased at 75% in genotypes 423/60 and 7403, but the number consistently decreased with increase in defoliation in genotype NPP 670 in non-stressed plants. In stressed plants the number decreased with increase in defoliation in genotypes ICPL 7403 and NPP 670 while 423/60 was not affected.

Water stress reduced the number of open flowers per plant in all genotypes in greenhouse experiment I (Table 10). As observed under the deflowering experiment, genotype 423/60 had more flowers than ICPL 7403 in non-stressed plants while the opposite occurred in stressed plants.

Table 10. Effects of defoliation and water stress on number of open flowers per plant in pigeonpea genotypes.

Greenhouse experiment I - 1986

Water level	Genotype	Percent defoliation 0	50	75	Mean
Non-stressed	423/60	184.42a*	127.83c	155.83b	155.03
	ICPL 7403	114.25a	109.67a	97.83a	107.25
	Mean	149.34a	118.75a	126.83a	122.79
Stressed	423/60	74.72a	75.33a	84.33a	78.29
	ICPL 7403	85.75a	83.5a	75.0a	81.42
	Mean	80.24a	79.42a	79.92a	79.86
Overall mean		114.29a	99.08a	103.37a	101.32

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between water levels = 21.05 flowers

LSD 0.05 between genotypes = 26.21 flowers

LSD 0.05 between genotypes at different water levels = 38.47 flowers

C.V.(a) = 8.01%, C.V. (b) = 20.58%

Table 11. Effects of defoliation and water stress on number of open flowers per plant in pigeonpea genotypes.

Greenhouse experiment II - 1976/77.

Water level	Genotype	Percent defoliation				Mean
		0	25	50	75	
Non-stressed	423/60	139.0a	139.33a	147.83a	76.67b	125.71
	ICPL 7403	100.77b	140.0a	156.0a	127.67ab	131.11
	NPP 670	183.17a	103.5b	104.1b	88.17b	119.73
	Mean	140.98a	127.61ab	135.98b	97.5b	125.52
Stressed	423/60	154.03a	158.0a	121.33a	132.67a	141.51
	ICPL 7403	193.77a	141.67b	158.67ba	124.33b	154.61
	NPP 670	171.67a	87.33b	79.33b	16.67c	88.75
	Mean	173.16a	129.0b	119.78b	91.22c	128.29
Overall mean		157.07a	128.31b	127.88b	94.36c	126.91

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and defoliation = 20.86 flowers

LSD 0.05 between genotypes and defoliation at different water levels = 71.61 flowers.

C.V.(a) = 15.14%

C.V.(b) = 28.46%.

4.1.2. Effects of Sink-Source Ratio Manipulation and Water stress on Yield and Yield Components of Pigeonpeas.

4.1.2.1 Grain yield per plant

Generally in both stressed and non-stressed plants, deflowering, genotypic and water stress treatments had no significant effect on grain yield per plant in the greenhouse experiment II (Table 12).

Grain yield per plant decreased from 14.05 to 13.63, 11.33 and 7.95 grammes per plant for the control, 25, 50 and 75 % defoliation treatments, respectively (Table 13). Genotype NPP 670 had a higher grain yield per plant than the other two genotypes in non-stressed plants while the opposite occurred in stressed plants. There was no difference between genotypes 423/60 and ICPL 7403. Generally water stress decreased yield per plant but this was not significant (P = 0.05).

4.1.2.2. Number of pods per plant

Deflowering treatments decreased the number

Table 12. Effects of deflowering and water stress on grain yield (grammes) per plant in pigeonpea genotypes.
Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
Non-stressed	423/60	15.55	17.28	15.29	16.47	16.15
	ICPL 7403	12.92	19.95	9.75	19.04	15.42
	NPP 670	24.26	18.56	19.93	23.94	21.67
	Mean	17.58	18.59	14.99	19.82	17.75
Stressed	423/60	10.87	10.16	6.69	6.67	8.59
	ICPL 7403	10.77	9.94	10.28	8.59	9.89
	NPP 670	9.92	7.77	6.88	9.07	8.41
	Mean	10.52	9.29	5.96	8.11	8.97
Overall mean		14.05	13.94	10.48	13.97	13.36

Differences between means were not significant (P = 0.05).

C.V. (a) = 4.03%

C.V. (b) = 4.39%

Table 13. Effects of defoliation and water stress on grain yield (grammes) per plant in pigeonpea genotypes.

Greenhouse experiment II - 1986/87.

		Percent defoliation				
Water level	Genotype	0	25	50	75	Mean
Non-stressed	423/60	15.55a*	11.39a	11.78a	5.75b	11.12
	ICPL 7403	12.92ab	13.72a	15.31a	9.12b	12.77
	NPP 670	24.26a	25.67a	18.83b	14.85b	20.9
	Mean	17.58a	16.93a	15.31a	9.91b	14.93
Stressed	423/60	10.87a	13.33a	8.99ab	6.38b	9.89
	ICPL 7403	10.77a	10.85a	7.54a	8.56a	9.42
	NPP 670	9.92a	6.79ab	5.52b	3.09b	6.33
	Mean	10.52a	10.32a	7.35ab	5.99b	8.55
Overall mean		14.05a	13.63a	11.33ab	7.95b	11.74

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD(0.05) between genotypes and defoliation = 4.38 grammes.

LSD(0.05) between genotypes and defoliation at different water levels = 9.67 grammes.

C.V.(a) = 41.2%

C.V.(b) = 32.0%.

of pods per plant at 50% deflowering then increased the number of 75% deflowering in greenhouse experiment I (Table 14). However the number decreased with increase in deflowering in genotype ICPL 7403 in non-stressed plants. Genotype 423/60 was not affected by deflowering in stressed plants.

Genotype NPP 670 had the same number of pods per plant as 423/60 in non-stressed plants but a lesser number than 423/60 and ICPL 7403 in stressed plants (Table 15). Generally the number of pods per plant was higher in genotype 423/60 than in ICPL 7403 in non-stressed plants. There was no significant difference between genotypes in stressed plants in both parallel experiments (Table 14, 15).

The number of pods per plant was decreased by 50 and 75% defoliation treatments in both parallel experiments (Tables 16 and 17). However the number was only decreased by the 75% defoliation level in non-stressed plants in genotypes 423/60 and ICPL 7403. All defoliation treatments decreased the number in genotype NPP 670 with the decrease being pronounced

Table 14. Effects of deflowering and water stress on number of pods per plant in pigeon pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent deflowering 0	50	75	Mean
Non-stressed	423/60	36.67a*	23.52b	35.27a	31.82
	ICPL 7403	22.42a	18.17ab	15.88b	18.82
	Mean	29.55a	20.55b	25.58ab	25.32
Stressed	423/60	11.03a	6.67a	9.33a	9.01
	ICPL 7403	16.33a	7.17b	12.33a	11.94
	Mean	13.68a	6.92b	10.83ab	10.48
Overall mean		21.62a	13.88b	18.20ab	17.89

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between water levels = 11.2 pods per plant

LSD 0.05 between genotypes and deflowering = 4.413 pods per plant.

LSD 0.05 between genotypes and deflowering at different water levels = 21.26 pods per plant.

C.V.(a) = 60.9%; C.V.(b) = 13.43%.

Table 15. Effects of deflowering and water stress on number of pods per plant in pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

		Percent deflowering				
Water level	Genotype	0	25	50	75	Mean
Non-stressed	423/60	28.97*	32.33	42.67	38.17	35.54
	ICPL 7403	24.17	31.0	24.17	29.17	27.13
	NPP 670	42.1	40.83	25.57	32.50	35.25
	Mean	31.75	34.72	30.8	33.28	32.64
Stressed	423/60	22.87	28.5	13.5	21.67	21.64
	ICPL 7403	20.00	19.5	24.00	19.00	20.63
	NPP 670	20.93	9.57	10.17	13.17	13.46
	Mean	21.27	19.19	15.89	17.95	18.57
Overall mean		26.51	26.96	23.35	25.61	25.61

*Difference between deflowering treatments were not significant (P = 0.05).

LSD 0.05 between genotypes at different water levels = 22.36 pods per plant.

C.V.(a) = 40.56%.

C.V.(b) = 48.36%.

Table 16. Effects of defoliation and water stress on number of pods per plant in pigeon pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent defoliation 0	50	75	Mean
Non-stressed	423/60	36.67a*	23.67b	18.33c	26.22
	ICPL 7403	22.42a	15.00b	10.33c	15.92
	Mean	29.55a	19.34b	14.33c	21.07
Stressed	423/60	11.03a	6.33b	9.4ab	8.92
	ICPL 7403	16.33a	12.67ab	11.33b	13.44
	Mean	13.68a	9.5a	10.37a	11.18
Overall mean		21.61a	14.42b	12.35b	16.13

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between water levels = 9.47 pods per plant.

LSD 0.05 between genotypes and deflowering = 4.28 pods per plant.

LSD 0.05 between genotypes and deflowering at different water levels = 10.3 pods per plant.

C.V.(a) = 23.65%

C.V.(b) = 22.03%

Table 17. Effects of defoliation and water stress on number of pods per plant in pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

		Percent defoliation				
Water level	Genotype	0	25	50	75	Mean
Non-stressed	423/60	28.97a*	19.33b	25.17a	10.67c	21.04
	ICPL 7403	24.17 b	23.5b	25.83a	15.33c	22.21
	NPP 670	42.1a	28.17b	25.17b	22.67b	29.53
	Mean	31.75a	23.67b	25.39ab	16.22c	24.27
Stressed	423/60	22.87b	29.17b	17.5b	22.67b	23.05
	ICPL 7403	20.00a	22.5a	15.83b	15.5b	18.46
	NPP 670	20.93a	5.83b	5.0b	6.5b	9.51
	Mean	21.27a	19.17a	12.78b	14.89b	17.03
Overall mean		26.51a	21.42a	19.08b	15.16b	20.65

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between defoliation levels = 6.91 pods per plant.

LSD 0.05 between genotypes and defoliation at different water levels = 14.1 pods per plant.

C.V.(a) =35.72%
C.V. (b) = 28.68%

in stressed plants.

Generally water stress decreased the number of pods per plant in all the greenhouse experiments (Tables 14, 15, 16 and 17).

4.1.2 (c) <u>Number of pods per node.</u>

The number of pods per node decreased at 50 percent deflowering then increased at 75 % deflowering in stressed plants in greenhouse experiment I (Table 18). However, the number increased with increase in deflowering in non-stressed plants of greenhouse experiment I and in all plants in greenhouse experiment II (Table 19). Genotype 423/60 had a higher number of pods per node than genotype ICPL 7403 in non-stressed plants while the opposite occurred in stressed plants in greenhouse experiment I. There was no genotypic difference in number of pods per node in greenhouse experiment II. Generally stress reduced the number though the difference was not statistically significant (P = 0.05) in greenhouse experiment II.

The number of pods per node decreased with increase in defoliation in all plants in greenhouse

Table 18. Effects of deflowering and water stress on number of pods per node in pigeon pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent deflowering			Mean
		0	50	75	
Non-stressed	423/60	1.17b*	1.42b	2.71a	1.77
	ICPL 7403	1.09b	1.32b	2.45a	1.62
	Mean	1.13b	1.37b	2.58a	1.69
Stressed	423/60	0.85b	0.20c	1.29a	0.78
	ICPL 7403	0.99ab	0.67b	1.35b	1.01
	Mean	0.92a	0.44b	1.32a	0.89
Overall mean		1.03b	0.90b	1.95a	1.29

*Means in a row followed by the same letter are not significantly different (P = 0.05).
LSD 0.05 between water levels = 0.095
LSD 0.05 between genotypes and deflowering = 0.422 pods per node.
C.V. (a) = 2.94%.
C.V. (b) =27.07%.

Table 19. Effects of deflowering and water stress on number of pods per node in pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering				Mean
		0	25	50	75	
Non-stressed	423/60	0.807c*	0.89c	1.63b	2.89a	1.554
	ICPL 7403	0.893b	0.98b	1.23b	2.23a	1.333
	NPP 670	0.98b	1.34b	1.16b	2.05a	1.383
	Mean	0.893b	1.07b	1.34b	2.39a	1.423
Stressed	423/60	0.737b	0.84b	0.63b	1.57a	0.944
	ICPL 7403	0.55b	0.893b	1.323ba	1.747a	1.128
	NPP 670	0.623b	0.707b	1.03ba	1.48a	0.96
	Mean	0.637b	0.813b	0.994b	1.599a	1.011
Overall mean		0.765b	0.942b	1.167b	1.995a	1.217

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between deflowering levels = 0.513 pods per node.

C.V.(a) = 29.27%

C.V.(b) = 36.11%

experiment I (Table 20) and in non-stressed plants in experiment II (Table 21).

The number of pods per node decreased with defoliation in genotype NPP 670 more than in the other 2 genotypes in stressed plants but not non-stressed plant. Genotype 423/60 had more pods per node than ICPL 7403 in nonstressed plants while the opposite occurred in stressed plants in greenhouse experiment I. NPP 670 had more pods per node in non-stressed plants but a less number than the other 2 genotypes in stressed plants.

4.1.2.4 Number of seeds per pod.

The number of seeds per pod decreased at 50% deflowering and increased at 75% deflowering (Table 22). Similar trend was observed in experiment II (Table 23) although the differences were not significant. Genotypes ICPL 7403 and 423/60 had a higher number of seeds per pod at higher deflowering levels of 75 % in non-stressed plants of greenhouse experiment II.

The number of seeds per pod was not affected

Table 20. Effects of defoliation and water stress on number of pods per node in pigeon pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent defoliation 0	50	75	Mean
Non-stressed	423/60	1.17a*	0.89b	0.64c	0.90
	ICPL 7403	1.09a	0.81b	0.55c	0.82
	Mean	1.13a	0.85b	0.59c	0.86
Stressed	423/60	0.85a	0.45b	0.64b	0.65
	ICPL 7403	0.99a	0.90ab	0.74b	0.88
	Mean	0.92a	0.68b	0.69b	0.76
Overall mean		1.03a	0.76b	0.64b	0.81

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and defoliation = 0.22 pods per plant.

LSD 0.05 between genotypes and defoliation at different water levels = 0.418 pods/node.

C.V.(a) = 28.15%

C.V.(b) = 22.53%

Table 21. The effects of defoliation and water stress on number
pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

		Percent defoliatio		
Waterlevel	Genotype	0	25	50
Non-stressed	423/60	0.807a	0.73a	0.87a
	ICPL 7403	0.893a	0.62b	0.593b
	NPP 670	0.98a	1.123a	0.92a
	Mean	0.893a	0.824a	0.794ab
Stressed	423/60	0.737a	0.793a	0.60a
	ICPL 7403	0.55a	0.633a	0.493a
	NPP 670	0.623a	0.32ab	0.347ab
	Mean	0.637a	0.582a	0.48a
Overall mean		0.765a	0.703a	0.637ab

*Means in a row followed by the same letter are not significantl

LSD 0.05 between genotypes and defoliation = 0.2081 pods/node.

LSD 0.05 between genotypes at different water levels = 0.426/noc

C.V. (a) = 30.49%

C.V. (b) = 26.67%

Table 22. The effects of deflowering and water stress on number of seeds per pod in pigeon pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent deflowering: 0	50	75	Mean
Non-stressed	423/60	4.13a*	3.57a	4.15a	3.95
	ICPL 7403	4.13a	3.72a	4.2a	4.02
	Mean	4.13a	3.65a	4.18a	3.98
Stressed	423/60	3.04a	2.53a	2.38a	2.65
	ICPL 7403	3.39a	1.83b	2.77a	2.66
	Mean	3.21a	2.18b	2.58ab	2.66
Overall mean		3.67a	2.91b	3.38ab	3.32

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between deflowering = o.737 seeds/pod

C.V.(a) = 17.25%

C.V.(b) = 18.44%

Table 23. Effects of deflowering and water stress on number of seeds per pod in pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
Non-stressed	423/60	4.48*	3.9	3.9	4.07	4.09
	ICPL 7403	4.65	4.63	3.97	4.07	4.33
	NPP 670	3.92	3.8	3.73	4.53	3.99
	Mean	4.35	4.11	3.87	4.22	4.14
Stressed	423/60	3.95	3.73	3.73	4.27	3.92
	ICPL 7403	4.03	4.30	3.77	4.00	4.03
	NPP 670	3.33	3.50	3.53	3.53	3.47
	Mean	3.77	3.84	3.68	3.93	3.81
Overall mean		4.06	3.98	3.77	4.08	3.97

*There was no significant difference between deflowering treatments (P = 0.05)

LSD 0.05 between genotypes = 0.552 seeds per pod.

C.V.(a) = 10.09%

C.V.(b) = 11.92%

by defoliation in both greenhouse experiments I and II (Table 24 and 25). The number of seeds per pod was more in genotype ICPL 7403 than in genotype 423/63 (Table 25). Genotype NPP 670 had lower number of seeds per pod than the other two. Stress decreased the number of seeds per pod in greenhouse experiment II but the decrease was not significant in greenhouse experiment I (Table 24).

4.1.2.5 100-Seed weight.

Deflowering treatments had no effect on 100-seed weight of all the plants (Table 26). Similarly the weight was not affected by defoliation (Table 27). Water stress significantly reduced 100-seed weight in all genotypes and in all deflowering levels. Genotype NPP 670 had a higher 100-seed weight than the other two genotypes in both stressed and non-stressed plants.

4.1.3 Effects of Sink-Source Ratio Manipulation and Water stress on Days to Maturity and Duration of Flowering and Podding in Pigeonpeas.

Deflowering and defoliation treatments were started at 95% flowering stage. There was no

Table 24. Effects of defoliation and water stress on number of seeds per pod in pigeon-pea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent defoliation 0	50	75	Mean
Non-stressed	423/60	4.13*	3.32	4.04	3.83
	ICPL 7403	4.13*	4.13	3.52	3.93
	Mean	4.13	3.73	3.78	3.88
Stressed	423/60	3.04	2.44	3.02	2.83
	ICPL 7403	3.39	3.51	3.95	3.62
	Mean	3.21	2.97	3.49	3.23
Overall mean		3.67	3.35	3.64	3.55

*There was no significant difference between deflowering treatments (P = 0.05).

LSD 0.05 between genotypes at different water levels = 1.202 seeds per pod.

C.V.(a) = 12.4%

C.V.(b) = 12.14%

Table 25. Effects of defoliation and water stress on number of seeds per pod in pigeon pea genotype.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent defoliation				Mean
		0	25	50	75	
Non-stressed	423/60	4.48*	4.33	4.77	4.27	4.46
	ICPL 7403	4.65	4.77	4.1	4.43	4.49
	NPP 670	3.92	4.00	4.20	3.77	3.97
	Mean	4.35	4.37	4.36	4.16	4.31
Stressed	423/60	3.95	4.13	3.93	3.47	3.87
	ICPL 7403	4.03	4.47	4.3	4.2	4.25
	NPP 670	3.33	3.2	3.37	2.8	3.18
	Mean	3.77	3.93	3.87	3.49	3.77
Overall mean		4.06	4.15	4.11	3.82	4.04

*There was no significant difference between defoliation treatments (LSD 0.05).

LSD 0.05 between water levels = 0.373 seeds per pod.

C.V.(a) 5.26%

C.V.(b) 11.54%.

Table 26. The effects of deflowering and water stress on 100-seed weight (grammes) in pigeonpea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering 0	24	50	75	Mean
Non-stressed	423/60	11.58*	13.06	12.04	12.62	12.33
	ICPL 7403	12.58	13.89	12.45	15.02	13.49
	NPP 670	19.17	21.84	18.01	20.49	19.88
	Mean	14.44	16.29	14.17	16.04	15.23
Stressed	423/60	10.29	10.75	12.15	20.37	13.39
	ICPL 7403	12.37	13.07	12.03	13.29	12.69
	NPP 670	16.42	17.45	19.31	15.59	17.19
	Mean	13.03	13.76	14.49	16.43	14.43
Overall mean		13.74	15.03	14.33	16.23	14.83

*There was no significant difference between deflowering treatments (P = 0.05).

LSD 0.05 between water levels = 1.396 grammes

LSD 0.05 between genotypes = 2.77 grammes

C.V.(a) = 5.48%

C.V.(b) = 16.41%.

Table 27. Effects of defoliation and water stress on 100-seed weight (grammes) in pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
Non-stressed	423/60	11.58*	12.38	13.65	10.52	12.03
	ICPL 7403	12.58	12.65	10.88	12.51	12.16
	NPP 670	19.17	21.07	18.83	19.11	19.54
	Mean	14.44	15.36	14.45	14.05	14.58
Stressed	423/60	10.29	9.29	11.02	11.37	10.49
	ICPL 7403	12.37	10.42	12.33	10.87	11.75
	NPP 670	16.42	13.05	11.35	14.02	13.71
	Mean	13.03	10.92	11.57	12.42	11.98
Overall mean		13.74	13.14	13.01	13.23	13.28

*There was no significant difference between defoliation treatments (P = 0.05).

LSD 0.05 between water levels = 1.041 grammes.

LSD 0.05 between genotypes = 1.72 grammes.

LSD 0.05 between genotypes at different water levels = 4.77 grammes.

C.V.(a) = 4.46%; C.V.(b) = 11.07%.

significant genotypic differences at the 95% flowering stage between genotypes 423/60 and ICPL 7403 in both experiments. Genotypes 423/60 and ICPL 7403 reached the stage after 103 and 105.9 days respectively in greenhouse experiment I. The plants took a shorter period in experiment II with genotypes ICPL 7403, 423/60 and NPP 670 taking 88.11, 94.02 and 102.36 days respectively to reach the 95 percent flowering stage.

4.1.3 (a) Days to maturity.

The end of the period of the first flower flush and drying of the pods was taken as an indicator of days to maturity.

Deflowering had no effect on days to maturity in experiment I (Table 28). There was an increase in the period with increase in deflowering in genotypes 423/60 and ICPL 7403 though the increase was not significant (Table 29). Generally deflowering treatments had no effect on the period in genotype NPP 670.

Days to maturity decreased with increase in defoliation (Table 30) though the difference

Table 28. Effects of deflowering and water stress on days to maturity in pigeon peas. Greenhouse experiment I - 1986.

		Percent deflowering			
Water level	Genotype	0	50	75	Mean
Non-stressed	423/60	163.42*	166.33	159.0	162.92
	ICPL 7403	155.33	165.17	148.67	156.39
	Mean	159.38	165.75	153.84	159.66
Stressed	423/60	163.47	170.17	174.5	169.38
	ICPL 7403	154.42	174.17	166.67	165.09
	Mean	158.95	172.17	170.59	167.23
Overall mean		159.16	168.96	162.21	163.44

*There was no significant difference between deflowering treatments (P = 0.05).

LSD 0.05 between genotypes 11.34 days

C.V.(a) = 3.05%

C.V.(b) = 5.26%.

Table 29. Effects of deflowering and water stress on days to maturity in pigeonpea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering				Mean
		0	25	50	75	
Non-stressed	423/60	168.9*	171.0	174.83	173.17	171.98
	ICPL 7403	163.67	168.5	170.5	172.73	168.85
	NPP 670	170.17	174.5	170.0	171.33	171.5
	Mean	167.58	171.33	171.78	172.41	170.78
Stressed	423/60	153.17	155.33	167.0	171.33	161.71
	ICPL 7403	155.6	166.5	161.83	156.5	160.11
	NPP 670	168.5	160.83	164.33	169.33	165.75
	Mean	159.09	160.89	164.39	165.72	162.52
Overall mean		163.34	166.11	168.08	169.07	166.65

*There was no significant difference between treatments.

C.V.(a) = 4.6%

C.V.(b) = 4.75%.

Table 30. The effects of defoliation and water stress on days to maturity in pigeon pea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
Non-stressed	423/60	168.9ab*	174.83a	157.17b	152.67b	163.39
	ICPL 7403	163.67a	161.83ba	158.83ba	149.0b	158.33
	NPP 670	170.17a	158.0a	156.8a	155.83a	160.20
	Mean	167.58a	164.89ab	157.6ab	152.5b	160.64
Stressed	423/60	153.17a	151.83a	143.67a	151.5a	150.04
	ICPL 7403	155.6a	140.17b	138.5b	113.33c	136.9
	NPP 670	168.5a	165.5a	166.5a	145.0b	161.38
	Mean	159.09a	152.5a	149.5ab	136.61b	149.43
Overall mean		163.34a	158.69ab	153.58ab	144.56b	155.04

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and deflowering = 14.96 days

LSD 0.05 between genotypes and deflowering at different water levels = 26.46 days.

C.V.(a) = 7.11%; C.V. (b) = 8.26

Table 31. The effects of defoliation and water stress on days to maturity in pigeonpea genotype. Greenhouse experiment I - 1986.

Water level	Genotype	Percent defoliation 0	50	75	Mean
Non-stressed	423/60	163.42*	169.17	159.5	164.03
	ICPL 7403	155.33	147.83	135.33	146.16
	Mean	159.38	158.5	147.42	155.09
Stressed	423/60	163.47	153.17	155.5	157.38
	ICPL 7403	154.42	143.17	140.3	145.96
	Mean	158.95	148.17	147.9	151.67
Overall mean		159.16	153.34	147.66	153.38

*There was no significant difference between defoliation treatments (P = 0.05).

LSD 0.05 between genotypes = 17.02 days.

C.V.(a) = 3.46%

C.V.(b) = 9.21%.

was not significant in greenhouse experiment I (Table 31). The days to maturity decreased in genotypes 423/60 and ICPL 7403, but not genotype NPP 670, with increase in defoliation in non-stressed plants (Table 30). However, the days decreased in genotypes ICPL 7403 and NPP 670 but not genotype 423/60 in stressed plants in greenhouse experiment II. In general genotype ICPL 7403 matured earlier than 423/60 which in turn matured earlier than NPP 670.

4.1.3 .2 Flowering and podding duration.

There was no significant difference between genotypes 423/60 and ICPL 7403 in the flowering and podding duration in both experiments (Table 32 and 33).

The flowering and podding duration was longer in genotypes 423/60 and ICPL 7403 than in genotype NPP 670 in non-stressed plants. However, there was no difference between the genotypes in stressed plants.

The flowering and podding duration decreased

Table 32. The effects of deflowering and water stress on flowering and podding duration in pigeonpea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent deflowering 0	50	75	Mean
Non-stressed	423/60	60.83*	61.0	55.67	59.17
	ICPL 7403	48.08	57.33	49.33	51.58
	Mean	54.46	59.17	52.5	55.38
Stressed	423/60	59.72	64.5	69.5	64.57
	ICPL 7403	52.5	71.5	62.0	62.0
	Mean	56.11	68.00	65.75	63.29
Overall mean		55.28	63.58	59.13	59.34

*There was no significant difference between deflowering treatments (P = 0.05)

LSD 0.05 between water levels = 12.48 days

C.V.(a) = 8.47%

C.V.(b) = 14.98%.

Table 33. Effects of deflowering and water stress on flowering and podding duration in pigeonpea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
Non-stressed	423/60	77.13*	80.33	81.5	85.67	81.16
	ICPL 7403	80.83	80.0	78.0	89.00	81.96
	NPP 670	70.57	66.0	72.67	71.17	70.10
	Mean	76.18	75.44	77.39	81.95	77.74
Stressed	423/60	54.17	61.00	75.00	76.33	66.63
	ICPL 7403	73.77	83.00	67.00	67.67	72.86
	NPP 670	64.67	48.83	53.67	78.83	61.5
	Mean	64.2	64.28	65.22	74.28	69.99
Overall mean		70.19	69.86	71.31	78.11	72.37

*There was no significant difference between deflowering treatments.

LSD 0.05 between water levels = 6.27 days

LSD 0.05 between genotypes = 10.91 days

LSD 0.05 between genotypes at different water levels = 15.71 days.

C.V.(a) = 4.94%; C.V.(b) = 12.96%.

Table 34. The effects of defoliation and water stress on flower

in pigeonpea genotypes.

Greenhouse experiment I - 1986.

Water level	Genotype	Percent defoliation	
		0	50
Non-stressed	423/60	60.83*	52.5
	ICPL 7403	48.08	46.67
	Mean	54.46	49.59
Stressed	423/60	59.72	54.83
	ICPL 7403	52.5	42.17
	Mean	56.11	48.5
overall mean		55.28	49.04

*There was no significant difference between defoliation treatm

LSD 0.05 between genotypes = 17.64 days

C.V. (a) = 13.71%

C.V. (b) = 29.79%.

Table 35. Effects of defoliation and water stress on flowering and podding duration in pigeonpea genotypes.

Greenhouse experiment II - 1986/87.

Water level	Genotype	Percent defoliation				Mean
		0	25	50	75	
Non-stressed	423/60	77.13a	82.83a	58.0b	55.0b	68.24
	ICP 7403	80.83a	77.67ab	61.5b	61.17b	70.29
	NPP 670	70.57a	53.67b	52.47b	53.00b	57.43
	Mean	76.18a	71.39ab	57.32b	56.39b	65.32
Stressed	423/60	54.17a	62.17a	54.17a	59.83a	57.59
	ICPL 7403	73.77a	61.67ab	53.33b	23.67c	53.11
	NPP 670	64.67a	57.67ab	55.00ab	47.33b	56.17
	Mean	64.2a	60.5a	54.17ba	43.61b	55.62
Overall mean		70.19a	65.95ab	55.94ab	50.0b	60.47

*Means in a row followed by the same letter are not significantly different ($P = 0.05$).

LSD 0.05 between defoliation = 16.32 days.

C.V.(a) = 12.12%

C.V.(b) = 19.13%.

with increase in defoliation in non-streesed than in stressed plants though the decrease was not significant in experiment I (Table 34 and 35).

In stressed plants the decrease in flowering and podding duration was pronounced in genotypes NPP 670 and ICPL 7403 but not in genotype 423/60. In general genotypes 423/60 and ICPL 7403 had the same flowering and podding duration that was longer than that of NPP 670.

4.2 THE FIELD EXPERIMENT - 1986/87

4.2.1 Effects of Sink-Source Ratio Manipulation and Water levels on Flower - and Pod-Abscission in Pigeonpeas.

4.2.1 (a) Percent flower-and pod-abscission

Results of flower tagging experiment showed that flower shedding was decreased with increase in deflowering (Table 36). This was significant at 50 and 75% deflowering treatments in genotypes 423/60 and ICPL 7403 and and at 75% deflowering treatment in genotype NPP 670 in medium water levels. Percent abscission increased from high to medium water levels then decreased at low water levels. The difference was only significant between the medium and low water levels.

Defoliation treatments affected flower retention in different ways. 25 and 50% defoliation treatments had no effect on percent abscission in high and medium water levels (Table 37). However there was a decrease in percent abscission at 25 percent defoliation in low water levels. 75% defoliation increased abscission. Decrease in abscission at mild defoliation

Table 36. Effects of deflowering and water level on percent flower - and pod-abscission of pigeonpea genotypes.

Field experiment - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	58.35a*	57.41a	51.75ab	47.31b	53.70
	ICPL 7403	70.25a	62.31b	63.03b	58.19b	63.44
	NPP 670	69.78a	72.03a	73.81a	71.33a	71.74
	Mean	66.1a	63.9a	62.8a	58.9a	62.96
Medium	423/60	58.71b	64.58a	54.38b	53.88b	57.89
	ICPL 7403	74.68a	68.33b	54.17c	55.69c	63.22
	NPP 670	74.86a	74.68a	76.68a	63.71b	72.48
	Mean	69.4a	69.2a	61.8b	57.8b	64.53
Low	423/60	58.66a	49.31b	43.61c	51.36b	50.74
	ICPL 7403	62.28b	71.94a	58.61b	62.78b	63.9
	NPP 670	69.7a	67.25a	69.78a	68.25a	68.75
	Mean	63.6a	62.8a	57.3b	60.8a	61.13
Overall mean		66.4a	65.3a	60.6b	59.2b	62.87

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between water levels = 1.86%

LSD 0.05 between genotypes and deflowering = 5.51%

C.V.(a) = 2.61%; C.V.(b) = 9.29%.

Table 37. The effects of defoliation and water level on percent flower - and pod-abscission of pigeonpea genotypes.

Field experiment-1986/87

Water level	Genotype	Percent defoliation				Mean
		0	25	50	75	
High	423/60	58.35b	56.06b	53.36b	70.97a	59.69
	ICPL 7403	70.25b	67.14b	70.51b	80.05a	71.99
	NPP 670	69.78b	71.78b	68.18b	80.71a	72.61
	Mean	66.1b	65.0b	64.0b	77.3a	68.10
Medium	423/60	57.71bc	55.19c	63.20b	78.36a	63.87
	ICPL 7403	74.68b	65.67c	79.28ab	81.76a	75.35
	NPP 670	74.86b	76.69b	76.39b	87.88a	78.96
	Mean	69.4bc	65.9c	73.0 b	82.7a	72.73
Low	423/60	58.75bc	52.41c	63.25b	69.77a	61.05
	ICPL 7403	62.28c	50.76d	69.8b	80.60a	65.86
	NPP 670	69.7ab	65.74ab	67.41b	77.68a	70.13
	Mean	63.6b	56.3c	66.8b	76.0a	65.68
Overall mean		66.4bc	62.4c	67.93b	78.67a	68.84

*Means in a row followed by the same letter are not significantly different (P = 0.05)

LSD 0.05 between genotypes and defoliation = 5.82%
C.V.(a) = 2.25%
C.V.(b) = 1.76%.

of 25 percent was pronounced in genotypes 423/60 and ICPL 7403 in medium and low water levels. There were genotypic differences in percent abscission. NPP 670 exhibited highest % abscission while 423/60 had lowest (tables 36 and 37).

4.2.1.2 Number of open flowers per plant

Overall deflowering had no effect on number of open flowers per plant (Table 38), even though significant decrease was observed in genotype 423/60 at 75% deflowering level. When the number of flowers removed by hand was taken into account, the results showed an increase in number of open flowers per plant with increase in deflowering (Table 39).

Reduction in photosynthetic area by defoliation led to a decrease in number of open flowers per plant (Table 40). However, only the highest defoliation treatment of 75% decreased the number significantly (P = 0.05). Defoliation had no effect on number of flowers per plant in genotype NPP 670 in medium and low water levels

Table 38. Effects of deflowering and water levels on number of open flowers per plant in pigeonpea genotypes.

Field experiment 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	567.7a*	446.1b	408.2b	379.2b	450.3
	ICPL 7403	738.9a	596.1b	781.5a	480.1c	649.2
	NPP 670	378.4a	262.2ba	274.7ba	236.3b	292.9
	Mean	561.66a	441.43b	488.13ba	365.2b	464.18
Medium	423/60	509.5a	505.0a	439.4ab	351.2b	451.3
	ICPL 7403	436.8b	474.9b	747.2a	491.9b	537.7
	NPP 670	282.7ab	359.4a	237.9b	196.5b	269.1
	Mean	409.7ba	446.4ba	474.8a	346.5b	419.4
Low	423/60	412.0ab	416.7ab	495.9a	348.5b	419.4
	ICPL 7403	495.4b	584.4ab	583.4ab	647.5a	577.7
	NPP 670	214.1a	234.7a	240.9a	230.9a	230.2
	Mean	373.8a	411.9a	440.1a	409.1a	408.7
Overall mean		448.4a	433.3a	467.7a	373.6a	430.7

*Means in a row followed by the same letter are not significantly different; P = 0.05.

LSD between genotypes and deflowering = 106.31 flowers

C.V.(a) = 9.76%
C.V.(b) = 26.18%.

Table 39. The effects of deflowering and water levels on corrected number of open flowers per plant for pigeonpea genotypes.

Field experiment - 1986/87

		Percent deflowering				
Water level	Genotype	0	25	50	75	Mean
High	423/60	567.7c	594.53c	816.4b	1516.7a	873.83
	ICPL 7403	738.9c	794.9c	1563.6b	1920.3a	1254.3
	NPP 670	378.4b	375.6b	549.3b	945.2a	562.1
	Mean	561.83c	588.31c	976.23b	1460.73a	896.74
Medium	423/60	509.5c	673.2bc	878.8b	1404.7a	866.55
	ICPL 7403	436.8c	633.03c	1494.3b	1967.9a	1133.02
	NPP 670	282.7b	479.1ab	475.8ab	589.5a	456.78
	Mean	409.67c	595.11c	949.64b	1320.7a	818.78
Low	423/60	412c	555.5c	991.9b	1394.4a	838.45
	ICPL 7403	495.4d	778.7c	1166.8b	2590.0a	1257.7
	NPP 670	214.1c	312.9bc	481.8b	923.3a	483.03
	Mean	373.83c	549.03c	880.17b	1635.9a	859.74
Overall mean		448.44c	577.48c	935.34b	1472.44a	858.42

*Means in a row followed by the same letter are not significantly different (P = 0.05)

LSD 0.05 between genotypes and deflowering = 106.31 flowers

C.V. (a) = 12.81%

C.V. (b) = 26.1%

Table 40. The effects of defoliation and water levels on number of flowers per plant in pigeonpea genotypes.
Field experiment - 1986/87.

		Percent defoliation				
Water level	Genotype	0	25	50	75	Mean
High	423/60	567.7a	521.9a	272.5b	268.5b	407.7
	ICPL 7403	738.9a	526.4b	549.7b	496.9b	577.9
	NPP 670	378.4a	303.9a	225.7b	204.6b	278.2
	Mean	561.1a	450.7b	349.3bc	323.1c	421.3
Medium	423/60	509.5a	432.4a	418.3a	403.8a	441.0
	ICPL 7403	436.8ba	338.6b	525.0a	206.1c	376.6
	NPP 670	282.7a	268.7a	188.7a	181.3a	230.4
	Mean	409.7a	346.6ab	377.3a	263.7b	349.3
Low	423/60	412.0a	410.9a	348.9ab	267.7b	359.9
	ICPL 7403	495.4a	322.3b	434.0a	269.9b	380.4
	NPP 670	214.1a	135.2a	130.2a	173.8a	163.3
	Mean	373.8a	289.5ab	304.4ab	237.1b	301.2
Overall mean		448.4a	362.3ba	343.7ba	274.7b	357.3

*Means in a row followed by the same letter are not significant different, (P = 0.05).
LSD 0.05 between genotypes and defoliation = 108.34 flowers.
LSD 0.05 between genotypes and defoliation at different water levels = 209.94 flowers.
C.V.(a) = 27.74%
C.V.(b) = 32.16%.

but affected the other 2 genotypes at all water levels. The number increased in genotype 423/60 but decreased in genotype ICPL 7403 in medium water levels. However, decrease in water levels reduced the number in genotype NPP 670. The trend of the genotype with the highest to the lowest number of flowers per plant was ICPL 7403, 423/60 and NPP 670, respectively.

4.2.2 Effects of Sink-Source Ratio Manipulation and Water levels on Yield and Yield Components of Pigeonpeas.

4.2.2.1 Grain yield per plant

Grain yield per plant was not affected by deflowering treatments (Table 41). Deflowering, especially at 25% deflowering treatment in medium water level and 50 % treatment in low water levels led to increased grain yield per plant in genotypes 423/60 and ICPL 7403 but not in genotype NPP 670.

The grain yield per plant was significantly

Table 41. The effects of deflowering and water levels on grain yield (grammes) per plant of pigeonpea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent deflowering				Mean
		0	25	50	75	
High	423/60	74.04a	75.3a	76.8a	56.42b	70.64
	ICPL 7403	80.61a	64.55b	84.72a	74.4ab	76.07
	NPP 670	30.49a	28.3a	23.12a	27.10a	27.25
	Mean	61.71a	56.05a	61.55a	52.64a	57.99
Medium	423/60	49.78b	75.82a	51.38b	55.09b	57.89
	ICPL 7403	39.33b	51.23b	86.65a	49.04b	56.56
	NPP 670	27.93a	27.91a	22.03a	18.87a	24.19
	Mean	39.01b	51.49a	53.35a	41.0ab	46.21
Low	423/60	52.4b	52.21b	80.96a	43.84b	57.35
	ICPL 7403	51.56b	38.55b	66.99a	60.71ab	54.45
	NPP 570	28.58a	20.12a	25.93a	22.72a	24.34
	Mean	44.18b	36.96b	57.96a	42.42b	45.38
Overall mean		48.30a	48.17a	57.62a	45.35a	49.86

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between deflowering and genotypes = 13.6 grammes/plant.

C.V.(a) = 18.28%

C.V.(b) = 28.95%.

Table 42. The effects of defoliation and water levels on grain yield (grammes) per plant of pigeonpea genotypes.

Field experiment - 1986/87.

Water level	Genotype	Percent defoliation				Mean
		0	25	50	75	
High	423/60	74.04a	64.71a	37.76b	31.9b	52.1
	ICPL 7403	80.61a	63.84b	36.87c	30.14c	52.87
	NPP 670	30.49a	26.08ab	28.86a	13.04b	24.62
	Mean	61.71a	51.54a	34.49b	25.03b	43.19
Medium	423/60	49.78ab	57.00a	41.98b	21.02c	42.45
	ICPL 7403	39.33ab	45.16a	31.16b	12.3c	31.99
	NPP 670	27.93a	26.76a	12.21b	9.68b	19.15
	Mean	39.01a	42.97a	28.45b	14.33c	31.19
Low	423/60	52.4a	54.29a	28.08b	25.43b	40.05
	ICPL 7403	51.56a	26.87cb	37.28b	15.80c	32.88
	NPP 670	28.58a	23.29ab	11.68b	8.77b	18.08
	Mean	44.18a	34.82ab	25.68b	16.67b	30.34
Overall mean		48.30a	43.11a	29.54b	18.67b	34.91

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotype and defoliation = 13.38 grammes/plant.

C.V.(a) = 34.58%

C.V.(b) = 40.65%.

reduced at 50 and 75% defoliation levels (Table 42). This trend was more true in plants under all water levels.

In both parallel experiments, genotype NPP 670 had the lowest grain yield per plant in comparison to the other 2 genotypes that were not different from each other. Generally yield per plant decreased with increase in water stress in all genotypes. However, this decrease was not statistically significant (P = 0.05).

4.2.2.2 Number of pods per plant.

Number of pods per plant was lowest at 25% deflowering treatment and highest for 50% deflowering in medium and low water levels (Table 43). Deflowering especially at 50% led to a greater number of pods per plant in genotype ICPL 7403, and in genotype 423/60 in medium and low water levels. The amount of deflowering had no effect on number of pods per plant in genotype NPP 670.

In general only 50 and 75% defoliation treatments significantly (P = 0.05) reduced the number of pods per plant (Table 44). This

Table 43. The effects of deflowering and water levels on number of pods per plant in pigeonpea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	235.9a	183.8b	211.6ab	190.9b	205.5
	ICPL 7403	241.4ab	256.2a	266.2a	206.7b	242.60
	NPP 670	83.4a	77.5a	66.3a	75.20a	75.60
	Mean	186.9a	172.5a	181.4a	157.6a	174.6
Medium	423/60	175.2a	186.5a	202.8a	166.2a	182.7
	ICPL 7403	110.7c	131.9c	273.1a	226.4b	185.6
	NPP 670	73.3a	76.0a	55.3a	69.9a	68.6
	Mean	119.7ab	106.2b	177.1a	154.2a	145.6
Low	423/60	206.7a	201.7a	279.8a	191.2a	219.9
	ICPL 7403	192.1b	125.7c	263.0a	248.7a	207.4
	NPP 670	70.4a	51.8a	70.5a	68.9a	65.4
	Mean	156.4b	126.4b	204.4a	169.6ab	164.2
Overall mean		154.4ab	135.0b	187.6a	160.5ab	161.5

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and deflowering = 37.66 pods/plant.

C.V.(a) = 14.88 pods/plant

C.V.(b) = 24.74 pods per plant.

Table 44. Effects of defoliation and water level on number of pods per plant in pigeonpea genotypes.

Field experiment - 1986/87.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
High	423/60	235.9a	221.1a	129.8b	93.1c	169.9
	ICPL 7403	241.4a	161.5b	131.7b	97.4c	158.0
	NPP 670	83.43a	73.1a	61.9a	25.7b	61
	Mean	186.9a	151.9b	107.8c	72.1d	129.7
Medium	423/60	175.2a	185.8a	155.9a	72.7b	147.4
	ICPL 7403	110.7a	132.3a	112.2a	34.2b	97.3
	NPP 670	73.3a	61.4ab	36.3b	21.3b	48.1
	Mean	119.7a	126.5a	101.5a	42.7b	97.6
Low	423/60	206.7a	198.0a	137.6b	72.4c	153.7
	ICPL 7403	192.1a	159.1ab	157.3b	52.9c	140.4
	NPP 670	70.4a	51.1ab	34.0b	31.9b	46.9
	Mean	156.4a	136.1ab	109.6b	52.4c	113.6
Overall mean		154.4a	138.2ab	106.4b	55.74c	113.6

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and defoliation = 34.54 pods/plant.

C.V.(a) = 19.7%

C.V.(b) = 32.2%.

decrease was pronounced in genotypes 423/60 and ICPL 7403 than in NPP 670. Genotype NPP 670 had the lowest number of pods per plant compared to genotypes 423/60 and ICPL 7403 that were not different from each other (Tables 43 and 44). The number was highest in high water level, then lowest in the medium water level, however this difference was not significant, in both parallel experiments.

4.2.2.3 The number of pods per node.

The number of pods per node increased with increase in deflowering in all genotypes and at all water levels (Table 45).

Heavy defoliation treatments of 50% and 75% significantly reduced the number of pods per node (Table 46). Genotype 423/60 had the highest number of pods per node in all water levels, while the number decreased with decrease in water levels for genotype NPP 670. The number in genotype ICPL 7403 decreased in medium water levels then increased in low water level plants. Generally water levels significantly affected the number of pods per node in the defoliation experiment. The number was reduced to 0.548

Table 45. The effects of deflowering and water levels on number of pods per node in pigeon pea genotypes.

Field experiment -1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	1.207c	1.717b	2.037b	3.123a	2.021
	ICPL	1.07d	1.747c	1.9b	3.393a	2.028
	NPP 670	1.357c	1.561cb	1.896b	3.163a	1.993
	Mean	1.211c	1.675b	1.942b	3.226a	2.014
Medium	423/60	1.041c	1.37c	1.96b	2.761a	1.783
	ICPL 7403	0.807c	1.193b	2.137b	3.417a	1.889
	NPP 670	1.10c	1.557b	1.797b	2..97a	1.856
	Mean	0.983d	1.373c	1.965b	3.049a	1.843
Low	423/60	1.086c	1.347c	2.34b	3.24a	2.003
	ICPL 7403	1.19c	1.013c	1.94b	2.813a	1.739
	NPP 670	1.1c	1.237c	1.853b	2.457a	1.662
	Mean	1.125c	1.199c	2.044b	2.837a	1.801
Overall mean		1.06d	1.416c	1.983b	3.037a	1.886

*Means in row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between deflowering = 0.37 pods/node.

C.V.(a) = 13.52%

C.V.(b) = 20.8%.

Table 46. The effects of defoliation and water levels on number of pods per node in pigeonpea genotypes.

Field experiment - 1986/87.

		Percent defoliation				
Water level	Genotype	0	25	50	75	Mean
High	423/60	1.207a*	1.197ab	0.996b	0.697c	0.998
	ICPL 7403	1.07a	0.883ab	0.833b	0.45c	0.809
	NPP 670	1.357a	1.053b	0.877b	0.353c	0.91
	Mean	1.211a	1.044ab	0.9b	0.5c	0.906
Medium	423/60	1.041ab	1.183a	0.863b	0.627c	0.929
	ICPL 7403	o.807ab	1.031a	0.72b	0.303c	0.715
	NPP 670	1.1a	0.993a	0.463b	0.347b	0.726
	Mean	0.983a	1.069a	0.682b	0.426bc	0.548
Low	423/60	1.086a	1.063ab	0.867b	0.656b	0.917
	ICPL 7403	1.19a	1.21a	0.737b	0.487c	0.906
	NPP 670	1.10a	0.953a	0.636b	0.5b	0.796
	Mean	1.125a	1.075a	0.745b	0.546b	0.873
Overall mean		1.106a	1.063a	0.776b	0.491c	0.776

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between water levels = 0.061 pods per node.

LSD 0,05 between defoliation and genotypes = 0.207 pods per node.

C.V.(a) = 6.35%

C.V.(b) = 25.51%.

Table 47. Effects of deflowering and water levels on number of seeds per pod. Field experiment - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	5.523b	5.647b	5.86ab	5.95a	5.745
	ICPL 7403	5.133a	5.067a	5.177a	5.14a	5.129
	NPP 670	4.563a	4.233b	4.403ab	4.503ab	4.426
	Mean	5.073a	4.982a	5.147a	5.198a	5.10
Medium	423/60	5.707a	5.643a	5.673a	5.89a	5.728
	ICPL 7403	4.933a	5.14a	5.05a	5.027a	5.028
	NPP 670	4.123a	4.257a	4.28a	4.127a	4.197
	Mean	4.921a	5.013a	5.001a	5.015a	4.988
Low	423/60	5.447a	5.653a	5.51a	5.44a	5.123
	ICPL 7403	4.947b	5.057b	5.35a	5.043b	5.099
	NPP 670	4.54a	4.48a	4.277a	4.24a	4.384
	Mean	4.978a	5.063a	5.046a	4.907a	4.999
Overall mean		4.99a	5.019a	5.065a	5.04a	5.026

*Means in a row followed by the same letter are not significantly different (P =
0.05).
LSD 0.05 between genotypes and deflowering = 0.274 seeds/pod.
C.V.(a) = 0.05%
C.V.(b) = 0.06%

in medium water level compared to 0.906 and 0.873 pod per node for high and low water levels respectively (Table 46).

4.2.2.4 Number of seeds per pod

The number of seeds per pod was generally not affected by the deflowering treatments and averaged 5.026 seeds per pod (Table 47). However, within each cultivar there were some significant but inconsistent differences. For example, the number increased with increase in deflowering in genotype NPP 670 in high water levels. In ICPL 7403 the number was increased with increase in deflowering treatments of up to 50% but decreased at 75% deflowering at low water levels.

Deflowering decreased the number of seeds per pod. This effect was more pronounced at 50 and 75% levels (Table 48).

Genotype NPP 670 had the lowest number of seeds per pod while genotypes 423/60 and ICPL

Table 48. Effects of defoliation and water levels on number of seeds per pod in pigeon pea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
High	423/60	5.523b*	5.96a	5.44b	5.35b	5.568
	ICPL 7403	5.133a	4.783bc	4.807b	4.487c	4.803
	NPP 670	4.563a	4.567a	3.083b	3.160b	3.843
	Mean	5.073a	5.103a	4.443b	4.332b	4.138
Medium	423/60	5.707a	5.777a	5.527ab	5.37b	5.595
	ICPL 7403	4.933a	4.84a	4.903a	4.32b	4.749
	NPP 670	4.123a	4.113a	3.69b	3.627b	3.883
	Mean	4.921a	4.91a	4.707ab	5.117a	4.439
Low	423/60	5.447a	5.707a	5.423a	5.117b	5.424
	ICPL 7403	4.947a	4.637b	4.717ab	4.44b	3.575
	NPP 670	4.54a	3.97b	4.087b	4.037b	3.149
	Mean	4.978a	3.448b	4.742ab	4.531b	4.049
Overall mean		4.99a	4.487b	4.631b	4.434b	4.511

*Means in a row followed by the same letter are not significantly different (P = 0.05)

LSD 0.05 between genotype and defoliation = 0.295 seeds/pod.
C.V.(a) = 2.27%
C.V.(b) = 0.07%.

7403 were not different from each other at all water levels in both parallel experiments (Table47 and 48). In general water levels did not affect the number of seeds per pod.

4.2.2.5 100-Seed weight.

100-Seed weight increased with the increasing level of deflowering at all water levels (Table 49). 100-Seed weight was significantly increased at the 75% deflowering level in genotype ICPL 7403 while genotype 423/60 was not affected in high water levels. The weight was increased at 50 and 75% deflowering treatments in medium water levels in the above 2 genotype. These genotypes were not affected by deflowering in low water levels. 100-seed weight was increased by deflowering treatments in genotype NPP 670 in high and low water levels. Mild water stress (medium water level) had no effect on 100-seed weight of genotype NPP 670.

100-Seed weight was not affected by defoliation treatments (Table 50). In general genotype NPP 670 had the highest 100-seed weight in comparison to the other 2 genotypes (Tables 49 and 50).

Table 49. The effects of deflowering and water levels on 100-seed weight of pigeonpea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	14.42a	14.59a	14.86a	14.87a	14.69
	ICPL 7403	14.15b	14.74b	14.94b	16.38a	15.05
	NPP 670	19.34b	20.35a	19.99ab	21.06a	20.18
	Mean	15.97b	15.56b	16.59ab	17.44a	16.65
Medium	423/60	13.63b	14.20b	15.28ab	15.64a	14.62
	ICPL 7403	15.04b	15.04b	15.19ab	16.27a	15.39
	NPP 670	19.87a	20.11a	20.34a	20.18a	20.13
	Mean	16.09b	16.45ab	16.94ba	17.36a	16.71
Low	423/60	14.27a	13.69a	14.01a	14.06a	14.01
	ICPL 7403	14.49a	15.04a	14.22a	14.13a	14.47
	NPP 670	17.45c	19.77b	20.08ba	21.43a	19.68
	Mean	15.40b	16.17ab	16.1ab	16.54a	16.05
Overall mean		15.82b	16.39ba	16.55ab	17.11a	16.47

*Means in a row followed by the same letter are not significantly different (P = 0.05).

LSD 0.05 between genotypes and deflowering = 1.09 grammes.
C.V.(a) = 4.15%
C.V.(b) = 7.02%.

Table 50. The effects of defoliation and water levels on 100-seed weight in pigeon-pea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
High	423/60	14.42*	14.04	14.43	13.45	14.09
	ICPL 7403	14.15	13.57	13.78	14.25	13.94
	NPP 670	19.34	19.85	18.98	19.00	19.29
	Mean	15.97	15.82	15.73	15.57	15.77
Medium	423/60	13.36	13.49	14.53	13.83	13.80
	ICPL 7403	15.04	12.96	14.15	13.71	13.96
	NPP 670	19.87	20.41	20.21	20.60	20.28
	Mean	16.09	15.62	16.29	16.05	16.01
Low	423/60	14.27	13.65	13.31	14.23	13.87
	ICPL 7403	14.49	12.28	13.23	13.38	13.34
	NPP 670	17.45	19.83	20.39	19.68	19.34
	Mean	15.4	15.25	15.64	15.76	15.52
Overall mean		15.82	15.56	15.89	15.79	15.77

*There was no significant difference between defoliation treatments (P = 0.05).
LSD 0.05 between genotypes = 1.106 grammes.
C.V.(a) = 3.97%
C.V.(b) = 7.45%.

4.2.3 Effects of Sink-Source Ratio Manipulation on Days to Maturity and Flowering and Podding Duration in Pigeonpeas.

The different genotypes reached the 95% flowering stage at different times. Genotype ICPL 7403, 423/60 and NPP 670 reached the stage after 103.5, 106.2 and 107.1 days respectively.

4.2.3 .1 Days to maturity.

The end of the period of the first flower flush and drying of the pods was taken as an indicator of days to maturity. Flower removal treatments significantly lengthened the days to maturity in all genotypes (Table 51).

Plants at 75% deflowering treatment matured 9 days later than the controls. Increase in days to maturity with increase in deflowering was pronounced in high and medium water levels but not in low water levels. Even in the high and medium water levels increase in days to maturity was more pronounced in genotypes 423/60 and ICPL 7403 than in genotype NPP 670.

Defoliation treatments of 25 and 50%

Table 51. Effects of deflowering and water levels on days to maturity of pigeonpea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	170.0b	171.5b	172.1b	180a	173.4
	ICPL 7403	154.3d	157.8c	161.5b	167.4a	160.3
	NPP 670	150.0b	154.17a	155.7a	155.7a	153.9
	Mean	158.1c	161.2b	163.1b	167.7a	162.5
Medium	423/60	165.5c	163.0c	170.6b	179.3a	169.6
	ICPL 7403	154.6c	156.8c	161.6b	170.7a	160.9
	NPP 670	149.7c	154.7b	160.5a	154.4b	154.8
	Mean	156.6c	158.2c	164.2b	168.1a	161.8
Low	423/60	170.4c	174.2b	175.0b	178.7a	174.6
	ICPL 7403	161.0b	154.6c	157.5d	164.1a	157.8
	NPP 670	150.1b	152.0ab	153.0ab	153.3a	152.1
	Mean	160.5b	160.3b	159.8b	165.4a	161.5
Overall mean		158.4c	159.9cb	162.4b	167.1a	161.9

*Means in a row followed by the same letter are not significantly different (P = 0.05).
LSD 0.05 between genotypes and deflowering = 3.08 days.
LSD 0.05 between genotypes and deflowering at different water levels = 5.72 days.
C.V.(a) = 1.43%
C.V.(b) = 2.02%.

Table 52. Effects of defoliation and water levels on days to maturity period in pigeonpea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
High	423/60	170.0ab	167.8b	173.7a	163.6c	168.8
	ICPL 7403	154.3a	166.3b	170.5a	158.9c	162.5
	NPP 670	150.0c	153.4b	159.6a	155.0b	154.5
	Mean	158.1c	162.5b	167.9a	159.2cb	161.9
Medium	423/60	165.5b	171.7a	172.0a	166.4b	168.9
	ICPL 7403	154.6c	168.4a	163.3b	166.4ab	163.2
	NPP 670	149.9b	158.8a	160.2a	159.6a	157.1
	Mean	156.6b	166.3a	165.2a	164.1a	163.1
Low	423/60	170.4a	172.8a	171.5a	165.3b	170.0
	ICPL 7403	161.0b	165.9a	161.7b	161.1b	162.4
	NPP 670	150.1b	159.1a	157.2a	158.0a	156.1
	Mean	160.5b	165.9a	163.5ab	161.5b	162.8
Overall mean		158.4b	164.9ba	165.5a	161.6b	162.6

*Means in a row followed by the same letter are not significantly different (P = 0.05).
LSD 0.05 between genotypes and defoliation = 3.52 days.
LSD 0.05 between genotypes and defoliation at different water levels = 6.5 days.
C.V.(a) = 1.6%
C.V.(b) = 2.3%.

led to more days to maturity of 164.9 and 165.5 days,respectively in comparison to the control with 158.4 days to maturity (Table 52). However, the days to maturity of 75% defoliation treatment was not significantly different from the control. The increase in days to maturity was more pronounced at 50% defoliation in high water levels and at 25% defoliation in medium and low water levels. The increase was more in genotype NPP 670 than the other 2 genotypes in medium and low water levels. In general the ranking was 423/60> ICPL 7403 > NPP 670 for the genotype with the longest to the shortest days to maturity.

4.2.3.1 Flowering and podding duration.

Flower removal treatments significantly increased the flowering and podding duration (Table 53). Plants at 75% deflowering treatment had their flowering and podding duration extended by 11 days over the control. The increase in the duration with increase in deflowering was more pronounced in high and medium water levels than in low water levels. This increase was observed more in genotypes 423/60 and ICPL 7403 than in NPP 670 at all water levels. Defoliation generally had no effect

Table 53. Effects of deflowering and water levels on flowering and podding duration of pigeonpea genotypes.
Field experiment - 1986/87.

Water level	Genotype	Percent deflowering 0	25	50	75	Mean
High	423/60	62.47cb*	67.6b	70.67b	77.1a	69.46
	ICPL 7403	50.17d	55.6c	60.83b	65.23a	57.96
	NPP 670	42.5b	48.17a	49.23a	52.0a	47.98
	Mean	51.71c	57.12b	60.24b	64.78a	58.47
Medium	423/60	59.6c	61.37c	70.57b	78.83a	67.64
	ICPL 7403	54.6c	54.77c	61.00b	68.83a	59.8
	NPP 670	46.1b	53.23a	56.27a	47.23b	50.71
	Mean	53.43b	56.52b	62.61a	64.96a	59.38
Low	423/60	64.23c	69.07b	68.33a	75.93a	69.39
	ICPL 7403	59.07b	64.93a	50.43c	63.13ab	59.39
	NPP 670	42.93b	47.17a	50.17a	48.67a	58.67
	Mean	55.41b	60.39a	56.31b	62.58a	58.67
Overall mean		53.52c	58.01b	59.72ba	64.11a	58.84

*Means in a row followed by the same letter are not significantly different (P = 0.05).
LSD 0.05 between genotype and deflowering = 4.04 days
LSD 0.05 between genotype and deflowering at different water levels = 7.99 days.
C.V.(a) 6.81%
C.V.(b) 7.27%.

Table 54. Effects of defoliation and water levels on flowering and podding duration of pigeonpea genotypes.
Field experiment - 1986/77.

Water level	Genotype	Percent defoliation 0	25	50	75	Mean
High	423/60	62.47a	60.43a	62.6a	56.07b	60.39
	ICPL 7403	50.17b	56.8a	60.27a	52.13b	54.84
	NPP 670	42.5a	45.9a	45.5a	43.1a	44.25
	Mean	54.71a	54.38ab	56.12a	50.43b	53.16
Medium	423/60	59.6b	55.23c	64.00a	57.87bc	59.18
	ICPL 7403	54.6b	61.37a	56.73b	58.4ab	57.78
	NPP 670	46.1b	51.2a	57.73a	51.9a	50.23
	Mean	53.43a	55.93a	57.49a	56.06b	55.73
Low	423/60	64.23ab	62.5b	66.33a	57.57c	62.66
	ICPL 7403	59.07a	57.8ab	54.33b	54.43b	56.41
	NPP 670	42.93b	45.07b	46.9b	57.83a	46.68
	Mean	55.41a	55.12a	55.85a	56.61a	55.25
Overall mean		53.52a	55.14a	56.49a	54.38a	54.71

*Means in a row followed by the same letter are not significantly different (P = 0.05).
LSD 0.05 between genotypes and defoliation = 4.12 days.
LSD 0.05 between genotype and defoliation at different water levels = 5.26 days.
C.V.(a) = 4.88%
C.V.(b) = 7.99%.

Defoliation generally had no effect on flowering and podding duration that averaged 54.71 days (Table 54). However the duration was reduced with increase in defoliation in genotypes 423/60 and ICPL 7403 but increased in genotype NPP 670. Also the flowering and podding duration increased in medium water levels and decreased at low water levels. In general the ranking from the longest to shortest podding and flowering duration was 423/60, ICPL 7403 and NPP 670.

5. DISCUSSION

5.1 Effects of Sink-Source Ratio Manipulations on Flower and Pod Abscission, Yield and Yield Components of Pigeonpeas.

Results of this experiment suggest that sink reduction resulted in reduced competition for limited resources among the remaining flowers and pods. Similar results have been reported in beans (Subhadrabhandhu et al, 1978; Binnie and Clifford, 1980; and D'Souza and Coulson, 1988) and in pigeonpeas (Sheldrake, 1984). It is apparent that translocation of assimilates occurred from leaves subtended on the section of the plant which had all flowers and pods removed to the remaining flowers and pods. Tayo (1980) reported that heavy flower and pod removal experiments resulted in increase in seed size and 100-seed weight in pigeonpeas. Weight per pod and seed weight per pod were also increased though the final yield per plant was reduced due to less pods per plant formed from the fewer flowers that remained after deflowering. Pandley and Singh (1981) found a reduction in flower drop and an accelerated flower production with increase in deflowering in pigeonpeas.

The number of seeds per pod was the yield component least affected by deflowering. Sheldrake *et al* (1979) reported similar results in deflowered pigeonpeas. It would appear that maximum number of seeds per pod is set through evolution of each variety so that it is independent of assimilate status of individual plants.

The floral removal treatments lengthened the days to maturity and flowering and podding duration. In greenhouse experiment I, the days to maturity and flowering and podding duration were lengthened at higher deflowering levels in water stressed plants. The results show the effects of sink reduction in lengthening the days to maturity and flowering and podding duration overshadowed those of stress which tend to reduce the periods. It has been reported at Hyderabad (Sheldrake *et al*., 1979) that removal of all flowers and young pods in pigeonpeas for upto 5 weeks after the beginning of the flowering period extended the period and delayed the senescence of the plants. The plants compensated for the loss of early formed flowers by setting pods on later formed flowers that would otherwise have dropped off. This suggests that it a hormone triggers senescence, the substance is formed later in deflowered plants.

Flower - and pod-abscission was lower while number of flowers, grain yield and number of pods per plant, 100-seed weight and number of seeds per pod were higher in the field experiment than in the greenhouse experiments probably because the plants were larger and therefore more vigorous in the field than in the greenhouse. Any differences in the measured parameters due to treatment were complicated by the large variations in plant characteristics. In spite of efforts to obtain a uniform stand of plants, some plants had more flowers, hence more pods and yield per plant and this may explain the high C.V. (Coefficient of variation) values.

Reduction in assimilatory capacity by defoliation, increased percent flower - and pod-abscission and decreased the number of open flowers per plant in the greenhouse experiments (Table 4 and 5). In the field experiment flower and pod abscission was only increased at 75% defoliation treatment. The number of open flowers per plant was not affected by 25 and 50% defoliation, but was significantly reduced at 75% defoliation treatemnt (Tables 11, 40). Grain yield per plant, number of pods per plant and pods per node were all adversely affected by defoliation treatments (Tables 13, 16, 17, 20, 21, 42, 44, 46). It was further revealed that yield reductions werelargely due to a decrease in pod number per plant. Seed number per pod and 100-seed weights were the yield components least affected.

The above observations agree with the results of several workers. Pandley and Singh (1981) had found that defoliation reduced the number of flowers and yield per plant in pigeonpeas. Tayo (1982) reported a reduced growth and seed yield following defoliation in pigeonpeas. Similar results have been obtained by Egliand and Leggett (1976), Hammerton (1975) and at Hyderabad (ICRISAT, 1975/76). The results also conform to the observations of Wilkerson et al (1984) who found a significant reduction in yield in defoliation experiments in groundnuts (*Arachis hypogaea*). The yield reductions following defoliation have largely been attributed to low number of pods per plant which could be a result of high percent abscission and/or low flower initiation. Plant performance might have been affected because reduction in assimilatory capacity affected the photosynthate supply to the various plant parts. Setter *et al* (1984) found that sugar contents were reduced by 44 and 64% in stems and pod walls respectively following defoliation. Defoliation treatment, in addition to its effect on photoassimilate supply, also might have altered the regulation of partition by changing water status or changing nutrient (Pate *et al*., 1979; Preiss, 1982) or hormone (Patrick and Wareing, 1976; Porter, 1981; Tiertz *et al*., 1981; Yu and Yang, 1980) levels. For example defoliation might have altered cytokinin levels in stem and seed regions by reducing transpiration (Heindl *et al*., 1982) or it might have altered abscisic acid levels by eliminating its translocation from leaves to sinks (Setter, *et al*., 1981).

The results of the present work show that the effects of defoliation depended on the degree of the source reduction. It was observed that there was an increase in number of open flowers per plant at mild defoliation (at 25 and 50%)treatments while heavier defoliation treatments reduced the overall plant performance significantly. Defoliation also had no effect on days to maturity at 25 and 50% treatments, but a decrease at the heaviest defoliation treatment. Similar results were obtained by Pandley and Singh (1981) and at Hyderabad (ICRISAT, 1976) in pigeonpeas. It has been reported, in soyabean, that removing 17 or 33% of the leaf area was compensated for by increased light penetration of the canopy so that yield was unaffected (Turnipseed, 1972. Increase in plant performance, at mild defoliation treatments could therefore, have occurred because the leaves removed were photosynthetically ineffective as a result of shading, or photosynthetic capacity of the plants exceeded that necessary to sustain the flower and pod load due to improved light penetration associated with mild defoliation (Hammerton, 1975; ICRISAT, 1976/77, Pandley and Singh, 1981). Neales and Incoll (1968) have pointed out that, in several species, partial defoliation can result in an increased rate of photosynthesis of the remaining leaf area, so that fruit growth is not limited, and such compensation may have occurred in the present work.

Percent pod-set varies widely in pigeonpea(Hammerton,1974; Ariyanayagam, 1975; Narayanan and Sheldrake, 1976, Sheldrake et al., 1979; Tayo, 1980; Pandley and Singh (1981). Data by Subhandrabhandhu et al (1978) Kamweti and Coulson (1984), Sheldrake (1984) and Egwatu (1975) suggest that factors such as weather conditions play a big role in determining the percentage flower-and pod-abscission. Hence photosynthetic capacity (or source strength) may not be the only factor determining the flower or pod load in the field, and even defoliated plants could have an excess of photosynthetic capacity relative to their flower or pod-load. Tayo (1982), suggested that pigeonpeas has an innate capacity to tolerate a certain degree of leaf loss. The plants could also compensate for leaf loss by altering level of nutrients and plant hormones (Pandley and Singh, 1981). D'Souza and Coulson (1988) reported increased remobilization of dry matter towards the reproductive structures during the reproductive period.

The results of this study and the above

review suggest that mild defoliation treatments during the reproductive period may have less effect on abscission and the yield of the plant as the plant performance is increased. It is also noted that other factors, for example hormonal and water status, apart from photosynthetic activities determine the efficiency of source activities.

5.2 Effects of Water stress.

Water stress treatments significantly increased percent abscission and decreased number of open flowers per plant in greenhouse experiment I. Similar observations were made in glasshouse experiment II but the differences were not significant. It should be noted that more stress developed in plants in greenhouse experiment I because water was applied after every three days compared to daily applications in greenhouse experiment II. Thus stressed plants in greenhouse experiment II could be described as under mild water stress conditions, while the stressed plants in greenhouse experiment I described as under severe water stress. The severe water stress lowered the yield and yield component values. The days to maturity and flowering and podding duration was reduced with increase in stress in greenhouse experiment I. Keatinge and Hughes (1981), Akinola and Whiteman (1974) and Reddy et al (1975) reported that water stress leads to reduced yield in pigeonpeas. The workers attributed the yield reduction to reduced number of flowers and pods per plant, and duration, both of which were reduced by stress. The same argument could be used to explain the observations in stressed plants of greenhouse experiment I.

There was an increase in percent abscission in medium water level plants but the increase was not significantly different from plants in high water status in the field experiment (Table 36, 37). Percent abscission then decreased significantly in plants under low water levels when compared to those under medium water status. Water levels had no effect on the number of open flowers per plant. It should be noted that plants under low water status had 412.75 mm rainfall before irrigation started. A total of 124.72 mm irrigation water was applied (Table I). Percent soil moisture content at various irrigation levels at different soil depths is shown in Appendix IV. The water applications resulted into mild water-stress conditions for plants under low water levels, while plants under high and medium water levels experienced high water status. Therefore under the mild water stress conditions flower retention was enhanced as stated above.

The number of open flowers per plant, pods per plant and pods per node decreased less in stresssed but more in non-stressed plants, with increase in defoliation in greenhouse experiments. These results show that the assimilatory capacity, which included leaf growth, had a less effect on reproductive performance of stressed plants. They further suggest that water stressed plants were sink limited. That is the leaves available could more than provide for the flowers and pods such that removal of some leaves had little effect. The results also show a possibility of defoliation improving plant water status by reducing the rate at which water is lost from the soil. Kohel and Benedict (1984), Constable and Hearn (1978), Sinha (1981) and Nyabundi (1985) reported that vegetative growth was more sensitive to water stress than the reproductive growth during the reproductive period. Photosynthesis is also less sensitive to mild water stress than expansive vegegative growth (Bradford and Hsiao, 1982). This means that photosynthates can be available for reproductive growth even after vegetative growth has stopped. Actually it has been reported that the proportion of assimilates translocated towards reproductive organs increases during mild water stress conditions (Johnson and Moss, 1976 ; Constable and Hearn, 1978 and Nyabundi, 1985). Kohel and Benedict (1984) reported that stress resulted in increase in the rate of dry matter accumulation in the seeds and a decrease in fibres of cotton (Gossypium hirsutum). It seems therefore that the proportion of assimilates translocated to the seeds was increased following conditions of mild water stress. The workers suggested that mild water stress may enhance flower-and pod retention as relatively more assimilates will be translocated to them. The field study of this experiment agrees with this suggestion (Table 36).

5.3 Genotypic Differences.

The order of the genotypes with the higher to one with the lowest percent flower and pod-abscission was 423/60, ICPL 7403 and NPP 670 in the greenhouse experiments (Tables 2, 3, 4, 5)which contrasts that of the field experiment (Table 36,37)of NPP 670,ICPL 7403 and 423/60. The number of open flowers per plant was highest for genotypes 423/60 and ICPL 7403 while NPP 670 had the lowest number in both the greenhouse and field experiments (Table 6, 7, 8, 9, 10, 11, 38, 39). There was no difference in grain in yield per plant with respect to genotypes 423/60 and ICPL 7403 in all experiments (Tables 12, 13, 41, 42). Genotype 423/60 had more pods per plant than ICPL 7403 in greenhouse experiment I (Table 14). The difference in yield was cancelled by higher 100-seed weight of genotype ICPL 7403 as occurred in greenhouse experiment II (Table 26, 27). The number of pods per plant in genotype 423/60 was however not significantly different from that of genotype ICPL 7403 in the field experiment. This could be a result of higher flower initiation in genotype ICPL 7403 (Table 38, 39). In the greenhouse experiments the grain yield per plant of genotype 423/60 was not different from the other genotypes (ICPL 7403 and NPP 670). This occurred possibly because it had same number of pods per plant, a lower number of seeds per pod compensated by a higher 100-seed weight over the other genotypes. In the field experiment genotype NPP 670 had the lowest yield per plant (Table 41, 42) due to a lower number of seeds per pod and number of pods per plant even though this was accompanied by the highest 100-seed weight. NPP 670 had the lowest number of pods per plant because of its high percent abscission and lower flower initiation (Tables 36, 37, 38, 39).

Sink reduction depressed abscission and increased number of open flowers per plant in genotypes 423/60 and ICPL 7403 but not NPP 670. There was increased yield per plant and number of pods per plant in genotypes 423/60 and ICPL 7403 with increase in deflowering but not in genotype NPP 670. Heavy defoliation treatments of 75 percent, led to decreased number of open flowers per plant in genotypes 423/60 and ICPL 7403. However, mild defoliation of 25 percent reduced the number in genotype NPP 670. Increase in defoliation decreased the number of pods per plant of genotypes 423/60 and ICPL 7403 but had no effect on genotype NPP 670.

Laffite and Travis (1984) found that rice (*Oryza sativa* L.) lines exhibiting higher sink-source ratios had higher source activities. Barnett and Pearce (1983) reported that maize hybrids, with high sink strengths had the capacity to store assimilates when source-sink ratio was high, that is, during deflowering and lower defoliation treatments, and remobilizing assimilates to other sinks when it is high (during heavy defoliation treatments).

If abscission is caused by lack of assimilates, then percent abscission would be low in genotypes with stored assimilates. In the field experiments genotypes 423/60 and ICLP 7403 had lower percent abscission (Table 36)and higher yields (Table 41) under conditions of high source-sink ratios (on deflowering) and a reduction in number of pods per plant when the source-sink ratio was low (on defoliation). The observations in this study therefore, suggest that genotypes 423/60 and ICPL 7403 had stronger sink characteristics than NPP 670.

In the greenhouse experiment I the percent abscission of genotype ICPL 7403 was not affected by deflowering in stressed plants. Also the number of open flowers per plant, number of pods per plant and pods per node was highest for genotype 423/60 then ICPL 7403 in non-stressed plants but the opposite in stressed plants. The number of open flowers per plant increased with deflowering in genotypes 423/60 and ICPL 7403 than NPP 670 in non stressed plants in greenhouse experiment II. There was larger decrease in number of open flowers per plant in genotype NPP 670 than the other two in stressed plants. NPP 670 had a high grain weight in non stressed but the lowest in stressed plants while the weights of genotypes 423/60 and

ICPL 7403 were not significantly different (Tables 12,13). Stress lowered the number of pods per plant in genotype NPP 670 while 423/60 and ICPL 7403 were not affected in the field experiment (Tables 43, 44).

The above observations suggest that genotypes 423/60 and ICPL 7403 are more drought resistant than NPP 670. Their drought resistance could be due to their indeterminate growth habits at Kabete. Indeterminate plants have the capacity to grow in unfavourable conditions and continue flowering after-stress (Laing *et al*., 1983; Norman *et al*., 1984; Raper and Barber, 1970; Floor, 1983). Genotype NPP 670 had determinate growth habits hence likely to be less resistant to water stress.

6. CONCLUSIONS.

Deflowering led to decreased percent flower- and pod-abscission, increased flowers per plant, pods per node and 100-seed weight. Grain yield per plant and number of seeds per pod were less affected by deflowering. The observations showed that sink reduction, by deflowering led to reduced competition for limited resources among the remaining flowers and pods. Also translocation of assimilates had occurred from leaves subtended on the section of the plant which had all the flowers and pods removed.

Source reduction, by defoliation, increased flower-and pod-abscission but decreased the number of open flowers per plant in greenhouse experiment I. In greenhouse experiment II and field experiment the effects of defoliation depended on the source reduction intensity. Mild source reduction (of 25 and 50% defoliation) had the same effect as deflowering, that is improved plant performance. This was attributed to improved light penetration hence increased processes of plant assimilation. However, high percent flower - and pod-abscission and decreased number of open flowers per plant was realized at the highest defoliation level. Similarly a significant reduction in yield and yield components, maturity period and flowering and podding duration at the highest defoliation level.

Water stress increased percent flower- and pod-abscission and decreased number of open flowers per plant in the greenhouse experiments. Similarly the high water stress led to lowered values of yield and yield components. The water stress conditions in the greenhouse experiments was severe due to the frequency of water applications not coping probably with plant uptake. In the field experiment percent flower - and pod-abscission was decreased by the mild water stress conditions. The number of open flowers per plant, yield and yield components was not affected by stress. However, there was a reduction in yield mainly due to low flower initiation that led to fewer pods per plant in high water stress levels. The observations revealed that mild water stress conditions may enhance flower retention. Defoliation had no effect on number of open flowers per plant, yield and yield components, in stressed plants. However, the values were significantly reduced with increased defoliation in non-stressed plants. This observation suggested that water stressed plants were sink limited that is the leaves available could more than provide for the flowers and pods such that removal of some leaves had no effect. Genotypes 423/60 and ICPL 7403 had lower percent abscission and higher yields under conditions of high source sink ratios (on deflowering) and a reduction in number of pods per plant when the source-sink ratio was low (on defoliation). The observations in this study, therefore, suggest that genotypes 423/60 and ICPL 7403 had stronger sink characteristics than NPP 670.

The decrease in number of open flowers per plant, grain yield and yield components with stress for NPP 670 was more than in genotypes 423/60 and ICPL 7403. Genotypes 423/60 and ICPL 7403 also had shorter maturity period and flowering and podding duration. This showed that ICPL 7403 and 423/60 were more drought resistant than NPP 670. Their drought resistance was attributed to their indeterminate growth habits.

This study has revealed the need for further studies on the extent of flower - and pod abscission in a number of pigeonpea cultivars. The cultivar study should include a difference in growth habits, and crop maturity hence different sink-source capacities and resistance to environmental stresses. The effects of different water stress levels on the vegetative and reproductive growth should also be measured and related to flower retention. There is, also, need to study the effects of other environmental factors on abscission.

7. LITERATURE CITED

Acland, J.D. 1972. East African crops. An introduction to the production of field and plantation crops in Kenya, Tanzania and Uganda. FAO/Longman, London.

Akinola, J.O. and P.C. Whiteman. 1974. Agronomic studies on pigeonpeas (*Cajanus cajan* (L.) Millsp.). Field responses to sowing time. Aust. J. Agric. Res. 26: 43-56.

Anonymous. 1976. Statistical Abstract, Central Bureau of Statistics, Ministry of Economic Planning and Community Affairs, Kenya.

Ariyanayagam, R.P. 1975. 'Status of research of pigeonpeas in Trinidad'. Proceedings of International Workshop on Grain Legumes, ICRISAT, Hyderabad, India.

Barnett, K.H. and R.B. Pearce. 1983. Source-sink ratio alteration and its effect on physiological parameters in maize. Crop Sci. 23: 294-299.

Binnie, R.C. and P.E. Clifford. 1980. Effects of some defoliation and decapitation treatments on productivity of *Phaseolus vulgaris*. Ann. Bot. 46: 811-813.

Bradford, K.J. and T.C. Hsiao. 1982. Physiological responses to moderate water stress. In O.L. Lange and P.S. Nobel, C.B. Osmond and H.Zeigler (eds) Encyclopedia of plant physiology, New series, Vol. 12B. Springer-verlag, New York pp. 263-324.

Brown, L.H. and J. Cochene. 1969. Technical report on a study of agroclimatology of the highlands of East Africa. FAO/UNESCO/UMO Interagency Agroclimatology project, FAO/ROME.

Ciha, A.J. and W.A. Brun. 1978. Effect of pod removal on nonstructural carbohydrate concentration in soyabean tissue. Crop Sci. 18: 773-776.

Constable, G.A. and A.B. Hearn. 1978. Agronomic and physiological responses of soyabean and sorghum crops to water deficits 1. Growth, development and yield Aust. J. Plant Physiol. 5: 159-167.

Dornhoff, G.M. and R.M. Shibles. 1970. Varietal differences in net photosynthesis of soyabean leaves. Crop Sci. 10: 42-45.

Doss, B.D., R.W. Pearson, and H.T. Rogers. 1974. Effects of soil water stress at various growth stages on soyabean yield. Agron. J. 66: 297-9.

D'Souza, H.A. and C.L. Coulson. 1988. The effects of temperature and relative humidity on the flowering pattern in beans. J. Trop. Agric. 65: 179-181.

Egli, D.B. and J.E. Leggett,. 1976. Rate of dry matter accumulation in soyabean seeds with varying source-sink ratios. Agron.J. 68: 371-374

Egwatu. R.I. 1975. Studies on the bionomics of Acanthomia tomentosicollis stal (Hemiptera, coreidae) and its egg parasite Gryon gnidus nixon (Hymenoptera, scelionidae). Ph.D. thesis, University of Ibadan, pp. 64-69.

Floor, E. 1983. Investigations on drought resistance of beans developed by Grain Legume Project, Thika. In: Phaseolus bean Newsletter for Eastern Africa No. 1 pp. 8-9.

Garrity, P.D., C.Y. Sullivan, D.G. Watts. 1984. Changes in grain sorghum stomatal and photosynthetic response to moisture stress across growth stages crop sci. 24(3): 441-446.

Hammerton, J.L. 1972. Effects of weed competition, defoliation and time of harvesting on soyabeans. Expl. Agric. 8: 333-338.

Hammerton, J.L. 1975. Effects of defoliation on pigeon peas (Cajanus cajan). Expl. Agric. (1975), 11: 177-182.

Heindl, J.C., D.R. Carlson, W.A. Brun, and W.L. Brenner. 1982. Ontogenetic variation of four cytokinins in soyabean root pressure exudate. Plant physiol. 1: 70: 1619-1625.

Hicks, D.R. and J.W. Pendleton. 1969. Effect of floral bud removal on performance on soybeans. Crop Sci. 9: 435-437.

International Crops Research Institute for Semi-arid Tropics. 1976. ICRISAT, Annual Report 1975-1976, Hyderabad, India.

International Crops Research Institute for Semi Arid Tropics, 1977. ICRISAT, Annual Report 1976-1977, Hyderabad, India.

International Crops Research Institute for Semi-arid Tropics, 1978, ICRISAT, Annual Report 1977-1978, Hyderabad, India.

Johnson, R.R. and D.N. Moss. 1976. Effects of water-stress on $^{14}CO_2$ fixation and translocation in wheat during grain filling. Crop Sci. 16: 697-701.

Kamweti, M.W. and C.L. Coulson,. 1984. The effects of water applications and flower abscission on three cultivars of *Phaseolus vulgaris*. Bean-cowpea CRSP progress report.

Keatinge, J.D.H. and G. Hughes. 1981. Pigeonpea as a dry season crop in Trinidad,West Indies. 1. Yield and yield components. Trop. agri. (Trinidad) 58: 45-57.

Khan, T.N. and K.O. Rachie. 1972. Preliminary evaluation and utilization of pigeonpeas. Germplasm in Uganda, E. Afr. Agr. For. J. 38(1); 78-82.

Kimani, P.M. 1987. Pigeonpea breeding in Kenya. Objectives and methods. Paper presented at pigeonpea scientists meet. 2-5 June 1987, Nairobi, Kenya.

Kohel, R.J. and C.R. Benedict. 1984. Year effects on partitioning of dry matter into cotton boll components. Crop Sci. 24(2): 268-270.

Kramer, P.J. 1949. Waterstress and plant growth. plant and soil water relationships. New York, McGraw-Hill.

Laing, D.R., P.J. Kretchmer, S. Zuluaga and P.J. Jones, 1983. Physiological studies on yield and adaptation of *P. vulgaris*. In: Potential productivity of field beans under different environments. Eds. S. Yoshida pp. 526. IRRI, Los Banos, Philippines.

Lafitte, H.R. and R.L. Travis. 1984. Photosynthesis and assimilate partitioning in closely related lines of rice exhibiting different sink-source relationship. Crop Sci. 24: 447-452.

Lawn, R.J. 1981. The potential contribution of physiological research to pigeonpea improvement pp. 151-164. In proceedings of international workshop on pigeonpeas. ICRISAT/ICAR, Vol. 1 ICRISAT, Patancheru, India.

Lawn, R.J. and W.A. Brun. 1974. Symbiotic nitrogen fixation in soyabeans. I. effects of photosynthetic source-sink manipulations. Crop Sci. 14: 11-16.

M'Arimi, A.M. 1977. The effects of some tillage methods and cropping sequence on rain-conservation in a semi-arid area of Eastern Kenya. MSc. Thesis, University of Nairobi.

McCarthy, F.D. and W.M. Mwangi. 1982. Kenya Agriculture toward 2000. I.I.A.S.A. Laxenburg, Austria.

Meadley, J.T. and G.M. Milbourn. 1970. The growth of vining peas. II. The effect of density of planting J. Agric. Sci. Camb. 74: 273-278.

Narayanam, A. and A.R. Sheldrake. 1976. ICRISAT Pigeonpea Physiology. Annual Report (1975/76).

Natarajan, M. and Willey, R.W. 1980. Sorghum-pigeonpea intercropping and the effects of plant population density. I. Growth and yield. J. Agric. Sci. Camb. 95: 51-58.

Norman, N.J.T, C.J. Pearson and P.G.E. Scarle, 1984. Common bean (P. vulgaris) In: The ecology of tropical crops Cambridge Univ. Press.

Neales, T.F. and L.D. Incoll. 1968. The control of leaf photosynthetic rate by the level of assimilate concentration in the leaf. A review of the hypothesis. Bot. Rev. 34: 107-124.

Nyabundi, J.O. 1980. A study of drought resistance in pigeonpeas (Cajanus cajan L. Millsp.) M.Sc. thesis, University of Nairobi.

Nyabundi, J.O. 1985. Water stress effects on biomass production and partitioning in processing tomatoes. Ph.D. thesis, University of California, Davis.

Nyandat, N.N. and D.O. Michieka. 1970. Soils of Kirima Kimwe, Faculty of Agriculture Farm, National Agric. Labs., Ministry of Agriculture, Kenya: 1-2.

Ogombe, I.J.O. 1978. Effects of plant density and phosphate fertilizer on the growth, flower - and pod-abscission, yield and yield components of pigeonpeas (Cajanus cajan (L.) Millsp.). M.Sc. thesis, University of Nairobi.

Onim, J.F.M. 1981. Development of pigeonpea populations for marginal rainfall areas of Kenya. Ph.D. Thesis, University of Nairobi.

Pandley, R.K. and V.B. Singh. 1981. Influence of source and sink size on flower drop and seed yield of pigeonpea; Indian J. agric. sci. 51: 185-188.

Pate, J.S, C.A. Atkins, K. Hamel, D.C. McNeil, and D.B. Laysell. 1979. Transport of organic solutes in phloem and xylem of a nodulated legume. Plant Physiol. 63: 1082-1088.

Patrick, J.W.; and P.F. Wareing. 1976. Auxin-promoted transport of metabolites in stems of Phaseolus vulgaris L.J. Exp. Bot. 27: 969-982.

Porter, N.G. 1981. The directional control of sucrose and asparagine transport in lupin by abscisic acid. Physiol. Plant 53: 279-284.

Preiss, J. 1982. Regulation of the biosynthesis and degradation of starch. Ann. Rev. Plant Physiol. 33: 431-454.

Purseglove, J.W. 1968. Tropical crops Dicotyledons. Longmans, London.

Rao, J .M., N. Venkataratnan and A.R. Sheldrake, 1981. 'Response to row to row and plant to plant spacing in pigeonpea' Proceedings of International Workshop on Pigeonpea, ICRISAT/ICAR, Vol. 2. ICRISAT, Patancheru, India.

Raper, C.D. and S.A. Barber, 1970. Rooting systems of soyabeans. Differences in root morphology among varieties. Agron. J. 62: 581-584.

Reddy, R.P., S., Singh and N.G.P. Rao. 1975. Character association in pigeonpea. Indian J. Genet. Plant Breed. 35; 119-122.

Rowden, R.R; D. Gardiner, P.G. Whiteman and E.S. Wallis, 1981. Effects of planting density on growth, light interception and yield of a photoperiod insensitive pigeonpea (Cajanus cajan); Field Crops Res., 4: 201-213.

Salter, P.J. and J.E. Goode. 1967. Crop responses to water at different stages of growth. Commonwealth Bur. Hot. Plant Crops. Res. Rev. No. 2.

Setter, T.L., W.A. Brun, and M.L. Brenner. 1981. Abscisic acid translocation and metabolism in soyabeans following depodding and petiole girdling treatments. Plant Physiol. 67: 774-779.

Setter, T.L., C.R. McDavid and F.B. Loper. 1984. Photosynthate partitioning in pigeonpea in response to defoliation and shading. Crop Sci. 24(2): 221-224.

Sheldrake, A.R., 1984. Pigeonpea. The physiology of tropical field crops. Edited by P.R. Goldsworthy and N.M. Fisher.

Sheldrake, A.R. and A. Narayanam, 1979. Growth development and nutrient uptake in pigeonpeas (Cajanus cajan); J. Agric. Sci. Camb., 92, 513-526.

Sheldrake, A.R., A. Narayanam. and N. Venkataratnan. 1979. The effects of flower removal on the seed yield of pigeonpeas (Cajanus cajan). Ann. appl. Bot. 91, 383-390.

Sharma, D., L.J. Reddy, J.M. Green and K.C. Jain. 1981. International adaptation in pigeonpeas p. 77-81. In proceedings of International Workshop on Pigeonpeas

Vol. 1. ICRISAT, Pantancheru, A.P. India.

Sinha, S.R. 1981. Water availability and grain yield in pigeonpeas. Proceedings of International Workshop on Pigeonpeas, ICRISAT/ ICAR, Vol. I. ICRISAT, Patancheru, India.

Steel, R.G. and H.J. Torrie. 1980. Principles and procedures of statistics. a biometric approach. McGraw-Hill Kogakusha Ltd.

Subhadrabhandhu, S., M.W. Adams and D.A. Reicosky. 1978. Abscission of flowers and fruits in Phaseolus vulgaris L. Cultivar differences in flowering pattern and abscission. Crop Sci. 18(5). 893-896.

Tayo, T.O. 1980. Compensatory growth and yield of pigeonpea (Cajanus cajan following pod removal at different stages of reproductive growth. J. Agric. Sci., Camb. 95, 487-491.

Tayo, T.O. 1982. Growth development and yield of pigeonpea (Cajanus cajan (L.) Millsp.) in the lowland tropics.
2. Effect of reduced assimilatory capacity. J. Agr. Sci., Camb. 98: 71-77.

Tiertz, A.M., Ludewig, M. Dingkuhn, and K. Dorffling, 1981. Effect of abscisic acid on the transport of assimilates in barley. Planta 152: 557-561.

Turnipseed, S.G.C. 1972. Response of soyabeans to foliage losses in South Carolina. Journal of Economic Entomology 65: 224-229.

Van Schaik, P.H. and A.H. Probst. 1958. Effects of some environmental factors on flower production and reproductive efficiency in soyabeans. Agron. J. 50: 192-197.

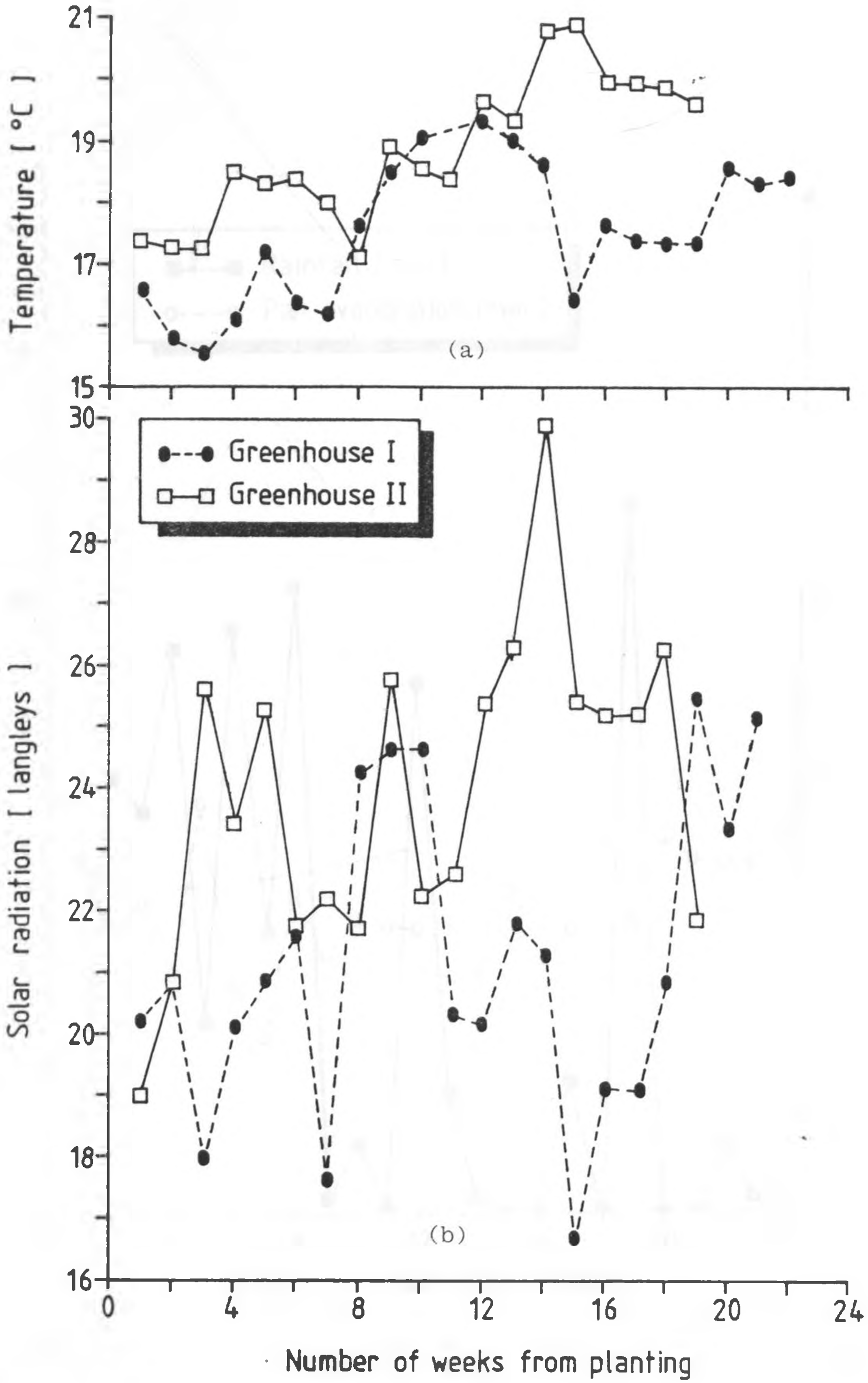
Wamburi, K.K. 1973. Notes on the Kabete Field Station, Faculty of Agriculture, University of Nairobi

Wikerson, G.G., J.W. Jones and S.C. Poe·1984. Effect of defoliation on peanut plant growth. Crop physiol. 24. 526-53).

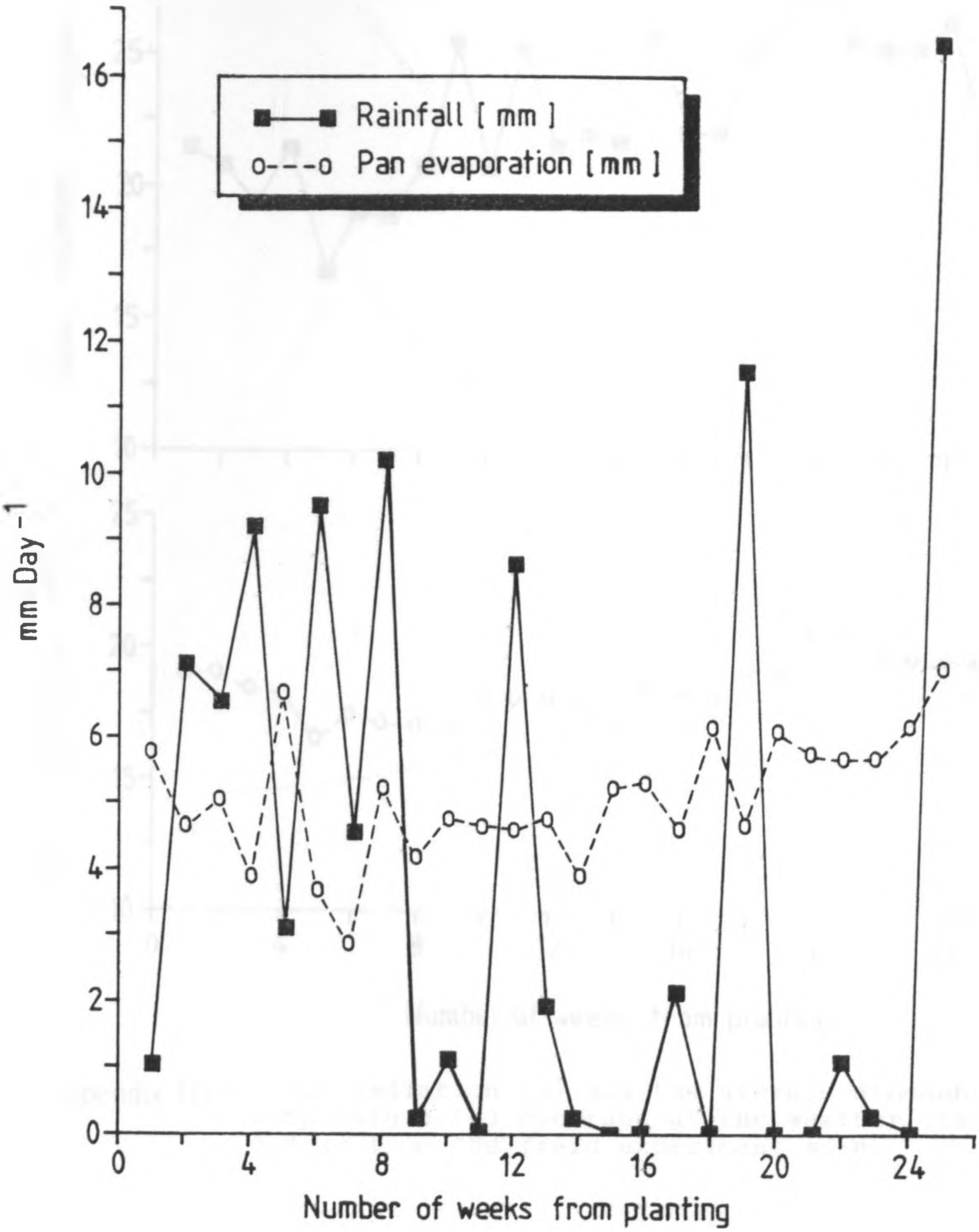
Wilson, J.W. 1972. Control of crop processes p. 7 - 30 A.R. Rees et al (ed) Crop processes in controlled environments, Academic press. New York.

Yu, Y.B., and S.F. Yang. 1980. Biosynthesis of wound ethylene .Plant physiol. 66: 281-285.

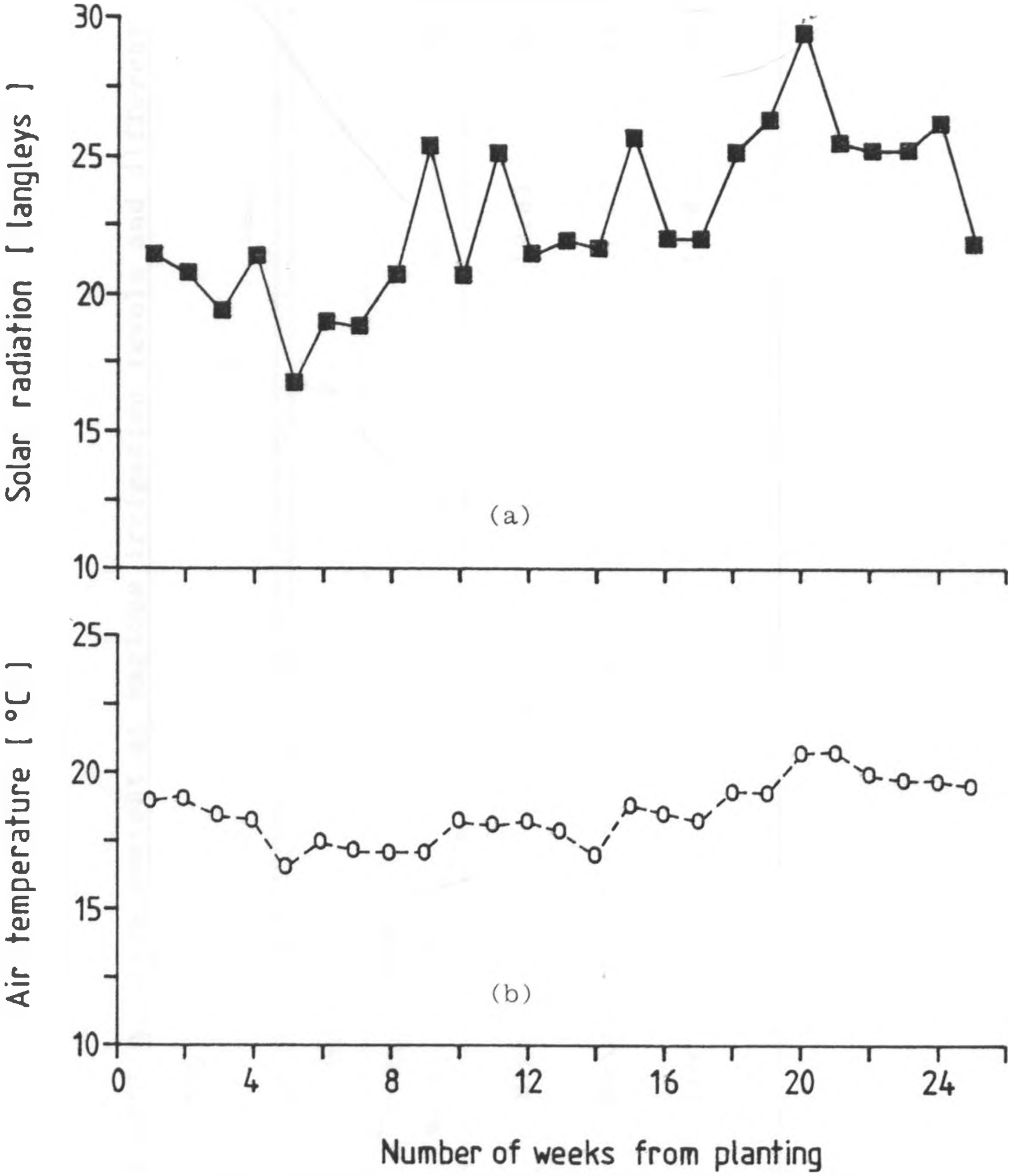
A P P E N D I C E S



Appendix I. Solar radiation (a) and average atmospheric temperature (b) recorded at weather station 0.1 km from the greenhouse experiments.



Appendix II. Rainfall and pan evaporation recorded at the weather station 0.8 km from the field experimental site.



Appendix III. Solar radiation (a) and the average atmospheric temperature (b) recorded at the weather station 0.8 km from the field experiment site.

Appendix IV. Percent moisture content at various irrigation levels and different soil depths.

Main plot	Date / Soil depth / Water level	11-2-87		1-3-87	
		10 cm	30 cm	30 cm	60 cm
M1	High	16.89	18.77	19.81	22.06
M3	Medium	16.04	16.42	17.03	19.03
M5	Low	15.34	15.13	15.43	18.29

Appendix V.I Analysis of variance for various characters (F-computed values). Greenhouse Experiment I.

Characters \ Source	Blocks (B)	Water level (W)	Genotype (V)	Deflo-wering (F)	VXF	WXV	WXF	WXVXF
DF	2	1	1	2	2	1	2	2
Percent abscission	4.84	47.9*	3.24	27.14**	5.52	3.39	3.79*	31.7**
Number of open flowers/plant	0.26	130.4**	15.4**	28.9**	0.33	24.4**	3.05	37.53**
Corrected number of flowers per plant	0.82	44.43*	101.7**	19.3**	1.74	15.55**	1.38	27.7**
Number of pods per plants	0.34	36.47*	11.54**	14.29**	0.56	33.64**	0.67	22.06**
Pods per node	18.45	1321.8**	8.3**	31.96**	0.5	2.44	6.96**	32.06 **
Seeds per pod	0.36	16.14	0.04	4.72*	0.59	0.01	1.03	5.33
Days to maturity	0.81	6.93	2.98	3.41	1.19	0.13	2.53	6.09*
Flowering and pod-ding duration	0.14	20.65*	2.94	2.62	1.39	0.71	1.3	5.7*

*, ** Significant at 5 and 1 percent probability level, respectively.

Appendix V.2. Analysis of variance for various characters (F-computed values). Greenhouse Experiment I.

Source / Character	Variance due to							
	Blocks (B)	Water level (W)	Genotype V	Defoli-ation (D)	VXD	WXV	VXD	WXVXD
DF	2	1	1	2	2	1	2	2
Percent abscission	0.23	0.83	1.35	3.95*	0.05	1.97	1.62	5.51*
Number of open flowers/plant	7.13	112.01**	9.9*	1.7	1.54	12.8**	1.51	6.12**
Number of pods per plant	1.14	20.17*	5.96*	22.47**	3.6*	39.21**	8.41**	23.55**
Pods per node	2.81	0.6	1.56	13.8**	0.87	6.57*	2.5	11.6**
Seeds per pod	2.96	6.68	9.4**	2.05	3.04	5.69*	1.69	2.34
Days to maturity	0.99	1.3	9.72**	2.01	0.49	0.45	0.53	7.07*
Flowering and podding duration	1.61	0.71	6.55*	2.07	0.35	0.08	0.56	4.93

*, ** Significant at 5 and 1 percent probability level, respectively.

Appendix V.3 Analysis of variance for various characters (F-computed values) Greenhouse Experiment II.

Source / Characters	Variance due to: Blocks (B)	Water level W	Geno-type V	Deflo-wering F	XXF	WXV	WXF	WXVXF
DF	2	1	2	3	6	2	3	6
Percent abscission	0.54	6.18	1.56	0.97	1.18	0.21	0.51	1.49
Number of open flowers/plant	5.49	2.78	1.13	8.25**	0.59	8.0**	2.93*	5.4*
Corrected number of open flowers per plant	3.44	7.63	1.49	34.41**	0.57	3.76*	1.41	18.4**
Grain yield/plant	0.0012	15.96	1.5	0.83	0.51	2.8	0.64	1.94
Total pods/plant	0.08	11.0	1.6	0.47	0.91	3.52**	0.26	3.03
Pods/node	0.34	8.08	0.2	27.4**	0.66	1.29	1.54	15.56**
Seeds/pod	0.56	4.08	5.3**	1.58	1.39	0.861	3.23	9.56**
100-seed weight	2.57	20.8*	53.8**	1.08	0.47	1.17	1.34	19.3**
Days to maturity	0.15	6.95	1.65	1.83	1.23	0.5	2.91*	3.78**
Flowering and pod-ding duration	8.16	58.63**	10.87**	2.47	2.35*	0.59	0.09	8.25**

*, ** Significant at 5 and 1 percent probability level, respectively.

Appendix V.4. Analysis of variance for various characters (F-computed values) Greenhouse Experiment II.

Source / Characters	Blocks (B)	Water stress (W)	Geno-type (V)	Defolia-tion (D)	VXD	WXV	WXD	WXVXD
	Variance due to							
DF	2	1	2	3	6	2	3	6
Percent abscission	0.14	1.59	7.41**	1.47	0.56	2.1	1.18	4.88**
No. of open flowers per plant	3.9	0.13	27.48**	6.85**	3.87**	3.9	2.98*	9.9**
Grain yield per plant	0.2	10.46	4.67*	9.97**	7.2	21.84**	0.97	7.95**
Total number of pods/plant	0.17	5.77	1.12	10.84**	2.52*	22.2**	3.49*	9.19**
Pods per node	0.08	6.79	4.61*	4.04*	0.78	16.47**	14.72**	6.22**
Seeds per pod	0.25	39.02**	18.9**	1.79	0.74	2.21	0.22	8.56**
100-Seed weight	0.02	111.4**	96.46**	0.8	2.52	21.63	3.65	36.91*
Days to maturity	0.93	6.19	6.64**	7.09**	0.92	4.79*	0.37	7.17**
Flowering and podding duration	5.17	10.52	1.29	7.86**	1.41	1.97	0.45	5.68

*, ** Significant at 5 and 1 percent probability level, respectively.

Appendix V.5. Analysis of variance for various characters. (F-computed values). Field experiment.

Source / Characters	Variance due to							
	Blocks (B)	Water stress (W)	Geno-type (V)	Deflo-wering (F)	VXF	WXV	WXF	WXVXF
DF	2	2	2	3	6	4	6	12
Percent abscission	2.59	12.84*	75.0**	9.4**	2.61*	1.46	1.72	17.81**
Number of open flowers per plant	0.26	5.87	74.56*	3.56*	1.97	0.92	2.00	0.05
Corrected number of open flowers per plant	0.09	0.94	86.22**	116.3**	10.5**	0.49	1.51	50.22**
Grain yield per plant	0.12	6.79	78.48**	3.7**	2.9*	1.5	1.43	16.62**
Total pods per plant	0.88	4.48	142.4**	5.98**	3.92**	2.11	2.24	28.65**
Pods per node	2.83	2.35	0.57	126.62**	1.01	1.09	1.19	32.35**
Seeds per pod	0.015	0.69	188.8**	0.305	0.68	1.6	0.68	31.54**
100-seed weight	1.19	3.36	253.2**	5.69**	0.69	1.174	0.179	8.2**
Days to maturity	3.33	0.37	304.7**	38.4**	6.25**	5.44**	2.89*	64.7**
Flowering and podding duration	0.29	0.17	200.84**	28.32**	4.52**	1.53	3.07*	44.84**

*,** Significant at 5 and 1 percent probability level, respectively.

Appendix V. 6. Analysis of variance for various characters (F-computed values). Field experiment.

Characters \ Source	Variance due to							
	Blocks (B)	Water stress (W)	Genotype (V)	Defoliation (D)	VXD	WXV	WXD	WXVXD
DF	2	2	2	3	6	4	6	12
Percent abscission	1.26	5.76	39.67**	34.18**	1.92	1.57	1.47	16.33**
Total number of open flowers/plant	1.52	4.46	37.56**	10.44**	1.99	3.32*	1.21	9.87**
Grain yield per plant	0.3	4.26	28.81**	24.09**	1.27	1.11	0.85	12.2**
Total pods per plant	0.19	6.15	80.67**	37.9**	3.16**	1.79	0.99	25.2**
Pods per node	4.91	16.12	5.28**	46.02**	1.32	1.15	0.87	13.38**
Seeds per pod	3.19	1.91	203.8**	17.37**	1.97	1.6	1.17	40.5**
100-seed weight	3.4	1.89	294.01**	0.39	2.18	1.14	0.36	50.69**
Days to maturity	1.28	0.68	114.4**	20.81**	4.48**	0.54	3.85**	27.12**
Flowering and podding duration	3.53	3.13	91.9**	2.73	2.95*	2.74*	0.92	17.9**

*, ** Significant at 5 and 1 percent probability, level.