A STUDY ON DROUGHT RESISTANCE IN PIGEON PEAS (Cajanus cajan L. Millsp.)

by

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DECLARATION

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

Date _Dec. 24ᵗʰ 1980_ . _____

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This thesis has been submitted for examination with my approval as University Supervisor

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DR. D.N. NGUGI

DEDICATION

To my Parents

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ABSTRACT

Two experiments were conducted over two seasons. The first
experiment (Experiment I) ran from October 1979 to March, 1980
while the second experiment (Experiment II), which was a repeat
of experiment I, was conducted between April and October, 1980.
Both experiments were conducted in glass-house.

Six genotypes of pigeon peas were planted in 5 litre plastic pots
such that there were two plants per pot. Planting medium
consisted of a mixture of forest soil and cow dung manure in
the ratio of 10:1 by volume. After one month of growth the
genotypes were subjected to four watering regimes: Watering daily
to container capacity, watering after every 7 days to container
capacity, watering after every 14 days to container capacity, and
watering after every 21 days to container capacity. These treat-
ments were replicated in 5 blocks.

The results showed that drought stress had depressing effect on
plant height, total plant dry weight, shoot dry weight, yield of
grains per plant and number of pods per plant. Effects of drought
stress on root dry weight, number of nodes per plant, number of
branches per plant and number of grains per pod were not very
clear but stress had little influence on 100-seed weight. It
was also found that water stress favoured deposition of dry matter
in vegetative parts at the expense of pods. Of the vegetative
parts drought stress favoured roots more than shoots with respect
to dry matter deposition.

Genotypic differences were noted in both growth and yield attributes.

Differences between seasons were remarkable in a number of cases
and were attributed to differences in temperature between the
two seasons:

Apparently two conclusions may be made from this study:

(i)   Pigeon peas in general are very resistant
        to drought but early maturing genotypes are
        more hardy than late maturing ones although
        the latter perform better under wet conditions.

(ii)   The study of plant water relations
       in pigeon peas is influenced to a large
       extent by other environmental factors
       such as ambient temperature and sun-shine
       so that it would be difficult to isolate
       the direct effects of water stress under
       field conditions.

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CHAPTER 1

INTRODUCTION

1.1. General

Crop plant development is known to be affected by
temperature and many cultivars are also affected by both
day length and vernalization. Less definite evidence is
available about the effects of water stress on development
although conflicting suggestions have been made in both
folklore and literature as to whether water stress hastens
or slows down development. Circumstances in which
development is hastened have been reported in various crops,
for example; Angus and Moncur (1977) in Wheat, Whiteman
and Wilson (1965) in Sorghum and El Nadi (1974) in Cotton.
On the other hand, examples have shown delayed development
for example, Chinoy (1960) and Angus and Moncur (1977)in
Wheat and Whiteman and Wilson (1965) in Sorghum. The overall
effects of water deficits on a crop yield appears to depend
very much on the stage of development of the crop during
which the stress occurs. Moderate deficiencies can result
in stunting, distorted development and much reduced crop
yields and prolonged drought can cause complete crop
failure but the yield components affected vary depending
on the physiological age of the crop during the period in
which the stress is experienced (Salter and Goode, 1967). .

These visible symptoms of deficiency not withstanding,
Slatyer (1969) noted that a clear and unambiguous state-
ment as to the effects of water deficits on crop yield is
difficult to make for a variety of reasons: Firstly,
despite the importance of the phenomenon to agriculture
in most of the food producing countries of the world,
relatively little attention has been devoted,to the subject.
Secondly, plant water status is a highly dynamic parameter,
strongly influenced by conditions in the soil and atmospheric
micro-environments and also regulated to different degrees,

in different situations and with different species by
physiological factors. It therefore constitutes a difficult
parameter to examine experimentally. This, in part, is
probably the reason for the relative lack of effort in this
field. Thirdly, as is the case with most types of lesion,
water deficits affect the growth and development of crop
in many ways both directly and indirectly. Consequently
it is frequently difficult to assign cause and effect
relationships with confidence.

Partly because of these implications, it is observed that
only two valid generalizations can perhaps be made
regarding effects of water availability:

(a) In most crops growth and development proceed
completely unimpaired and crop yield is
maximal only when high water status is
maintained throughout the life of the crop.
(b) The deleterious effects of water deficits are
usually most pronounced in tissues and organs
which are in stages of most rapid growth and
development.

It follows from the second point that there are stages
of growth when there is relatively greater or lesser
sensitivity to water stress as far as grain yields are
concerned.

The present study explores the effects of water stress
on growth and yield in pigeon pea (Cajanus oajan L. Millsp).
C. cajan   was recorded in Egyptian tombs dating
2000 - 2400 B.C. (Akinola and Whiteman, 1972) although it is
believed to have evolved in the region between Egypt and
East Africa (Krauss, 1932; Purseglove, 1968). It is the
only known species of the genus Cajanus D.C. of the tribe
Phaseoleae, subfamily Papilonaeceae in the family
Leguminosae (Cobley, 1956; Purseglove, 1968; Royes, 1976;
Smartt, 1976). It is variously known by other common names
as Ambrevade, doll, Angola pea, Congo pea, red gram, no
eye pea, Nzuu mbaazi, njugu, obong, Angor, grandul and

tur. Pigeon pea is known to be drought- resistant and survives well in the semi-arid areas of the tropics. In Kenya it is a popular crop in the marginal rainfall areas of Central, Eastern and Coast provinces and, although no accurate data is available on the ranking (hectarage) of the crop among other pulses in Kenya due to the fact that the crop is usually intercropped, it probably ranks fourth after beans (Phaseolus vulgaris L.), groundnuts (Arachis hypogaea L.) and cowpea (Vigna Unguiculata L.) (Ngugi, 1979). However, whereas a lot of work has been done to study the effects of water stress in some other pulses (Salter and Goode, 1967), no study has been carried out to examine the effects of soil moisture stress on pigeon peas. It is therefore hoped that the present study will stimulate further research into water relations of this crop which thrives in some of the least watered parts of the world with an aim of further improving its water use efficiency.

1.2. Importance and Uses of Pigeon Pea

Pigeon peas are primarily grown for the dry seeds. These are usually either boiled mixed with maize or fried and eaten as vegetables. At the Kenya coast the dry seeds are cooked in coconut oil and eaten with either bread or mandazi especially for breakfast (Ogombe, 1978). The green immature seeds are occasionally harvested and eaten as vegetables. There is a Canning Industry at Thika also using the unripe green seeds with a big market potential particularly for export. Pigeon peas are often grown as boundary plants, hedges or windbreaks. The woody stems are used as firewood.

Pigeon peas can also be used in a number of ways as is done elsewhere in the world (Whyte et al, 1953; Saville and Wright, 1955; Oyenunga, 1968; Purseglove, 1968; Pathak, 1970; Khan and Rachie, 1972; Westphal, 1974). In India the dry seeds are split and made into "dhal". The dried husks and broken dhal are used as cattle feed. The immature green seeds are sometimes used as vegetables in many countries and are canned in Puerto Rico and Trinidad. The tops of the plants with fruit provide good fodder and

are made into hay and silage. Pigeon peas can be
planted alone or in pastures as browse plants
(West, 1956). They are also planted as green
manures, as cover crops, as temporary shade for
young cocoa plants and for soil erosion control.
Pigeon peas are particularly useful as soil improving
plants and are frequently planted at the end of a
rotation as a fertility restoring crop in the shifting
farming areas of West African Savanna (Webster and
Wilson, 1966). It has also been planted as a fallow
crop in Savanna area of Northern Nigeria (Dennison,
1959) and Kenya coast (Clarke, 1962). The dried
stalks are not only used as firewood and for
charcoal making but also as material for roofing,
and basket making.

The role of pigeon peas and other pulses in human
and animal nutrition is largely that of supplying
protein. Protein content of dry seeds is in the
range of 17.5-28 per cent with a mean of 20.9 per
cent (Aykroyd and Doughty, 1964; Hulse, 1975).
However, the special value of pigeon peas lies in
their security to yield even on exhausted soils of
semi-arid areas where few alternative crops are
available.

Objectives

.3.1.   To determine the effects of different watering regimes
on the growth and yield of pigeon peas.

.3.2.   To determine differences among the genotypes of
pigeon peas with respect to their responses to
watering regimes as expressed in their growth and
yield.

CHAPTER 2

LITERATURE REVIEW

2.1. Effects of water availability on growth and development

2.1.1.   Whole plant: Growth of a plant can be divided into
vegetative and generative stages. Water availability
has been found to influence growth in both stages
(Salter and Goode, 1967). Growth is suspended during
periods of water stress and resumed upon elimination
of the stress. The extent of damage caused to the
plant depends on their physiological age, the degree
of water stress, its frequency and duration and the
species concerned (Gates, 1968). Generally the organ
growing most rapidly at the time of stress is the one
most affected and the effects are more severe at the
beginning of a particular growth process (Tiver, 1942;
Aspinall et al., 1964) suggesting impairment of cell
division by tissue moisture stress. Growth is reduced
by decrease in relative turgidity below 90 per cent
(May and Milthorpe, 1962). The relations between
turgor and growth are, however, not fully understood
(Kramer, 1959). Water deficits cause dehydration of
protoplasm associated with loss of turgor. Reduction
in cell division and cell expansion are usually
associated with loss of turgor and result in decrease
in growth of stem, leaves and fruit (Arnon, 1975).

2.1.2.   Shoot: Periods of water stress during vegetative
growth usually have depressing effect on several growth
attributes. El Nadi (1969a) found significant
reductions in leaf area, net assimilation rate and
relative growth rate of broad bean (Vicia faba L.) due
to water stress. However, despite the significant
effects on these aspects, the moisture content of shoot
tissues of plants suffering from moisture stress

decreased very slightly compared to moisture content of plants that were always supplied with water.

Abd el Rahman et al. (1967) found that barley plants receiving highest amounts of water grew tallest. However, the effect was less pronounced during the early stages than at the later stages when cummulative effects of water supply appeared. These authors also reported an increase in both fresh and dry weights with increase in level of water supply through-out the whole of the vegetative growth period, a response which they attributed to increase in height and number of tillers. Wien et al. (1979) reported reduction in total dry weight in moisture stressed (V. unguiculata L.) and Soy-bean (Glycine max L.) plants. Plant heights were also significantly reduced in instances where stress began before stem had ceased growing. Soil moisture status has also been shown to influence the number of branches which a plant produces. Thus Salter (1963a) reported increase in number of branches per plant with increasing levels of soil moisture in peas (Pisum sativum L.). However, an initial phase of drought followed by favourable water regime was found to stimu-late production of more branches in (V. faba) (El Nadi, 1969a) and more tillers in wheat (El Nadi, 1969c) and El Nadi (1974) reported that irrigating after drought temporarily increased vegetative growth in cotton.

Leaf enlargement can be reduced even by small degrees of desiccation generally long before photosynthesis is affected (Boyer, 1973; Hsiao, 1973). Boyer (1970) reported that leaf enlargement was sensitive to moisture stress in maize (Zea mays L.), soya bean and sunflower (Helianthus annus L.) virtually ceasing at leaf water potential of -4 bars and Wien et al. (1979) found that the rate at which leaves unfolded at the apex of cowpea and soybean plants decreased as the moisture stress developed. Since

cell division and cell enlargement are sensitive to drought stress, water deficits during vegetative phase can have marked effects on leaf area and, therefore, on dry matter production. Furthermore, as the rate of evapotranspiration is determined to a large extent by leaf area up to complete ground cover (Turner, 1966; Ritchie and Burnett, 1971), reduction of leaf expansion provides a mechanism for reducing water loss from soil and delaying severe water stress.

In natural communities leaf shedding and a reduction of leaf area are recognized as an important adaptive feature for drought tolerance in arid regions (Orshan, 1963; Evanari et al., 1971; Kozlowski, 1976). In cultivated crops one of the responses to water deficits is for the leaves to be shed or to die (McMichael et al., 1973; Ludlow, 1975; and for tillers to die (Turner, 1966; Rackham, 1972; Begg and Turner, 1976). Leaf shedding reduced water loss in native vegetation (Orshan, 1963) but the importance of leaf shedding and senescence on evaporation in cultivated crop has, however, not been evaluated. Differences in the sensitivity of leaf expansion to stress has been observed between species (Turner and Begg, 1978) but has not been measured among cultivars.

When exposed to water stress, some plants have been observed to reduce water loss by reducing the radiation intercepted by the plant community. This can be achieved by active and passive leaf movements, increasing pubescence and/or increasing leaf waxiness. Begg and Torssell (1974) observed active leaf movements in Townsville stylo (Stylosanthes humilis) to reduce the radiation intercepted by the leaves when water deficits develop; when the water supply is adequate, the leaves follow the sun and are perpendicular to the incident radiation but as the water deficits

develop the plant orientates its leaves parallel to
the incident radiation. Similar parahelionastic leaf
movements have been reported in P. vulgaris
(Dubetz, 1969). Leaves of crops
frequently roll or hang limp when stressed. This
passive leaf movement reduces the interception of
radiation (Begg and Turner, 1976) thereby counteracting
the increase in leaf temperature arising from stomatal
closure (Gates, 1968) and preventing further develop-
ment of leaf water deficits.

In natural communities pubescence (or hairiness)
increases along a gradient of increasing aridity and
is considered an adaptation to water deficits
(Ehleringer et al., 1976). Likewise water deficits
have been observed to increase leaf hairiness in some
varieties of sunflower (Begg and Turner, 1976) and
wheat (Quarrie and Jones, 1977). Recently Ehleringer
et al. (1976) showed that increased hairiness in Encelia
increased the reflection and decreased the absorption
of photosynthetically active radiation by as much as
56 per cent below values in non-pubescent Encelia.
Although the influence of this loss of energy on water
conservation has not been studied, it would be expected
to reduce water loss (Abou-Khaled et al., 1970). The
increased reflectance of energy rather than the increase
in boundary layer resistance resulting from pubescence
is considered to have the greater effect in reducing
water loss (Johnson, 1975; Quarrie and Jones, 1977).
Epicuticular wax bloom noted on some sorghum leaves
also increases the energy reflection and reduces water
loss (Chatterton et al., 1975).

2.1.3.   Root: Root growth is affected by soil potential in
a number of ways. The growth rate of roots decreases
with increasing degree of water stress, however, growth
of roots is actually less affected by water shortage
than is that of aerial parts so that the overall shoot:

root ratio is decreased (Begg and Turner, 1975; Turner and Begg, 1978).
Harris (1914) found that wheat plants cultivated in soils at 30 percent
field capacity had shoot:root ratio of 8:1 whereas those planted in soils
at 15 percent field capacity had shoot:root ratio of 3:1. Martin (1940)
also found that the growth of leaves as compared with that of root was
more sensitive to moisture stress in H. anuus. Similar phenomenon was also
reported by Davis (1942) for the stem of nutgrass (Cyperus rotundus L.) as
compared to its tubers. Hence it is generally agreed that the decrease in
shoot:root ratio with decreasing stress usually arises from a greater
decrease in growth of tops relative to growth of roots. But evidence for
absolute increase in root growth under stress has been provided in maize
(Hsiao and Acevedo, 1974); Ladino clover (Trifolium repens L.), Atlantic
alfalfa (Medicago sativa L.), orchard grass (Dactylis glomerata L.),

and reed canarygrass (Phalaris arundinacea L.) (Bennet and Doss,
1960) and common Bermudagrass (Cygnodon dactylon L.), Bahia-grass (Paspalum
notaturn Flugge.), and Dallis grass (Paspalum dilatatum Poir.) (Doss et
al., 1960). An increase in root weight may indicate a greater density of
roots or a greater depth of roots both of which are important morphological
adaptations to water deficits in that they can enable a greater degree of
extraction of soil water and maintenance of high plant water potential.

Salter (1957) commented that wet soil regimes led to shallow root-
ing in contrast to deeper development of roots under dry regions.
Work with V. faba (Kausch, 1955) also showed that correlation between
the growth of tap root and lateral roots can be influenced in such
a way that, when the plant is grown in sodium chloride or sucrose
solutions of increasing suction force, the growth of lateral roots
is retarded before that of tap roots. Likewise Lundkvist (1955)

observed that in V. faba   the proportion of
lateral roots with respect to total root length was
favoured by wet conditions. Development of deep
root systems would be a useful adaptative feature
if water is available at depth (Passioura, 1974).
Varietal differences in rooting depth have been
demonstrated in Wheat (Hurd, 1968; Derera et al, 1969),
Soyabean (Raper and Barber, 1970) and tomato (Zobel,
1975). Hurd (1968;1974) showed that deeper rooting
varieties of Wheat yielded better under drought stress.

Dry conditions have been found to favour production
of finer and more fibrous roots (Kmoch et al. 1957)
Roots subjected to water stress also tend to become
suberized. Marked reductions in root growth has been
observed in flax (Linum usitatissimum L.) when the
soil moisture potential was reduced to -7 bars but
some growth was still found to occur in soils drier
than -20 bars (Newman, 1966). Root growth in each
soil layer appears to be independent of moisture
content in other soil layers or in the shoot. Thus
plants of herding grass (Phalaris tuberosa L.) were
found to survive when water potential in the upper
metre of the soil was below -15 bars because some of
the roots penetrated to deeper horizons which contained
more readily available moisture (McWilliam and Kramer,
1968).

Roots grow towards water in the soil provided the
distance from the water is small (Arnon, 1975).

2.1.4.   Water availability at flowering period: For many grain
crops moisture stress at flowering period has been
found to be critical. Hiler et al. (1972) found that
the flowering stage was the most susceptible to severe
stress   (-14 to -28 bars leaf water potential) imposed
on cowpea plants. Aspinall et al. (1964), studying the
effects of moisture stress at various stages of plant
development in barley, found that all stages were

affected but the most sensitive stage was between
the completion of spikelet formation and anthesis.
Even a short period of water stress at anthesis will
markedly reduce the number of flowers that set seed
(May and Milthorpe, 1962). The critical period in
cereals begins with appearance of pollen mother cells,
(pollen . viability appears to be particularly
susceptible) and ends after pollination (Henkel, 1964).
An investigation in the field (Doss et al., 1974) and
one in pots in a growth chamber (Sionit and Kramer,
1977) showed that soyabean plants are more sensitive
to water stress in the post flowering than pre-
flowering periods. Largest yield decreases were
found when water was withheld in the mid-podfill period.

El Nadi (1969a) found that a wet regime during
flowering phase significantly reduced the intensity
of flower shedding in broad beans irrespective of
the type of the water treatment during part or whole
of the vegetative period. On the other hand, whenever
plants were subjected to wet treatment during part
or whole of the vegetative phase but received a dry
treatment during flowering phase, the incidence of
flower shedding was aggravated to a large extent. It
appears therefore that the beneficial effects of wet
treatment, during vegetative phase, in producing
bigger plants with more nodes may be partially reduced
by unfavourable water regimes during flowering phase.

Loewing (1940) working with   P. vulgaris
 and other crops under controlled environmental
conditions found that the plants were conspicuously
sensitive to drought at flowering. At the time of
flower inception there was an abrupt progressive
increase in the rate of transpiration and despite a
transitory rise in the rate of water absorption, the
plants tended to have lower water content and higher
percentage of dry matter. In the roots of these
plants at this time, Loewing(1940) found that salt uptake
was reduced and as flowering approached its peak the

water content of the roots was altered; root activity
lapsed into a state of retarded absorption of both
salt and water which tended to accentuate the
dehydration of tissues throughout the plant.

Evidence is thus available from Loewing's work that
water absorption and salt uptake are apt to decline
because of reduced root activity during the flowering
period of beans and it would reasonably be suggested
that a plentiful supply of water at this time would
tend to offset the adverse effects of reduced root
activity. Drawing on results of Liebscher (1887)
and Remy (1926) as well as his own work in Germany,
Brouwer (1959a) suggested that beneficial effects of
irrigating during flowering is due to increased
availability of nutrients to the plant. He noted that
during the three week flowering period of   P.
Sativum   in Germany, 10 per cent of total nitrogen
requirement, 40 per cent of phosphorus, 40 per cent of
potash and 45 per cent of Calcium oxide were taken up
by the plants. He, therefore, proposed that it was
because there was a comparatively large uptake of
nutrients during flowering that the availability of
nutrients to plants at this stage was important;
hence the greater plant growth and yield which resulted
when availability was enhanced by irrigating at this
time. Studies on other crops, however provide much
evidence to suggest that all aspects of plant water
relations undergo profound changes at the time of
floral initiation and flowering and it seems more
reasonable to assume that the beneficial effects of
plentiful supply of soil moisture at flowering is
primarily through alleviation of water stress conditions
in the plant rather than the effect on nutrient
availability and uptake although this may be a
contributory factor (Salter and Goode, 1967).

The root activity of leguminous plants has been
studied (Salter and Drew, 1965). The results showed

that root growth of determinate variety of   P.
sativum   increased rapidly after germination until
it reached maximum just before the initiation of the
first floral primordia. Shortly after, and before
the first flowers opened the production of new roots
declined sharply and this was accompanied by death
of many of the older roots. At the time the first
flowers opened the plants made little, if any new
growth but at the start of pod development a slight
resurgence of root growth was observed although this
again stopped as the pods matured. It is thus suggested
that when root growth is much reduced water absorption
by plants becomes particularly dependent on the supply
and flow through the soil to the root surface. However,
conductivity of unsaturated soils is very low (Marshall,
1959) and water stress would quickly occur in plants
that had ceased making root growth and in the absence
of renewed water supply to the existing root surface.

2.1.5. <u>Water availability and maturity</u>: Whereas it has been
well established that water stress retards vegetative
growth, some workers have observed that mild water
stress tends to stimulate early maturity. El Nadi
(1974) observed that cotton plants that were given
75mm of water every 20 days matured earlier than those
receiving the same quantity of water but after 10 or
15 days. Mild water deficits between floral initiation
and anthesis hastened anthesis and maturity in wheat
(Turner, 1966) and hastened the period from flowering
to maturity in some cultivars of alfalfa (Clarkson and
Russell, 1976). Work by Angus and Moncur (1977) showed
that maturity was hastened in wheat plants which
encountered mild stress, however, there was develop-
mental retardation in plants which had been heavily
stressed. The delay in development was apparently
due to cessation of development of shoot apex and
possibly due to cessation of all cell division during
severe stress. The mechanisms of hastening development
in conditions of mild stress are difficult to explain.

However, the increase in temperature which is known
to accompany water stress (Slatyer, 1969) may have
an effect in hastening development similar to that
of an increase in ambient temperature. Alternatively
it is possible that the plant may adapt to stress
by modifying the normal sequence of development so
that fewer cell divisions are required before anthesis
(Angus and Moncur, 1977).

Results of work by Aspinall and Hussain (1970) suggest
that the process associated with photoinduction of
flowering in both long day plant, Lolium temulentum
and a short day plant, Pharbatis nil may be inhibited
by osmotic stress. Water stress during induction
achieved by withholding water from soil-grown plants
also prevented flowering in Xanthium strumarium.
With L. temulentum and X. strumrium stress accompanied
by defoliation during the period immediately following
the inductive cycle also prevented flowering. The
data were consistent with stress imposed inhibition
of translocation of the floral stimulus from the leaf.
L. temulentum plants which were stressed but not
defoliated during this period formed flowers suggesting
that the floral stimulus itself is relatively stable
within the leaf during a period of stress.

Information on the effects of water stress on trans-
location is confusing due to its close relationship
to effects on photosynthesis, phloem transport and
activity of the importing organ (Wardlaw, 1968).
Although several authors have interpreted their data
in terms of stress induced inhibition of phloem trans-
port (Hartt,1967; Plant and Reinhold, 1965; 1967),
there is some evidence that translocation in itself
is relatively insensitive to stress when not affected
by changes in photosynthesis or growth of importing
organ (Wardlaw, 1967). It is known that water stress
retards apical growth but whether this is the chief
factor at work in the inhibition of transport of
flowering stimulus when a plant is exposed to stress

is not yet well established.

2.2. Effeot of Water Availability on grain yield

2.2.1. <u>Water availability and total grain yield</u>: When drought
occurs during a growing season crop yield will depend
not only on its ability to survive drought but also
on its ability to grow and complete development
before, during or after the drought. Derera et al.
(1969), for example, observed strong consistent
negative correlation between grain yield and days
to first ear emergence in wheat under simulated
drought conditions and concluded that between 40 and
90 per cent of the variation in wheat yields under
drought are accountable for by earliness. Chinoy (1960)
also showed that drought resistance was greater in
earlier lines than late ones even at the same
intensity of drought and Fischer and Maurer (1978)
have provided evidence from 53 wheat and barley
cultivars that the increase in yield that can be
ascribed to earliness was greater when the water
dificits were more severe. However, given adequate
water supply yield is often positively correlated to
maturity date in determinate annual crops such as
Sorghum, maize and sunflower (Gunn and Chriestensen,
1965; Dalton, 1967; Goldsworthy and Colegrove, 1974)
and therefore selection for earliness to avoid severe
soil moisture deficits may mean lower yields in years
of adequate rainfall (May and Milthorpe, 1962).

Salter and Goode (1967) cited numerous reports in
literature which show that water deficits limit yield
and/or that irrigation increases yield and they
utilized many of these to determine the stage of growth
during which crops are most sensitive to water deficits.
In this work they indicated that water stress may
depress or have no effects on grain yield of crops
and that the yield components affected vary depending
on the physiological age of the crop during the
period of stress. The ability of a crop species to

grow and yield satisfactorily in areas subjected to
periodic water dificits has been termed its drought
resistance. This contrasts with the definition in
ecological terms, viz: The ability of a plant to
stay alive during periods of low water supply (Levitt
et al., 1960). In crop species one is concerned
not only with the ability to survive periods of water
deficits but also to produce a harvestable   yield.

Abd el Rahman et al. (1967). in the work in which
barley plants were given 10mm, 15mm and 20mm respectively
at 15 days intervals over a period of 150 days, reported
that there was a drop in yield of barley from the
highest water supply to the lowest. This drop amounted
to 69 per cent of the highest yield. The reduction
in yield was more influenced by the number of grains
per plant than 100 seed weight. This agrees with
results obtained by Henkel (1962)and by Kreeb (1963).
El Nadi (1975) also found that the number of seeds
per pod and their average weights decreased with
increasingly longer irrigation intervals in
P.   Vulgaris . . It is worth noting that whereas
these experiments shewed that higher yields were
associated with wetter regimes they did not show
which developmental stages were particularly sensitive
to moisture stress as measured by grain yields. The
effects of moisture stress during the various growth
stages on yield and yield components has, however been
reported by many workers as revealed in the review by
Salter and Goode (1967).

Studies in Germany (Brouwer, 1949; 1959a) gave results
which suggested that irrigation before flowering was
often without effect or sometimes, even depressed
grain yield in   P   sativum \   but the amount
of haulm was generally increased. Similar results
were reported by Salter (1962; 1963a). Work by Frohlich
and Henkel (1961c) also indicated that plentiful supply

of water during vegetative period of growth increased
haulm weight but the pea plants did not produce the
highest yield of pods. Carter (1961), on the other
hand, obtained results which showed that yield of
peas was markedly improved by watering before
flowering and Thomas and Lindert (1962), working
in Rhodesia, observed that dry conditions in the period
upto flowering reduced grain yield of   P.
sativum   but it was still noted that even a long dry
spell prevailing in the early part of this period of
growth did not reduce yields appreciably.

Effects of irrigation during flowering period have also
been widely studied. Brouwer (1949) found that
irrigation during flowering gave the greatest increases
in yields of   P.   sativum   . Beneficial
effects of supplying water to peas at flowering have
also been reported from Germay by Baumann   (1951),
Muhleisen (1951) and Schendel (1952). Salter (1963a)
showed that wet soil conditions during flowering greatly
influenced the yields of pods and seeds and also
increased haulm weight compared with plants that were
not irrigated at this time. Desiccation at the time of
flowering in cereals has been observed to reduce the
number of seeds set and even if a subsequent improve-
ment in water availability occurred yields remained
depressed. Thus grain yield of maize has found to be
reduced by 25 per cent when the soil moisture was
depleted to wilting point for 2 days during tasselling
period and by 50 per cent when soil moisture was
depleted to wilting point for 6-8 days (Robinson and
Domingo, 1953). This reduction resulted from the fact
that grains formed in only part of the ear. It thus
indicates that pollination and/or fertilization were
affected by drought. Results of work by El Nadi (1969),
however showed that the number of pods per plant was
lower in broad bean plants that received dry treatment
during the vegetative state and a wet one during

flowering than in those that received the reverse
(i.e. wet vegetative period and dry flowering stage)
but the yields per plot of the former were still
higher due to heavier seeds and slight increase in
number of seeds per pod.

Some evidence has shown that even the various stages
of flowering period can exhibit different responses
to moisture availability, for example, Frohlich
(1959) and Frohlich and Henkel (1961c) have suggested
that under German conditions   P.   sativum
need drier soil conditions from shortly before
flowering until 10 days after the start of flowering.
They found that irrigation during this period increased
the amount of haulm and often reduced grain yields.
By contrast irrigation during the second half of the
flowering period and during pod swelling was found to
increase yields considerably. Batz (1959), working
in glass-house and Thomas and Van Lindert (1962),
working in the field also reported that excess water
was damaging to peas at this time.

2.2.2. Water availability and yield components: Apart from
determining whether vegetative growth or generative
development will be favoured, soil moisture condition
at certain stages will influence the relative importance
of the various yields components. Salter (1963a),
working with   P.   sativum   found that the
number of pod bearing branches per plant were
significantly greater in plants irrigated from germi-
nation to flowering than in unirrigated plants. However,
no increase in yield of peas resulted from irrigating
before flowering whereas applying water at the start
of flowering increased yield by 30 per cent by
increasing the number of marketable pods per plant
and increasing the mean weight of peas per pod.
Although the number of seeds per pod was significantly
increased by watering at the start of flowering, the
weight per grain was somewhat reduced. Thus it appears
that low soil moisture tension during flowering
facilitates seed set. Results which bear similar

implication have been reported in maize (Robins
and Domingo, 1953), linseed (Tivers and Williams,
1943), beans (El Nadi, 1969) and wheat (El Nadi,
1969c).

During the stage of fruit enlargement considerable
quantities of nutrients are transported into the
fruit. Severe moisture stress during this phase
usually results in small or shrivelled grains
(Arnon, 1975). Thus work by El Nadi (1969c) showed
that, whereas reduction in yield of wheat due to
drought during the flowering period was mainly as
a result of reduction in the number of ears per
plant, the reduction due to water shortage during
grain filling and ripening stage was mainly due to
reduction in 100 grain weight. After grain filling
stage further ripening normally involves dehydration
and certain biochemical changes. Arnon (1975) noted
that the moisture regime during this stage has
little effect on yield components but may affect the
length of the ripening period.

2.3. Conclusion

From the literature cited so far it is shown that
although vegetative growth is also retarded by moisture
stress, the flowering period is more sensitive to
drought. Reduced root growth and activity and increased
nutrient requirement have been observed during this period
but it is not clear whether they are causes or results
of this high sensitivity. Both hastened and delayed
maturity have been reported in plants under stress.
Retarded cell division and hence apical growth has been
pointed out as possible cause of the delay but recently
some work has revealed that drought stress may also
inhibit translocation of the flowering stimulus (Aspinall
and Hussain, 1970) probably by its effects on photo-
synthesis, active sinks or both as phloem transport per
se appears to be insensitive to drought (Wardlaw, 1967).
Increased leaf temperature may be responsible for the
hastening of maturity but it is likely that this effect

will only be realised where drought stress is not as high
as to adversely affect the other attributes of plant
growth and, even then, only where low temperatures
constitute an important limitation to crop development.

Moisture availability at flowering and pod filling seem
to be critical for grain yield. A plentiful supply at
these stages is very beneficial while a shortage of water
can seriously reduce the yields even where wet conditions
prevail before and after these stages. On the contrary,
while dry conditions before flowering can seriously reduce
vegetative growth, these appear to have little or no
effect on the ultimate grain yield of the plant.

Finally, this review has revealed, probably more than
anything else, the paucity of information on the effects
of water stress on tropical pulses. In particular, no
work in pegion pea has been reported in this field.
This could be partly because the crop performs better
than most food crops under fairly arid conditions so that
there is little doubt about its ability to resit drought.
However, it would probably be useful to understand the
drought resistance mechanisms applied by this crop
together with the direct effects of water stress on the
crop. Such information would be invaluable to physiolo-
gists and breeders in their attempt to further develop
the crop so that its cultivation can be extended into
even more arid areas.

CHAPTER 3

MATERIALS AND METHODS

3.1. Location and planting medium

The experiment was conducted at Kabete field station of
the Faculty of Agriculture, University of Nairobi. The
station is about 1800 metres above sea level and lies
within latitudes 1° 14' 20" S and 1° 15' 15" S and
longitudes 36° 44' E and 36° 45' 20" E. (Wamburi 1973).

The growing medium used was prepared by mixing forest
soil with animal (cow dung) manure in the ratio of 10:1
by volume. Onim (personal communication) had used
similar medium in growing pigeon peas for several
years with good results. The soil was obtained from a
forest in the University of Nairobi farm, Faculty of
Agriculture, Kabete. This is a forest planted with
eucalyptus trees but there was also a heavy undergrowth
of weeds dominated by Lantana camara L.

The soil pit was about 40 cm deep. The soil in the area
is a deep nitosol containing more than 60 per cent clay
particles after complete dispersion (Ogombe, 1978).
However, due to its stable microstructure, it has many
of the properties of a loam. According to the detailed
soil survey of the farm by Nyandat and Michieka (1970),
the clay mineral is predominantly Kaolin and the parent
material is the Kabete trachyte. The soil which is
dominant in the farm has a top soil pH ranging between
5.2 and 7.2 and subsoil pH of 5.2-7.7.

3.2. Experimental

Two experiments, I and II, were conducted. Experiment I
was planted on October 19, 1979 and harvested on March
16, 1980 while experiment II, which was a repeat of

experiment I, was planted on April 16, 1980 and harvested on October 10, 1980.

The experiments were conducted in glass-house. The atmospheric (outside glass-house) temperature and sunshine hours for the periods of the two experiments are shown in figures 1 and 2 and should be indicative of the temperatures inside the glass-house which were not recorded.

Six genotypes of pigeon peas were used. The genotypes which were all of the dwarf type were obtained from University of Nairobi pigeon pea project (N.P.P) where they bear the following accession numbers:

Accession number in N.P.P.	Code number Used in experiment
N.P.P. 609	V_1
" 624	V_2
" 633	V_3
" 627	V_4
" 203/1	V_5
" 617	V_6

The genotypes were selected from a previous study at Kodiaga prison farm near Kisumu during the 1977-78 short rains (Onim personal communication) to represent low yielding (V_1 and V_2), medium yielding (V_3 and V_4) and high yielding (V_5 and V_6) genotypes. The genotypes included five inbred lines which had been obtained from the International Crop Research Institute for Semi-arid Tropics (I.C.R.I.S.A.T.) and one (V_5) which was selected locally from material which originally came from Makerere - Uganda (Onim, personal communication).

The genotypes were planted in 5-litre plastic pots each containing .9 Kilograms of soil. The soil in the pots
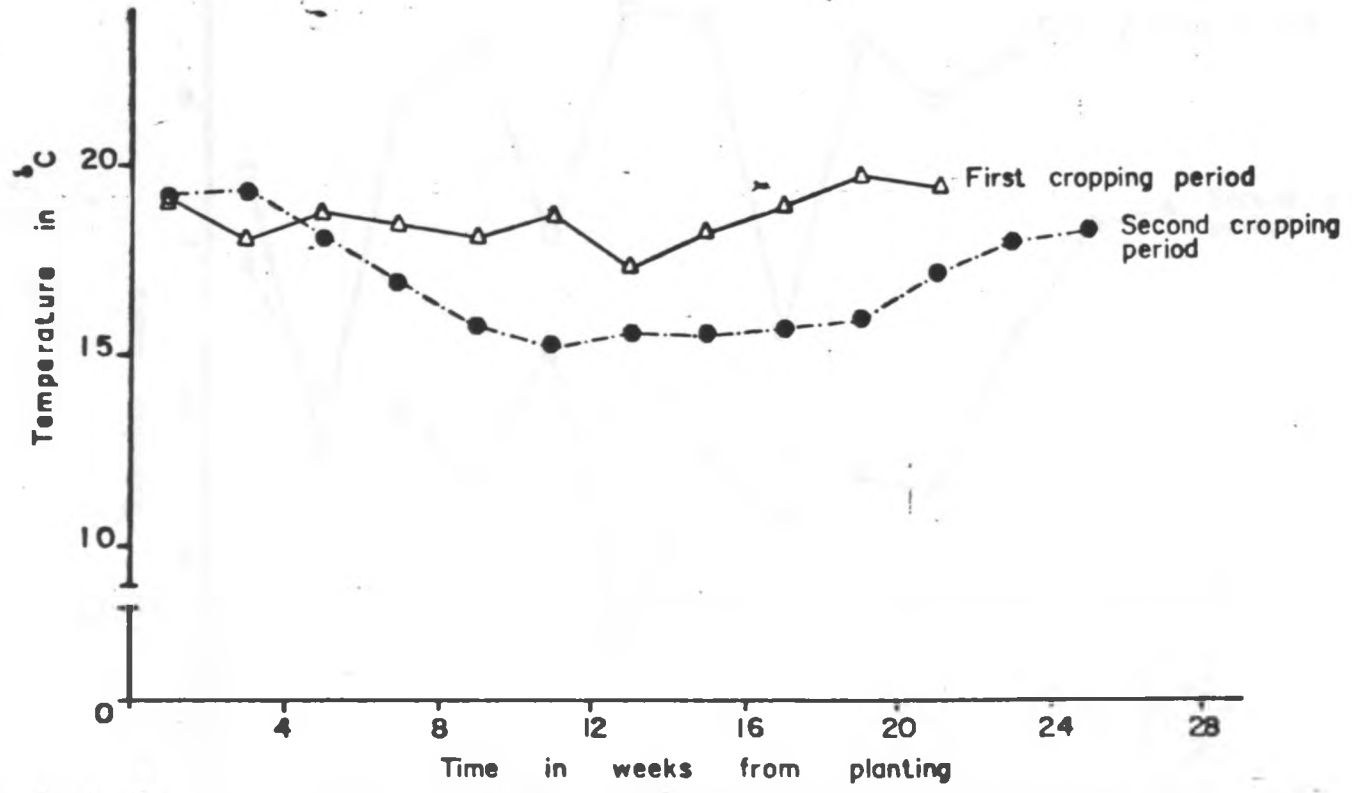
Fig. I   Mean   temperatures   during   the   two   cropping
          periods.
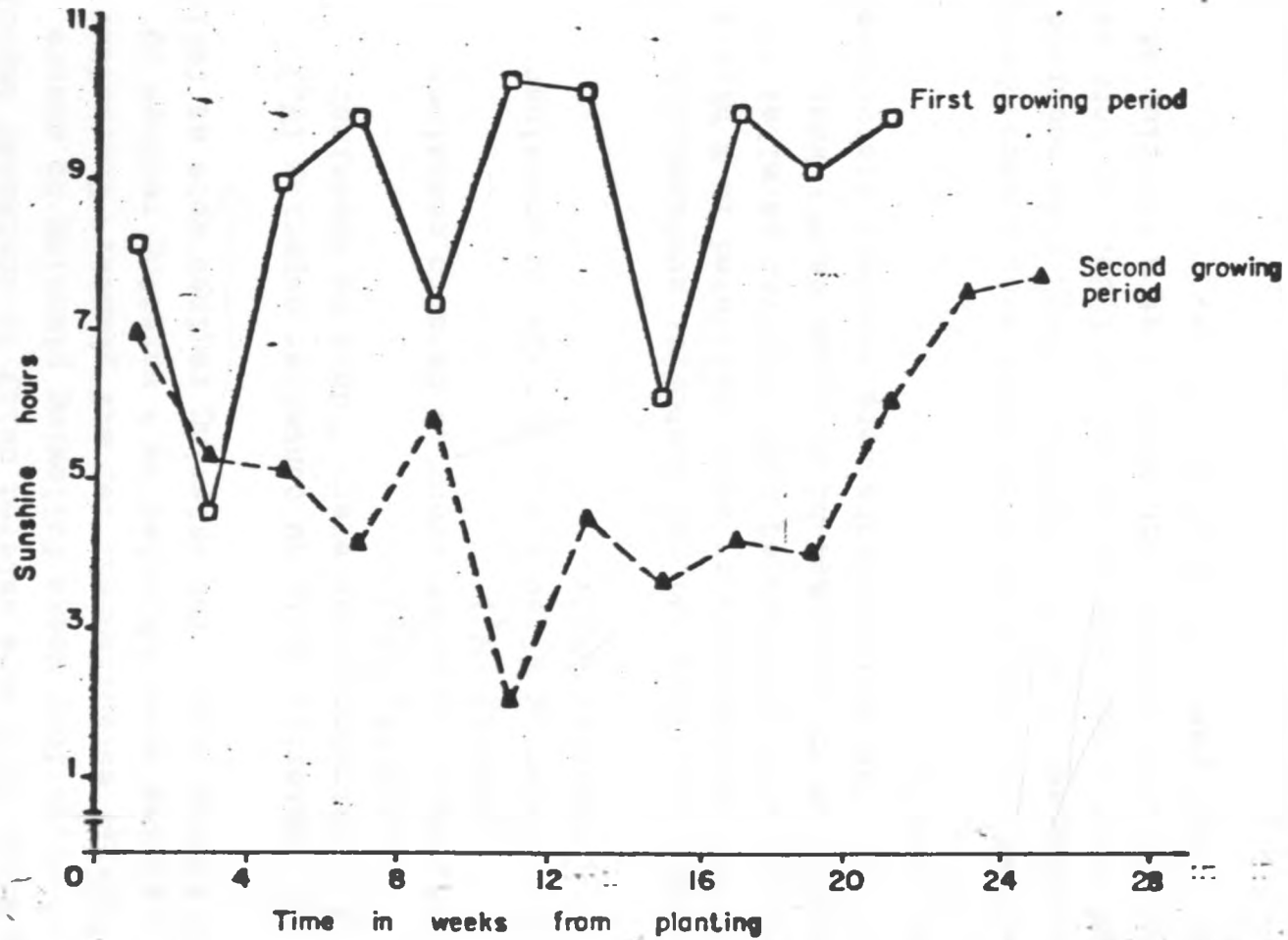
Fig. 2   Mean Sunshine hours during the two cropping periods.

had been watered daily for one week prior to planting
in order to allow the soil to settle. Each pot was
planted with 4 seeds but the stand was later reduced to
2 plants per pot three weeks after planting.

The planted pots were watered daily to container capacity
for the first four weeks following planting to ensure
good initial establishment for all plants. Thereafter
the genotypes were subjected to 4 watering regimes up
to harvesting time. The watering regimes were as follows:

(i)   Watering daily to container capacity (W_1)
(ii) Watering after every 7 days to container
      capacity (W_2)
(iii) Watering after every 14 days to container
      capacity (W_3)
(iv) Watering after every 21 days to container
      capacity (W_4).

Each experiment thus had 6x4 factorial combinations
giving 24 treatments which were replicated in 5 blocks.
The blocks were so arranged that they ran parallel to
the long side of the glass-house in an East - West
direction. The 24 treatments were randomly distributed
in each block.

On December 29, 1979 plants of experiment I were observed
to be attacked by aphids. Similar attack also occurred
on plants of experiment II on May 8, 1980. In both cases
the plants were sprayed with Rogor E at a dilution of
1 part to 600 parts of water by volume.

Harvesting was started after 151 and 177 days in experiments
I and II respectively. Pods were harvested by hand
picking. The soil was then washed off the roots and
the plants separated into shoots and roots which were
separately dried in oven at 80°C for 48 hours. The pods
were sun dried then threshed by hand and the seeds weighed.
The seeds and husks from individual plants were subsequently

further dried in oven at 80°C for 48 hours as was the case with vegetative parts.

The following information was recorded:

(a) Height of each plant from soil level to to growing tip measured using a meter rule at weekly intervals for the first ten weeks from the beginning of the watering treatments.

(b) Final plant height measured at harvest using the same method as in (a)

(c) Days from planting to opening of the first flower on each plant.

(d) Number of nodes per plant at harvesting.

(e) Number of primary branches per plant at harvesting.

(f) Number of harvested pods per plant.

(g) Clean grain weight of sun-dried grains per plant.

(h) Number of grains per pod in each plant.

(i) 100-seed weight of sun-dried seeds per plant.

(j) Dry weights per plant of roots, vegetative shoot, pods and seeds.

3.3. Data analysis

All the data for these experiments were analysed using analysis of variance unless specifically stated otherwise. The treatment effects were separated into effects due to:

(i)   Watering regimes

(ii) Genotypes

(iii) Interaction between genotypes and watering regimes.

Pairwise comparison of means was done using least significant difference (L.S.D.) method.

The data for 100-seed weight was not subjected to any statistical analysis because some treatments yielded no seeds. 100-seed weight in such cases could not be determined and so they represented missing values thus making some blocks incomplete in this particular respect. Estimation of missing values was found difficult as some treatments produced no seeds in a number of replicates.

CHAPTER 4

RESULTS

4.1. General Observations: Experiments I and II

It was observed that as time passed from one watering day to another plants in the less frequently watered treatments often showed signs of wilting. In experiment I wilting was first noticed around December 28, 1979, that is about one month and a half after the beginning of the watering treatments and two months and a half from planting. Plants subjected to W_2, W_3 and W_4 watering regimes showed signs of wilting at one stage or another in this experiment. In experiment II, however, the first signs of wilting were noticed about three months from planting, that is two months from the beginning of watering treatments, on July 18, 1980. Only plants subjected to W_3 and W_4 watering regimes showed signs of wilting but even these were never as severely affected as plants which were subjected to similar watering regimes in experiment I.

By the time these first signs of wilting were observed, in either experiment, some plants had started flowering and it was noticed that the wilting appeared earlier (from planting) in plants that had either flowered or were bearing flower buds in any particular genotype. Wilting also appeared earlier in growth of plants subjected to longer watering intervals. Thus W_4 plants were observed to wilt earliest in their growth cycle followed by W_3 plants and lastly, in experiment I, by W_2 plants. However, during the periods when plants in these watering regimes; W_2, W_3 and W_4 in experiment I and W_3 and W_4 in experiment II had all started showing wilting signs during their respective watering intervals, it was noticed that, for any particular genotype, the shorter the watering interval, the sooner the plants started wilting from a previous watering. Thus, in experiment I plants subjected to W_3 and W_4 watering regimes rarely showed signs of wilting within a week from

a previous watering but W_2 plants often started wilting
about four days after a previous watering. Similarly,
after two weeks when W_3 plants were often badly wilted,
W_4 plants were frequently not so badly affected until
a later day in their watering interval. A difference
of this kind was also observed in experiment II between
W_3 and W_4 plants.

It was observed that the plants aligned their wilting
leaves in a vertical orientation so that the leaves
tended to close up around the main stem and branches
as water stress developed following a previous watering.
Leaf shedding was also observed and, in any particular
genotype, it occurred earlier and to a larger extent
the longer the watering interval. It was noted that
V_1, V_2 and V_4 tended to minimise leaf shedding and kept
most of their leaves in the vertical orientation until
they recovered from water stress on re-watering. V_3,
V_5 and V_6 also exhibited vertical orientation of leaves
when under stress but this was usually followed by
shedding of most of the lower leaves so that, in subsequent
watering intervals, these genotypes tended to maintain
their normal leaf orientation even in the later days
of a watering interval in the less frequently watered
regimes. In experiment II, however, leaf shedding was
much reduced even though V_3, V_5 and V_6 were still more
affected than V_1, V_2 and V_4. It was noticed in both
experiments that larger plants among the genotypes and
in any particular genotype tended to shed more of their
leaves than smaller ones.

Water-stressed, wilted leaves normally developed light
green colouration. Upon re-watering most of these wilted
and sometimes scorched leaves shed leaving the upper,
younger leaves. These leaves which were retained assumed
slightly darker colouration but they never fully regained
the normal green colour of leaves that had never been
stressed.

Whereas the lowermost leaves, in both experiments, showed
signs of wilting and dropped off earlier in growth and
within a watering interval, it was observed in experiment
I that the uppermost young and not fully expanded leaves
often died before the young but fully expanded leaves
in plants of genotypes V_5 and V_6 which were subjected to
W_4 watering regime. In some cases the growing tip also
died while in others the growing tip remained alive but
the enclosing leaves dried. The third, fourth and fifth
leaves from the tip were usually the first to recover
from wilting on re-watering in such plants. These leaves
were also the most resistant to shedding and drying
during the times of water stress.

Where the growing tip dried during the period of water
stress growth of lateral buds was enhanced leading to
development of more branches. Enhanced growth of lateral
buds was also noticed in genotype V_4 when most pods had
dried and apical growth had ceased.

4.2. <u>Results of Experiment I</u>

4.2.1. <u>Effects of Watering regimes on growth and</u>
<u>development in 6 genotypes of pigeon peas</u>

4.2.1.1. <u>Plant height</u>: Effects of treatments on plant
heights at harvest are presented in Table 1.
Analysis of this data revealed that interaction
between genotypes and watering regimes was
significant (P=0.01). There was, however, a
consistent decrease in plant height with decreasing
frequency of watering in genotypes V_3, V_4, V_5 and V_6.
In V_2, the tallest plants, on the contrary, were
recorded in W_2 watering regime and in genotype V_1,
plants subjected to W_3 watering regime were taller,
on average, than those subjected to W_2 watering
regime. It is probably the result of these two
genotypes which contributed much to the significant
interaction effect.

Genotype V_3 had the tallest plants, on average in
all the watering regimes and V_1 had the shortest.
In genotypes V_3, V_4, V_5 and V_6 which showed consistent
decrease in plant height with decreasing frequency
of watering, the effect was more marked in some
genotypes than others. Thus V_4 plants which received
W_4 watering treatment had mean height which was-about
75 per cent of that of V_4 plants which were subjected
to W_1 watering regime. A similar comparison gave
only 53 per cent in the case of genotype V_5. These
inter-genotype differences in response to different
watering regimes further contributed to the interaction
effects.

Weekly height measurements (Fig. 3) showed that there
was very little difference in heights of plants
subjected to different watering regimes for the
first two weeks following the beginning of the

Table 1: Effect of 4 watering regimes on plant height (cm) of 6 pigeon pea genotypes.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	54.4	54.3	95.5	72.9	88.4	81.2	74.5
W_2	33.8	61.1	82.9	65.0	66.1	63.8	62.1
W_3	41.6	51.6	74.2	55.0	57.2	61.6	56.9
W_4	29.6	46.0	58.4	54.9	47.0	52.3	48.0
GENOTYPE MEANS	39.9	53.3	77.8	62.0	64.7	64.7.	
							60.4

S.E. Watering regimes = 2.22
S.E. Genotypes = 2.72
S.E. Watering regimes X Genotypes = 5.43
C.V. = 14.2%

80

70

W₁

60

W₂

Plant height (Cm.)

50

W₃

40

W₄

30

20

10

0

2   4   6   8   10

Time in weeks from start of watering treatments
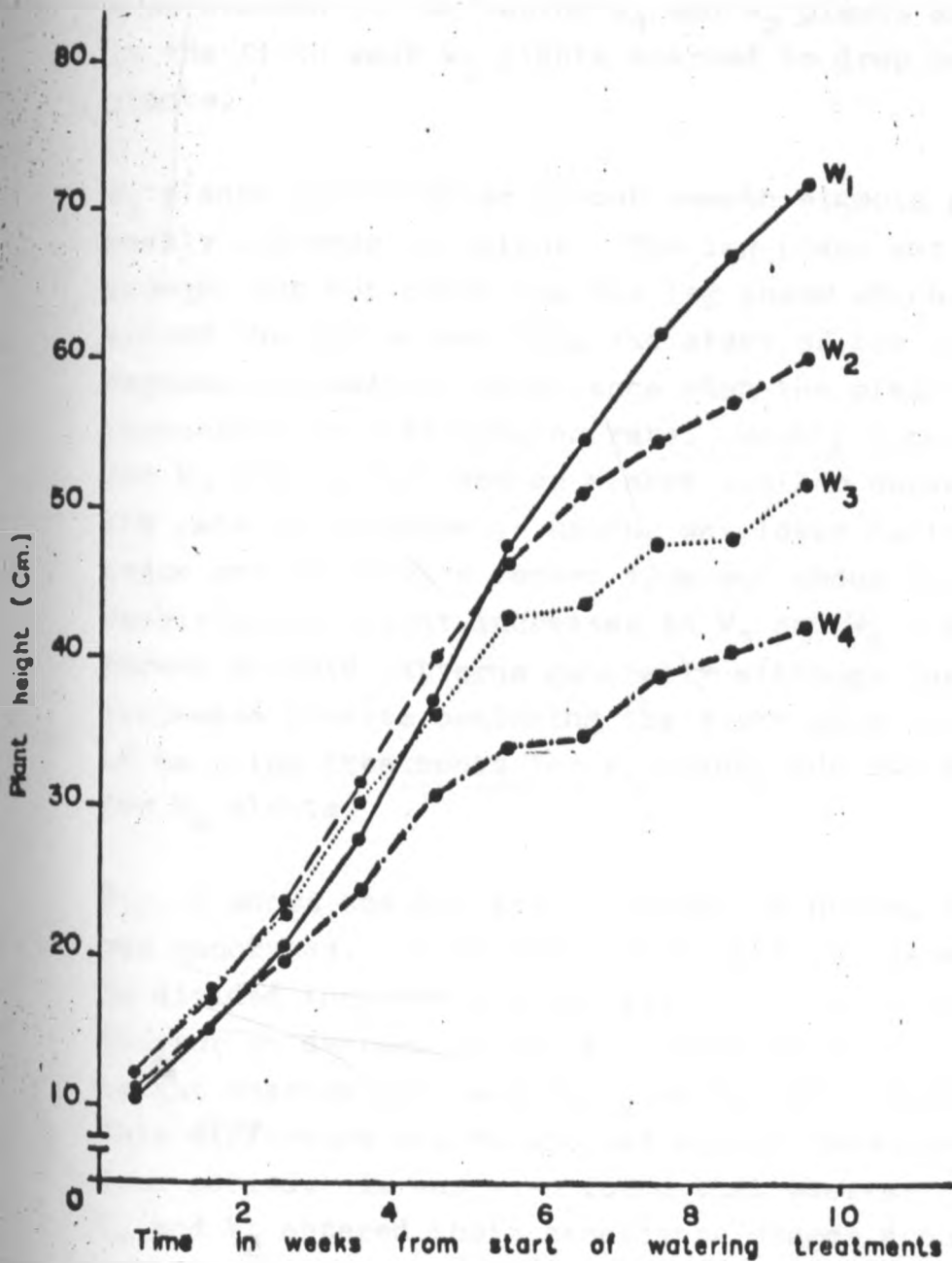
Fig. 3   Mean effect of watering regimes on
increase in plant height (Expt. I).

watering treatments. Thereafter, however, W_4 plants
began to show lower rates of increase in height whereas
plants in the rest of the watering treatments continued
to show no marked differences upto the fourth week after
the start of the watering regimes. At this stage W_3 plants
also started to lag behind W_1 and W_2 plants and finally,
in the fifth week W_2 plants started to drop behind W_1
plants.

W_1 plants exhibited an almost smooth sigmoid curve of
weekly increase in height. The lag phase was only slightly
brought out but there was the log phase which went upto
around the sixth week from the start of the watering
regimes followed by senescence when the plant height was
increasing at a decreasing rate. Weekly increase in height
for W_2 plants followed an almost similar curve although
the rate of increase in height was lower during the log
phase and senescence became apparent about one week earlier.
Weekly plant height increases in W_3 and W_4 plants also
showed sigmoid patterns generally although they assumed
step-wise courses beginning the sixth week from the start
of watering treatments for W_3 plants but the fifth week
for W_4 plants.

Fig. 4 shows the average increases in height for the
six genotypes. It is noticeable that the genotypes can
be divided into two groups; V_1, V_2 and V_5 which were
shorter on average at the beginning of these weekly
height measurements and V_3, V_4 and V_6 which were taller.
This difference was maintained almost throughout the ten
week period. It was also found that whereas genotypes
V_1 and V_2 entered their senescence stages around the
fifth week, the rest of the genotypes entered senescence
about one week later.

4.2.1.2. <u>Number of nodes per plant</u>: Effects of treatments
on the number of nodes per plant at harvest are
presented in Table 2. There was significant intera-
ction between watering regimes and genotypes on the

Table 2: Effect of 4 watering regimes on number of
nodes per plant in 6 genotypes of pigeon
peas.

WATERING REGIMES	G E N O T Y P E S						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	21.1	20.5	32.8	26.1	33.0	28.2	27.0
W_2	14.4	20.7	31.8	24.7	28.4	25.6	24.3
W_3	15.4	19.3	31.1	25.9	25.7	26.2	24.1
W_4	14.1	21.3	25.7	26.0	19.6	21.7	21.4
GENOTYPE MEANS	16.5	20.5	30.4	25.7	26.7	25.4	
							24.2

S.E. Watering regimes = 0.87
S.E. Genotypes = 1.06
S.E. Watering regimes X genotypes = 2.12
C.V. = 13.9%
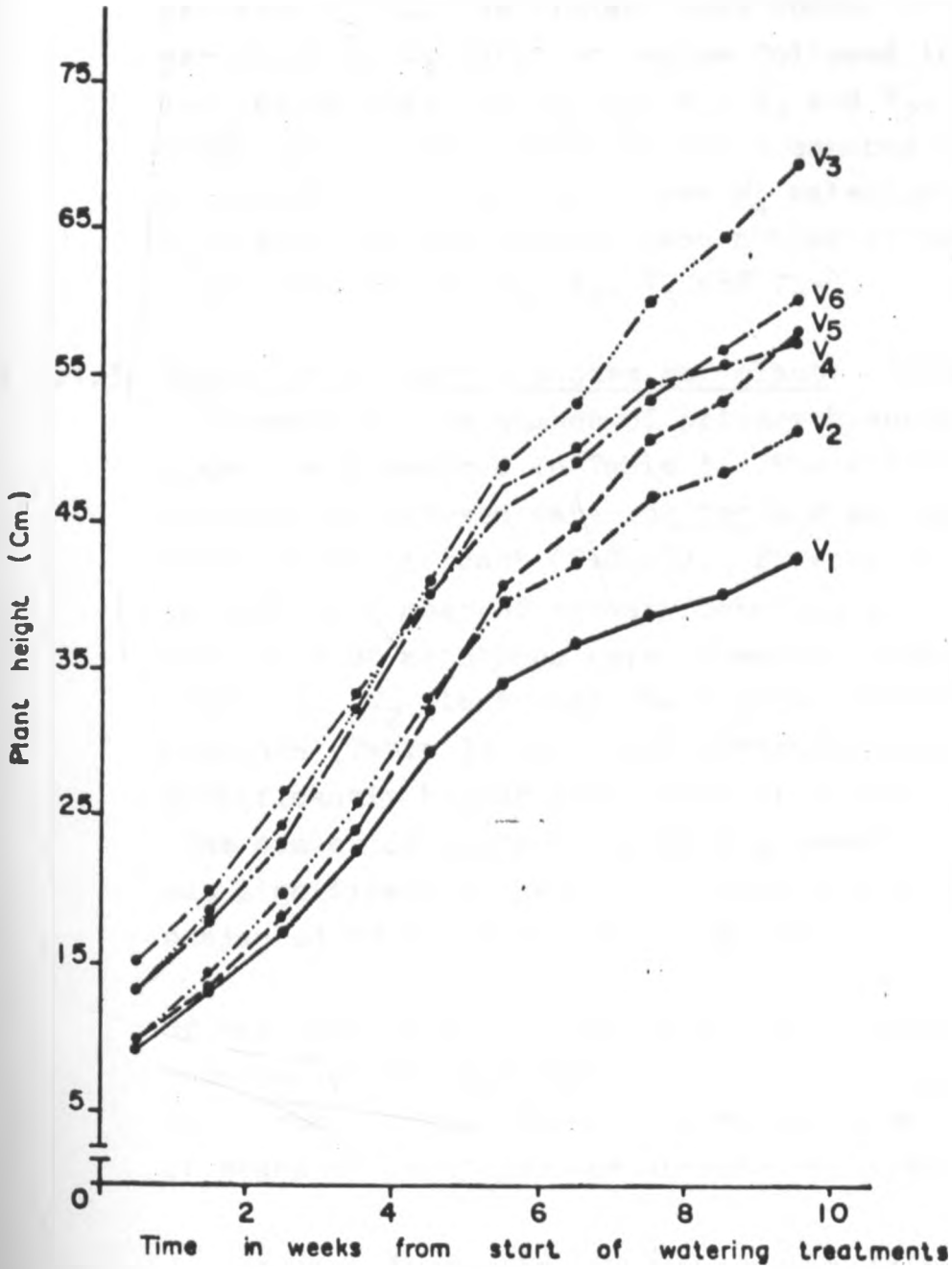
Fig. 4   Mean effect of   genotypes on increase
in   plant   height   (Expt.I)

number of nodes per plant (P=0.01). Thus while
the number of nodes per plant decreased consistently
with decreasing frequency of watering in genotypes
V_3 and V_5, different trends were observed in the
rest of the genotypes (Table 2). Furthermore, while
genotype V_5 had the highest mean number of nodes
per plant in W_1 watering regime followed in a
descresing order by V_3, V_6, V_4, V_1 and V_2, this
trend was not maintained as the frequency of watering
decreased. For example, given W_4 watering regime,
V_4 plants had the highest mean number of nodes per
plant followed by V_6, V_2, V_5 and V_1.

4.2.1.3. <u>Number of Primary branches per plant</u>: Effects of
treatments on the number of primary branches per
plant are presented in Table 3. The effects of
interaction between watering regimes and genotypes
were not significant (P=0.01). Effects of watering
regimes on number of primary branches per plant
and those of genotypes were, however, significant
(P=0.01). W_2 plants had the highest number of
branches (Table 3) per plant although this was not
significantly higher than those of W_1 and W_3 plants.
 The number of primary branches produced by W_4 plants
was significantly lower than those produced by plants
subjected to any other watering regime.

Of the genotypes, V_5 had the highest number of
branches on average followed by V_6, V_2, V_3, V_4 and
V_1 in that order. The result of pairwise comparisions
of means of genotypes are summarized below:

$$V_5 \qquad V_6 \qquad V_2 \qquad V_3 \qquad \underline{V_4 \qquad V_1}$$

Any two means not underscored by the same line are
significantly different and any two lines under-
scored by the same line are not significantly
different (P=0.01).

Table 3:   Effect of 4 watering regimes on number of branches
per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	7.4	6.7	7.7	6.3	10.2	7.7	7.7
W_2	5.4	7.6	8.2	6.1	11.1	9.0	7.9
W_3	5.3	8.3	7.3	6.3	7.8	8.8	7.3
W_4	4.4	6.4	5.5	5.4	5.3	7.2	5.7
GENOTYPE MEANS	5.6	7.3	7.2	6.0	8.6	8.2	
							7.1

S.E. Watering regimes = 0.42
S.E. Genotypes   = 0.51
S.E. Watering regimes X Genotypes = 1.04
C.V. = 22.9%

4.2.1.4. <u>Plant dry weights</u>: Results for total dry weights
are given in Table 4. The effects of interaction
between watering regimes and genotypes were
significant (P=0.01). There was, however a clear
decrease in total dry weight with decreasing
frequency of watering in all the genotypes so that
the interaction can only be attributed to differences
in relative responsiveness among genotypes in
responding to decreasing frequency of watering. Hence
V_3 had the highest dry weight per plant under W_1
watering regime while V_2 had the lowest. This trend
however, changed with decreasing frequency of watering
so that V_6 genotype had the highest dry weight while
V_3 had the second lowest under W_4 watering regime.
Last row in Table 4 reveals the extent to which each
genotype was affected by decreasing frequency of
watering between W_1 and W_4 watering regimes.

Tables 5, 6 and 7 give some information about the
distribution of dry weights between shoot and root
at harvest.

It is clear from Table 5 that the shoot dry weights
decreased with decreasing frequency of watering in
all the genotypes. However, the effects of intera-
ction between watering regimes and genotypes were
significant (P=0.01) since the decrease in shoot dry
weight resulting from the decrease in frequency of
watering was more rapid in some genotypes than others.
For example, the mean shoot dry weight per plant of
genotype V_2 given W_4 watering regime was about 19
per cent of that of V_2 plants which were subjected
to W_1 watering regime while a similar comparison in
genotype V_3 gave only 9 per cent. It was found that
genotype V_3 experienced the largest drop in shoot dry
weight between W_1 and W_4 watering regimes followed by
V_5, V_1, V_6, V_4 and V_2 in that order.

Table 4: Effect of 4 watering regimes on total dry weight (g) per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	32.05	29.61	56.59	38.34	53.01	48.62	43.04
W_2	15.61	20.02	21.27	20.87	20.47	17.35	19.27
W_3	7.89	12.80	9.87	12.01	10.15	11.88	10.77
W_4	5.23	7.03	5.72	6.67	5.77	7.39	6.30
GENOTYPE MEANS	15.19	17.37	23.30	19.47	22.35	21.31	
							19.85
W_4/W_1%	16.31	23.75	10.10	17.40	10.88	15.20	

S.E. Watering regimes = 1.60
S.E. Genotypes   = 1.96
S.E. Genotypes X Watering regime = 3.91
C.V. = 31.17%

Table.5: Effect of 4 watering regimes on shoot dry
weight (g) per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	29.27	25.15	51.60	35.97	47.38	44.59	38.99
W_2	12.72	16.19	13.76	18.53	15.83	13.68	15.12
W_3	6.47	9.08	7.36	10.53	7.55	8.99	8.33
W_4	3.77	4.83	4.70	4.92	4.50	5.82	4.76
GENOTYPE MEANS	13.06	13.81	19.36	17.49	18.81	18.27	
							16.80
$W_4/W_{1\%}$	12.56	19.20	9.11	13.68	9.49	13.06	

S.E. Watering regimes = 1.40
S.E. Genotypes = 1.71
S.E. Genotypes X watering regimes = 3.42
C.V. = 32.23%

Results for root dry weight are shown in Table 6.
There was a consistent decrease in root dry weight
as the frequency of watering decreased. The effects
of watering regime on root dry weight per plant were
significant (P=0.01). Comparison of mean root
weights for plants subjected to the various watering
regimes can be summarized as follows:

$$W_1 \qquad \underline{W_2 \qquad \underline{W_3 \qquad W_4}}$$

Any two means not underscored by the same line are
significantly different (P=0.01).

Genotype V_5 had the highest mean root dry weight while
V_1 had the lowest. V_6, V_3, V_4 and V_2 came in between
in that decreasing order. These differences among
genotypes were, however not significant.

The shoot: root ratio was also found to decrease with
decreasing frequency of watering (Table 7). Both
effects of watering regimes and those of genotypes
were significant (P=0.01). Effects of interaction
between genotypes and watering regimes were not
significant. W_1 plants had the highest mean shoot:
root ratio and this was significantly higher than the
mean shoot:root ratio of plants which were subjected
to any other watering regime. The mean shoot: root
ratio for W_2 plants was also significantly higher
than that of W_3 plants. The mean shoot:root ratios
of W_3 and W_4 plants were, however not significantly
different from each other although the former was
higher than the later. Comparison of the mean
shoot:root ratios for the various genotypes can be
summarized as follows:

$$\underline{V_2 \qquad V_4 \qquad V_1} \qquad \underline{V_3 \qquad V_5 \qquad V_6}$$

Any two means not underscored by the same line are
significantly different (p=0.01).

Table 6: Effect of 4 watering regimes on root dry
weight (g) per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	2.79	1.97	4.99	2.37	5.63	4.66	3.74
W_2	1.19	1.60	3.70	2.34	3.58	3.18	2.60
W_3	1.13	1.64	2.21	1.57	2.61	2.81	2.00
W_4	1.01	1.10	1.02	1.76	1.37	1.58	1.31
GENOTYPE MEANS	1.53	1.58	2.93	2.01	3.30	3.06	
							2.48
$W_4/W_{1\%}$	36.11	55.52	20.47	74.03	24.40	33.85	

S.E. Watering regimes = 0.56
S.E. Genotypes = 0.69
S.E. Genotypes X watering regimes = 1.37
C.V. = 89.9%

Table 7: Effect of 4 watering regimes on shoot:root ratio (based on dry weights) in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	11.00	13.85	10.84	15.02	9.90	9.78	11.73
W_2	11.10	10.43	4.19	9.80	5.10	5.16	7.63
W_3	6.37	6.21	3.42	6.84	3.15	3.20	4.87
W_4	3.74	4.51	4.18	3.09	4.14	3.99	3.94
GENOTYPE MEANS	8.05	8.75	5.66	8.69	5.57	5.53	
							7.04

S.E. Watering regimes = 0.62
S.E. Genotypes = 0.76
S.E. Genotypes X Watering regimes = 1.52
C.V. = 34.1%

It was found that the genotypes could be divided
into two groups based on their mean shoot:root
ratios. One group included V_1, V_2 and V_4 and had
mean shoot: root above 8 where the other group, which in-
cluded V_3, V_5 and V_6 had had mean shoot:root ratios between
5 and 6.

4.2.1.5. <u>Earliness to maturity</u>: The effects of interaction
between genotypes and watering regimes on earliness
to maturity were significant (P=0.01)   such that,
although the number of days to flowering increased
consistently with decreasing frequency of watering
in genotypes V_3, V_4 and V_5 (Table 8) such a trend
was not observed in V_6 where W_2 plants flowered
earliest while W_3 plants flowered latest. In
genotype V_2 plants subjected to W_2 watering regime
again flowered earliest but there was a trend of
increasing lateness to maturity in plants from W_2
to W_4 watering regimes. In genotype V_1, plants
subjected to W_1 watering regime flowered latest and
there was increasing earliness as the frequency of
watering decreased in plants subjected to W_1, W_2 and
W_3 watering regimes. W_4 plants, however flowered
later than W_3 plants.

4.2.2. <u>Effects of 4 watering regimes on yield
and yield components of 6 genotypes of pigeon peas</u>

4.2.2.1. <u>Total grain yield per plant</u>:   The results of
grain yield per plant is presented in Table 9. The
effects of interaction between genotypes and
watering regimes on grain yield per plant were
significant (P=0.01). There was, however a general
trend of yields dropping as a result of decreased
frequency of watering in all the genotypes so that
the significant interaction effects could only be
attributed to the fact that this drop in yield was
more pronounced and more rapid in some genotypes
than others. For example, a fall in frequency of
watering from W_1 to W_2 resulted in upto 90 per cent
drop in grain yield in genotype V_3 compared to about

Table 8: Effect of 4 watering regimes on the number of days to flowering in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	86.4	89.7	91.4	74.6	96.2	89.3	87.9
W_2	80.3	74.1	98.5	75.2	97.1	84.0	85.0
W_3	74.1	82.4	105.8	78.0	101.9	106.5	91.5
W_4	76.6	97.4	122.7	89.1	128.4	102.3	103.3
GENOTYPE MEANS	80.2	85.9	104.6	79.2	105.9	95.5	
							91.9

S.E. Watering regimes = 1.86
S.E. Genotypes = 2.28
S.E. Genotypes X watering regimes = 4.57
C.V. = 7.8%

Table 9: Effect of 4 watering regimes on yield of grain (g) per plant in 6 genotypes of pigeon peas

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	13.38	12.69	22.55	16.46	17.48	19.13	16.95
W_2	5.09	5.28	3.26	5.62	3.88	4.02	4.86
W_3	1.59	2.28	0.19	1.05	0.00	0.00	0.85
W_4	0.76	0.64	0.00	0.14	0.00	0.01	0.26
GENOTYPE MEANS	5.46	5.47	6.50	5.82	5.34	5.79	
							5.73
$W_{2/W_1\%}$	45.50	49.46	14.45	34.16	22.21	21.02	

S.E. Watering regimes = 0.65
S.E. Genotypes   = 0.80
S.E. Watering regimes X Genotypes = 1.59
C.V. = 43.8%

50 per cent drop in genotype V_2. In all the drop
in yield associated with decrease in frequency
of watering was more marked in genotypes V_3, V_5 and
V_6 than in V_1, V_2 and V_4.

Genotype V_3 was the highest yielder and V_2 the
lowest in W_1 watering regime with V_6, V_5, V_4 and V_1
coming in between in that order. Exactly the same
order but in a reversed sequence is seen in the
last row of Table 9 which shows the percentage drop
in yield between W_1 and W_2 watering regimes.

4.2.2.2. Yield components: The results of yield components
are presented in Tables 10, 11 and 12.

The effects of interaction between watering regimes
and genotypes on the number of pods per plant were
significant (P=0.01). The number of pods per plant,
however showed a general trend of decrease as
frequency of watering decreased (Table 10) so that,
once again, the significant interaction effects may
only be attributed to the fact that the drop in **number**
of pods per plant was more rapid in some
genotypes than others. Genotypes V_3, V_5 and V_6
were affected to a greater extent than the other
three genotypes since they produced almost no pods
even under W_3 watering regime. However, given W_1
watering regime, these three genotypes (V_3, V_5 and V_6)
produced more pods per plant than the other three
genotypes. In each genotype, W_1 watering regime
produced the largest number of pods per plant while
W_4 was the least productive.

The results for the number of grains per pod are
presented in Table 11. The effects of interaction
between genotypes and watering regimes were
significant (P=0.01). Once again, however, there
was a clear decrease in number of grains per pod
resulting from decrease in frequency of watering so

Table 10:   Effect of 4 watering regimes on the number of pods per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	48.4	50.2	70.0	45.7	93.1	74.8	63.7
W_2	24.3	25.4	15.7	23.1	22.6	20.2	21.9
W_3	9.9	11.5	0.3	6.7	0.0	0.0	4.7
W_4	7.2	5.1	0.0	1.4	0.0	0.1	2.3
GENOTYPE MEANS	22.5	23.1	21.5	19.2	28.9	23.8	
							23.2
$W_2/W_{1\%}$	50.20	50.60	22.43	50.55	24.27	27.01	

S.E.   Watering regimes = 2.76
S.E.   Genotypes   = 3.38
S.E.   Genotypes X Watering regimes = 6.77
C.V.   = 46.2%

Table 11:   Effect of 4 watering regimes on number of
grains per pod in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	2.4	2.5	2.8	2.7	2.3	2.7	2.6
W_2	1.8	2.0	1.9	2.1	1.5	2.0	1.9
W_3	1.2	1.3	0.3	1.3	0.0	0.0	0.7
W_4	0.9	0.9	0.0	0.3	0.0	0.1	0.4
GENOTYPE MEANS	1.6	1.7	1.2	1.6	1.0	1.2	
							1.4

S.E.   Watering regimes = 0.13
S.E.   Genotypes   = 0.16
S.E.   Genotypes X watering regimes = 0.32
C.V.   = 36.54

that the significant interaction effects can only be
accounted for by the fact that some genotypes were
more responsive to decreasing frequency of watering
than others. For example, genotype V_3 which had the
largest number of seeds per pod at W_1 watering regime
had no seeds at all at W_4 watering regime while V_1
which had comparatively fewer grains per pod at W_1
still produced seeds at W_4 watering regime.

The results for 100 seed weight are presented in Table
12. These results were not subjected to statistical
analysis but it can be noticed that, where seeds were
produced, the watering regimes did not affect 100-
seed weight to a large extent in any particular
genotype. Differences in 100-seed weight among
genotypes were also slight except for genotype V_5
which tended to have lower values of 100-seed weight.

Table 12: Effect of 4 watering regimes on 100-seed weight (g) in 6 genotypes of pigeon peas.

| WATERING REGIMES | G E N O T Y P E S | | | | | | WATERING REGIME MEANS |
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	11.73	9.99	11.49	13.26	7.70	10.14	10.72
W_2	9.99	12.83	10.76	12.77	9.33	11.29	11.16
W_3	11.50	15.19	3.75	12.55	0.00	0.00	8.00
W_4	10.24	9.00	0.00	10.14	0.00	5.00	5.78
GENOTYPE MEANS	10.87	11.75	7.75	12.18	4.26	6.61	
							8.92

4.3. Results for Experiment 2

4.3.1. Effect of 4 watering regimes on growth and development of 6 genotypes of pegion peas

4.3.1.1. Plant height:

Effects of treatments on plant height at harvest are given in Table 13. W_4 watering treatment had the tallest plants on average followed by W_2, W_3 and W_1 in that order. These differences among watering treatments were, however, not significant (P=0.01). The effects of interaction between watering regimes and genotypes were also not significant but the effects of genotypes on plant height per plant were significant (P=0.01). Genotype V_3 had the tallest plants followed by V_5, V_6, V_4, V_1 and V_2 in that order. Pairwise comparison of means for the various genotypes can be summarized as follows:

$$V_3 \quad V_5 \quad V_6 \quad V_4 \quad V_1 \quad V_2$$

Any two means not underscored by the same line are significantly different (**P**=0.01).

Weekly plant height measurements (Fig. 5) revealed that plants subjected to all the watering regimes exhibited almost similar pattern of increase in height. The lag phase was not well brought out but, in all the watering regimes, the plants entered senescence between the fifth and sixth weeks from the start of the watering treatments. Surprisingly W_1 plants showed the lowest rate of increase in height all through the ten weeks.

In Figure 6 it is noticeable that genotypes V_1, V_2, V_4 and V_6 exhibited almost same pattern of height increase. Once again the lag phase was not well

Table 13: Effect of 4 watering regimes on plant height (cm) in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIMES MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	48.4	44.3	68.0	49.7	62.0	55.3	54.6
W_2	52.2	50.3	67.7	53.1	62.9	51.4	56.3
W_3	51.4	44.1	69.0	50.4	62.3	58.8	56.0
W_4	52.7	51.7	67.9	55.0	59.7	64.8	58.6
GENOTYPE MEANS	51.2	47.6	68.2	52.1	61.8	57.6	
							56.4

S.E.   Watering regimes = 2.50
S.E.   Genotypes   = 3.05
S.E.   Genotypes X Watering regimes = 6.10
C.V.   = 17.1.%
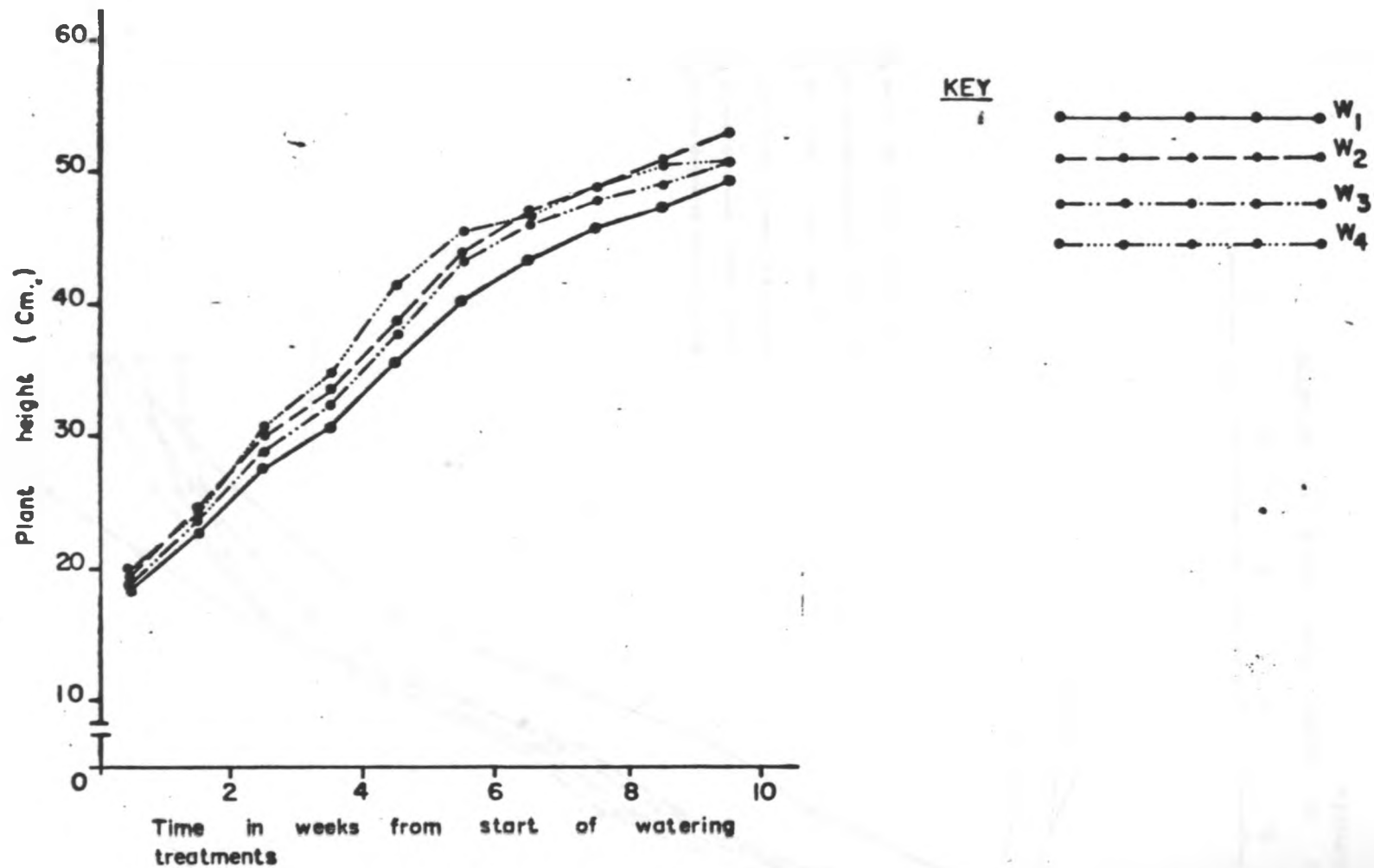
Fig. 5   Mean   effect   of   watering   regimes
on   increase   in   plant   height (Expt. II).
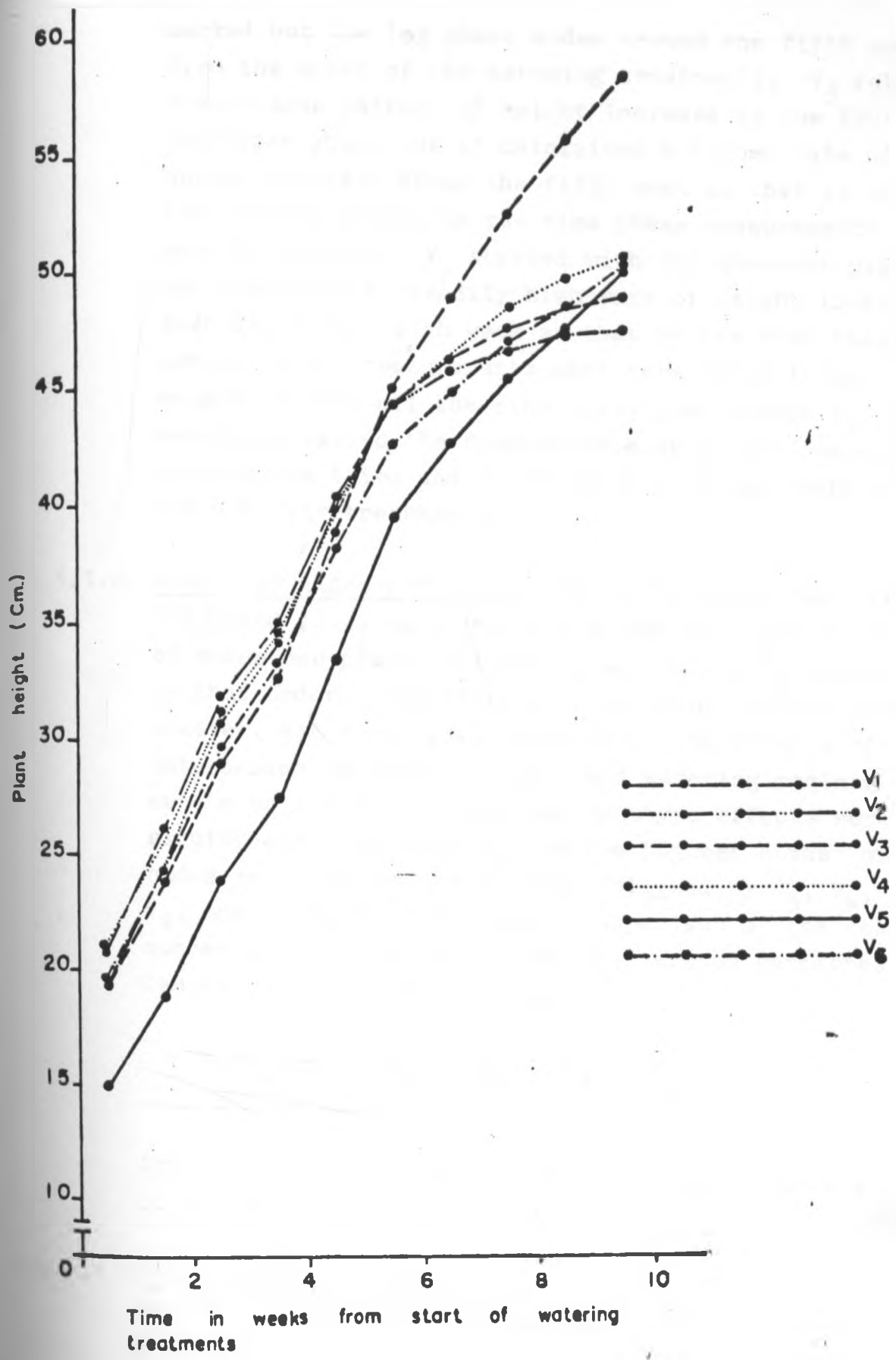
Fig. 6   Mean effect of genotypes on
          increase in plant height (Expt. II)

marked but the log phase ended around the fifth week
from the start of the watering treatments. V_3 followed
almost same pattern of height increase as the four
genotypes above but it maintained a higher rate of
height increase after the fifth week so that it had
the tallest plants by the time these measurements
were terminated. V_5 started with the shortest plants
but exhibited a steadily high rate of height increase
even after the fifth week so that by the time these
weekly height measurements were terminated it had
caught up with all the other genotypes except V_3. All
genotypes showed the fastest rate of height increase
between the third and fifth weeks from the start of
the watering treatments.

4.3.1.2. <u>Number of nodes per plant</u>: Table 14 shows that plants
subjected to W_3 watering regime had the highest number
of nodes per plant followed by W_4, W_1 and W_2 plants
in that order. The effects of watering regimes were,
however, not significant (P=0.01). The effects of
interaction between genotypes and watering regimes
were also not significant but genotype effects were
significant. Genotype V_5 had the highest number of
nodes per plant on the average followed by V_3, V_4, V_6,
V_1, and V_2 in that order. Comparison of the mean
number of nodes per plant for the various genotypes
can be summarized as follows:

$$V_5 \qquad V_3 \qquad \underline{V_4 \qquad V_6} \qquad \underline{V_1 \qquad V_2}$$

Any two means not underscored by the same line are
significantly different (P=0.01).

4.3.1.3. <u>Number of branches per plant</u>: Effects of treatments
on the number of primary branches per plant are
presented in Table 15. Plants subjected to W_3 watering
regime had the highest mean number of primary branches
per plant and those subjected to W_1 had the lowest
with W_4 and W_2 coming in between in that decreasing
order. The effects of watering regimes were, however,

Table 14: Effect of 4 watering regimes on number of nodes per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	18.4	17.5	25.7	20.5	27.6	20.3	21.7
W_2	19.5	17.4	24.1	20.4	26.8	19.5	21.3
W_3	18.6	16.2	29.7	29.7	27.2	24.1	24.3
W_4	18.9	17.0	26.7	22.0	26.1	27.2	22.6
GENOTYPE MEANS	18.9	17.0	26.6	23.2	26.9	22.8	
							22.5

S.E. Watering regimes = 0.97
S.E. Genotypes = 1.19
S.E. Genotypes X Watering regimes = 2.37
C.V. = 16.9%

Table 15:   Effect of 4 watering regimes on number of branches
             per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	G E N O T Y P E S						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	2.5	1.5	2.1	0.4	3.1	2.9	2.1
W_2	1.8	2.7	2.5	1.7	2.5	2.8	2.3
W_3	3.0	1.2	2.9	2.4	4.0	3.7	2.9
W_4	2.7	2.0	3.0	2.0	3.4	3.6	2.8
GENOTYPE MEANS	2.5	1.9	2.6	1.6	3.3	3.3	
							2.5

S.E.   Watering regimes = 0.28
S.E.   Genotypes   = 0.34
S.E.   Genotypes X Watering regimes = 0.68
C.V.   = 42.6%

not significant (P=0.01). Effects of interaction
between watering regimes and genotypes were not
significant but effects of genotypes were significant
(P=0.01). Genotypes V_5 and V_6 had'highest mean
number of primary branches per plant followed in
decreasing order by V_3, V_1, V_2 and V_4. Comparison
of the mean number of primary branches per plant
for the various genotypes is summarized below:

$$\underline{V_5 \qquad V_6 \qquad \underline{V_3 \qquad V_1} \qquad \cdot V_2} \qquad V_4$$

Any two means not underscored by the same line are
significantly different (P=0.01).

4.3.1.4. <u>Plant dry weights</u>:   Effects of treatments on total
dry weights are presented in Table 16. The effects
of watering regimes were significant (P=0.01). The
total dry weight per plant decreased with decreasing
frequency of watering. Comparison of means for the
various watering regimes showed that the mean total
plant dry weight for any one watering regime was
significantly different from that for any other
regime.

Genotype V_3 had the highest mean total plant dry
weight and V_4 had the lowest. Genotype V_6, V_1, V_5
and V_2 came in between in that decreasing order but
the effects of genotypes were not significant (P=0.01).

Tables 17, 18 and 19 give some information about the
distribution of dry matter between shoot and root at
harvest.

Shoot dry weight (Table 17) was found 'to decrease with
decreasing frequency of watering. The effects of
watering were significant (P=0.01) and the mean shoot
dry weight for each watering regime was found to be
significantly different from that of any other regime

Table 16: Effect of 4 watering regimes on total dry
weight (g) per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	18.92	17.18	27.97	16.71	23.73	24.53	21.66
W_2	16.60	18.36	20.72	17.81	18.06	17.71	18.21
W_3	14.73	12.59	11.55	11.81	9.90	12.89	12.25
W_4	9.33	7.88	8.73	7.58	7.69	8.49	8.28
GENOTYPE MEANS	14.90	14.00	17.24	13.48	14.85	15.91	
							15.10

S.E. Watering regimes = 1.23
S.E. Genotypes = 1.51
S.E. Watering regimes X genotypes = 3.01
C.V. = 31.6%

Table 17: Effect of 4 watering regimes on shoot dry weight (g) per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	17.39	15.91	25.70	15.26	21.88	22.96	19.85
W_2	15.07	16.63	18.80	16.31	15.98	16.29	16.51
W_3	13.09	11.48	9.80	10.62	8.36	11.18	10.76
W_4	8.18	6.57	7.21	6.34	6.25	6.75	6.88
GENOTYPE MEANS	13.43	12.65	15.38	12.13	13.12	14.30	
							13.50

S.E. Genotypes   = 1.37
S.E. Watering regimes = 1.12
S.E. Watering regimes X Genotypes = 2.74
C.V. = 32.1%

($P=0.01$). Genotype . V_3 had the highest shoot dry weight followed by V_6, V_1, V_2, V_4 and V_5 but the effects of genotypes were not significant ($P=0.01$).

Root dry weights did not show the consistent decrease with decrease in frequency of watering observed in the case of total and shoot dry weights. The effects of treatments on root dry weight presented in Table 18 show that plants subjected to W_2 watering regime had the highest weight of dry roots per plant followed by W_1, W_3 and W_4 in that order. Likewise, genotype V_3 had the highest mean dry roots per plant followed by V_5, V_6, V_2, V_4 and V_1. The effects of treatments on root dry weight were, however, not significant ($P=0.01$).

Table 19 presents the data for the effects of the treatments on shoot:root ratio. Effects of watering regimes on shoot:root ratio were significant ($P=0.01$). There was a decrease in shoot:root ratio with decreasing frequency of watering. W_1 plants exhibited the highest shoot:root ratio although this was not significantly higher than that of W_2 plants. The shoot:root ratios of W_3 and W_4 plants were, however, each significantly different from that of plants belonging to any other watering regime. Among the genotypes, V_5 plants had the lowest shoot:root ratio followed in ascending order by V_3, V_6, V_4, V_1 and V_2. The effects of genotypes were, however, not significant ($P=0.01$).

4.3.1.5. <u>Earliness to maturity:</u> Duration to maturity was expressed in terms of the number of days from planting to opening of first flower in each plant. Effects of watering regimes on days to flowering were not significant ($P=0.01$). But it was still noted (Table 20) that W_3 plants flowered earliest followed by W_2, W_4 and W_1 plants in that order. Effects of genotypes were significant ($P=0.01$). V_4 plants flowered earliest

Table 18: Effect of 4 watering regimes on root dry weight (g) per plant in 6 genotypes of pigeon peas.

WATERING REGIMES	G E N O T Y P E S						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	1.53	1.27	2.27	1.45	1.85	1.57	1.66
W_2	1.53	1.73	1.84	1.51	2.08	1.42	1.69
W_3	1.64	1.11	1.75	1.91	1.54	1.71	1.49
W_4	1.15	1.31	1.52	1.24	1.44	1.74	1.40
GENOTYPE MEANS	1.46	1.36	1.85	1.35	1.73	1.61	
							1.56

S.E.   Genotypes   = 0.21
S.E.   Watering regimes = 0.17
S.E.   Genotypes X watering regimes = 0.42
C.V.   = 43.1%

Table 19:   Effect of 4 watering regimes on shoot:root
            ratio. (based on dry weights) in 6 genotypes
            of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	11.92	14.22	11.24	11.04	12.21	14.68	12.55
W_2	11.17	9.74	11.01	12.34	9.42	11.56	10.87
W_3	9.28	11.53	5.94	11.15	5.59	6.83	8.39
W_4	8.87	5.81	5.05	5.70	4.61	3.90	5.66
GENOTYPE MEANS	10.31	10.32	8.31	10.09	7.96	9.24	
							9.37

S.E. Genotypes = 0.96
S.E. Watering regimes = 0.78
S.E. Genotypes X watering regimes = 1.92
C.V. = 32.3%

Table 20: Effect of 4 watering regimes on number of days to flowering in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	90.7	94.6	101.4	39.1	105.0	101.3	97.0
W_2	93.6	85.0	100.7	84.8	103.7	108.3	96.1
W_3	86.2	91.7	102.4	84.8	103.3	100.9	94.9
W_4	85.7	90.7	109.7	86.4	97.1	108.5	96.4
GENOTYPE MEANS	89.1	90.5	103.6	86.3	102.3	104.9	
							96.1

S.E.   Genotypes   = 2.48
S.E.   Watering regimes = 2.02
S.E.   Genotypes X watering regimes = 4.95
C.V.   = 8.2%

followed by V_1, V_2, V_5, V_3 and V_6 plants in that order. The differences among means of the various genotypes are summarized below:

$$\underline{V_6 \qquad V_3 \qquad V_5} \qquad \underline{V_2 \qquad V_1 \qquad V_4}$$

Any two means not underscored by the same line are significantly different   (**P= 0.01**).

4.3.2.   <u>Effect of 4 watering regimes on grain yield and yield components.</u>

4.3.2.1. <u>Total grain yield per plant</u>: Effects of treatments on total grain yield are presented in Table 21. Effects of watering regimes on grain yield per plant was significant (P=0.01). There was a decrease in yield per plant with decreasing frequency of watering. A comparison of means for the various watering regimes (P=0.01) showed that, while the mean grain yield per plant for W_1 plants was not significantly higher than that for W_2 plants, the mean yield per plant for W_3 and W_4 plants were each significantly different from the mean yield for any other watering regime. The effects of genotypes on yield of grain per plant were not significant but it was still noticed that V_1 plants had the highest yield of grain per plant followed by V_3, V_2, V_6, V_4 and V_5 in that order.

4.3.2.2. <u>Yield components</u>: Effects of treatments on the various yield components are presented in Tables 22, 23 and 24.

The effects of interaction between watering regimes and genotypes on the number of pods per plant were significant (P=0.01). Hence, while the number of pods per plant decreased consistently with decreasing frequency of watering in genotypes V_3, V_5 and V_6 (Table 22), the highest numbers of pods per plant for genotypes V_1, V_2 and V_4 were recorded in W_2 watering regime. In these latter genotypes there was an initial

Table 21:   Effect of 4 watering regimes on yield
            of grain (g) per plant in 6 genotypes
            of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	6.92	6.30	9.94	5.23	7.65	7.77	7.31
W_2	5.93	6.49	8.06	5.97	5.30	6.92	6.45
W_3	4.27	4.05	1.11	4.01	2.03	3.12	3.11
W_4	2.92	1.26	0.35	1.59	0.49	0.19	1.13
GENOTYPE MEANS	5.01	4.53	4.87	4.21	3.88	4.50	
							4.50

S.E.   Genotypes   = 0.74
S.E.   Watering regimes = 0.60
S.E.   Genotypes X watering regimes = 1.48
C.V.   = 51.8%

Table 22: Effect of 4 watering regimes on the number
of pods per plant in 6 genotypes of
pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	21.1	19.4	22.8	16.6	48	31.8	26.6
W_2	22.2	23.4	21.7	22.0	27.2	21.7	23.0
W_3	18.0	17.4	7.0	13.0	12.6	14.2	13.7
W_4	11.6	6.6	2.0	5.9	4.4	1.7	5.4
GENOTYPE MEANS	18.2	16.7	13.4	14.4	23	17.4	
							17.2

S.E. Genotypes = 2.16
S.E. Watering regimes = 1.76
S.E. Genotypes X watering regimes = 4.32
C.V. = 39.7%

increase in number of pods per plant with a decrease in frequency of watering from W_1 to W_2 followed by a consistent decrease from W_2 to W_4.

The effects of interaction between genotypes and watering regimes on the number of grains per pod were also significant (P=0.01). Thus the results presented in Table 23 show that, whereas there was a consistent decrease in number of seeds per pod with decreasing frequency of watering in genotypes V_2 and V_3, V_1 exhibited an initial rise in number of grains per pod with decrease in watering frequency from W_1 to W_2 followed by a decrease between W_2 and W_3 and finally another increase between W_3 and W_4. V_4 showed a pattern which was almost opposite that of V_1 that is, a decrease between W_1 and W_2, an increase between W_2 and W_3 and another decrease between W_3 and W_4. Genotypes V_5 and V_6 showed almost similar response to the watering regimes; there was an initial increase between W_1 and W_2 followed by a decrease between W_2 and W_4 watering regimes.

The effects of watering regimes and genotypes on 100 grain weight were not subjected to statistical analysis but Table 24 shows that, although there was a tendency for 100 seed weight to decrease with decreasing frequency of watering, the differences were normally slight. Genotype V_4 had the highest 100 seed weight in all the watering regimes while V_5 had the lowest.

Table 23: Effect of 4 watering regimes on number of grains per pod in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	2.49	2.19	3.02	2.27	1.95	1.97	2.32
W_2	2.62	2.06	2.90	1.99	2.22	2.97	2.46
W_3	1.96	1.92	1.48	2.33	2.20	2.14	2.01
W_4	2.03	1.57	1.11	2.21	1.06	0.76	1.46
GENOTYPE MEANS	2.28	1.94	2.13	2.20	1.86	1.96	
							2.06

S.E. Genotypes = 0.20

S.E. Watering regimes = 0.17

S.E. Genotypes X watering regimes = 0.41

C.V. = 31.5%

Table 24: Effect of 4 watering regimes on 100-seed
weight in 6 genotypes of pigeon peas.

WATERING REGIMES	GENOTYPES						WATERING REGIME MEANS
	V_1	V_2	V_3	V_4	V_5	V_6	
W_1	13.39	13.29	13.69	14.69	8.56	12.41	12.67
W_2	12.62	13.39	12.99	13.18	9.41	11.30	12.15
W_3	12.22	12.53	11.55	13.12	7.78	9.86	11.18
W_4	10.74	9.66	10.81	12.51	6.84	7.56	9.69
GENOTYPE MEANS	12.24	12.22	12.26	13.38	8.15	10.28	
							11.42

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1. Effects of watering regimes and genotypes on growth and development in pigeon peas

5.1.1. General Observations.

It was observed that plants showed signs of wilting after staying without water for some time. Wilting of leaves is a common sign of internal water deficit in a plant. It usually represents development of internal water deficit when transpiration exceeds absorption. Slatyer (1969) observed that the rate of absorption relative to that of transpiration is not the only factor affecting internal water deficit althoughit is generally true that the deficit develops when transpiration exceeds absorption. The level of plant water potential and hence the internal water deficits is influenced by both the level of soil moisture potential and the diurnal lag of absorption behind transpiration. In turn each of these factors is influenced by other factors both environmental and physiological. For absorption to occur a gradient of water potential must extend from the soil to the leaf. It follows that as soil water content is progressively reduced during a period of drought there is a concomitant drop in level of plant water potential. That is, plant water potential can never be higher than soil water potential (except in rare cases of absorption of atmospheric water by shoots). Hence there is a base level of plant water potential and internal water deficits which is limited by the the level of soil water potential.

After the start of watering treatments the plants in all treatments showed no sign of wilting for several weeks. This probably indicates that, given the plants' sizes and stages of development, none of the watering

regimes subjected the plants to a water stress high enough to trigger off wilting during these weeks. When the wilting signs finally started to appear, they were first noticed in W_4 plants, in any one genotype, followed by W_3 plants and, in experiment I, W_2 plants in that order. W_1 plants never showed signs of wilting in both experiments while W_2 plants showed signs of wilting in experiment I but not in experiment II. This observation could possibly be explained if it is appreciated that the daily water requirement of a plant increases as it grows bigger. It follows, therefore that when water was supplied upto container capacity the duration over which it could provide the plants with readily available water decreased as the plants grew bigger. Hence it is not suprising that W_4 plants which had the longest watering interval were affected earliest. Similarly, W_3 plants were expected to be affected before W_2 plants.

In experiment I W_1 plants never showed any signs of wilting while W_2 plants often exhibited severe signs of wilting in between watering days, particularly around flowering and pod filling stages. It may, therefore be concluded that the best watering regime was between daily and weekly watering. Similarly the best watering regime in experiment II was apparently between W_2 and W_3 watering regimes as W_2 plants never showed any signs of wilting while W_3 plants frequently exhibited severe wilting in between watering days. Furthermore, there was no significant ($p=0.01$) difference in mean yield of grain per plant between W_1 and W_2 plants in experiment II but mean yield per plant in W_3 watering regime was significantly lower than that in W_1 plants.

Once the plants subjected to W_2, W_3 and W_4 watering regimes, in experiment I, had all started showing signs of wilting during various watering intervals, it was noted (section 4.1.) that, in any particular genotype, the shorter the watering interval, the sooner the plants started wilting following a previous watering. It

was stated earlier that for any particular genotype, W_2 plants were taller on average (section 4.2.1.1.), had more branches per plant (section 4.2.1.3.) and had higher dry weights per plant (section 4.2.1.4.) than plants in W_3 and W_4 watering regimes. Similarly W_3 plants were better favoured with respect to these growth attributes than W_4 plants. It is expected that, in a particular genotype, a bigger plant should need more water for maintenance than a smaller one and so deplete available water faster. Hence these observations were not suprising. Furthermore, it was observed that W_2 plants had more leaves than those of W_3 plants which were in turn better favoured in this respect than W_4 plants and that W_2 plants had the lowest rate of leaf shedding followed by W_3 and W_4 plants in that order. Since leaf is the transpiratory organ, it is to be expected that W_2 plants were transpiring more and therefore were depleting water in the pots at faster rates than plants in the other two regimes.

In experiment II only W_3 and W_4 plants showed signs of wilting but it was again found that W_3 plants normally started wilting after fewer days following a previous watering than W_4 plants. The results of this experiment, however, showed that the watering regimes did not have significant (P=0.01) effects on plant height or number of branches per plant. Differences in leaf shedding between plants in the two watering regimes was most pronounced around flowering and pod setting and it has been pointed out (section 4.3.2.1.) that grain yield of W_3 plants was significantly (P=0.01) higher than that of W_4 plants. Therefore the earlier wilting of W_3 than W_4 plants may be attributed, at least in part, to the heavier water demand imposed on W_3 plants as a result of them bearing more flowers and pods than W_4 plants.

In both experiments whenever wilting occurred in a watering regime, plants of genotypes V_3, V_5 and V_6

normally showed signs of wilting before V_1, V_2 and V_4 plants. The former genotypes had larger plants, on the average than the latter genotypes and probably needed more water for maintenance and dry matter production.

In their review of work on crop responses to water at different stages of growth, Salter and Goode (1967) cited many examples in pulses to show that these crops are more sensitive to water stress during flowering than vegetative stages. Similarly Hiler et al. (1972) found the flowering stage most susceptible to severe stress (-14 to -28 bars leaf water potential) imposed on cowpea plants. Their results agree with the findings in this study that, in any particular genotype and watering regime (W_2, W_3 and W_4 in experiment I and W_3 and W_4 in experiment II), plants bearing flower buds, flowers or young pods showed signs of wilting before those still in the vegetative state. Several explanations have been given to this pheno- menon. Loewing (1940) reported an abrupt and subse- quently progressive increase in rate of transporation at the time of flower inception in P_t vulgaris which, despite a transitory rise in the rate of water absorption, led to the plant having lower water content and higher percentage of dry matter. In this study such a rise in transpiration could lead not only to the development of temporary water deficit and thus temporary wilting due to higher rate of transpiration than absorption but also to faster depletion of available water in the container thus leading to earlier occurrence of permanent wilting. Loewing (1940) also reported reduction in root activity as flowering approached its peak so that absorption of water was retarded leading to accentua- ted dehydration of tissues throughout the plant.

The observed response of leaves to water stress were similar to those reported by other workers elsewhere. That stressed plants tended to shed their leaves at faster rates than non-stressed ones support result of

work by McMichael et al. (1973), Ludlow (1975), and
Constable and Hearn (1978). Leaf shedding reduces
total leaf area thus reducing the evaporative surface
and has been reported to reduce water loss in native
vegetation (Orshan, 1963). However, the importance
of leaf shedding and senescence on crop evaporation
has not been fully evaluated (Turner, 1979) although
it is likely to be similar to that reported by
Orshan (1963) in native vegetation. It was observed
in this study that plants belonging to genotypes
V_3, V_5 and V_6 tended to shed their leaves at higher
rates than V_1, V_2 and V_4 plants. Turner (1979)
reported that no evidence of difference in rate of
leaf senescence or shedding in response to similar
degrees of stress have been reported between cultivars.
In this study the degree of water stress was not
measured and it is possible that the differences in
leaf shedding observed among the genotypes could be
due to the fact that some genotypes actually experienced
higher water stress than others. It was described
earlier that V_3, V_5 and V_6 had larger plants (sections
4.2.1.4 and 4.3.1.4.) than the other three genotypes
so it is possible that they required more water per
unit time and thus depleted water in the container
at a faster rate and were, therefore, exposed to
higher soil water stress at any one time during the
intervals in any watering regime. Alternatively or
additionally there could be some inherent genotypic
differences so that V_3, V_5 and V_6 genotypes had
higher rates of transpiration per unit leaf area than
the other three genotypes.

The vertical leaf orientation observed in some stressed
plants could be a way of reducing water stress.
Turner (1979) noted that water loss in plants could
be reduced by reducing the amount of radiation
intercepted by the plant community. Active and/or
passive leaf movements provide some of the means for
reducing the amount of radiation intercepted thereby
counteracting the increase in leaf temperature arising

from stomatal closure. Begg and Torsell (1974).
observed active leaf movements in Stylosanthes
humilis in which the plants orientated their leaves
parallel to the incident radiation as water deficit
developed. Similar parahelionastic movements have
been shown in beans (Dubetz, 1969). In this study
although the leaves assumed vertical alignment when
under water stress and thus reduced the leaf surface
exposed to direct radiation for most part of the day,
no active tendency by the leaves to orientate
parallel to the incident rays was observed; the leaves
remained in almost one position of alignment through-
out the day. However, further reduction of moisture
loss was probably achieved by the closing up of leaves
around main stem and braches as this could reduce
diffusion deficit between the leaf and the atmosphere
in the micro-environment around the leaves. This
mechanism could be especially important in the glass-
house where the plants were grown as there was minimal
turbulence as opposed to what would be found in an
open field. It is worth noting that both vertical
orientation and leaf shedding occurred in all genotypes,
the former coming before the latter. They probably
represented response to different degrees of water
stress shedding being a response to more serious
water stress.

Whereas the shedding of lower leaves has been explained
as being a response to moisture stress the death of
the uppermost young and expanding leaves and sometimes
the growing tip, leaving the third, fourth and commonly
fifth leaves which was observed in genotypes V_5 and
V_6 in experiment I was not so easy to explain. However,
the most likely cause of this phenomenon was high
temperature and the fact that no such observation was
made in experiment II which was conducted during cooler
season (Fig.1) adds credibility to this explanation.
When a plant starts wilting stomatal closure usually
occurs leading to rise in leaf temperature (Gates,
1968). Benda (1962) reported heat induced leaf

chlorosis in tobacco plants. Chlorotic areas
developed in actively expanding leaves of tobbaco
and continuation of this stress was observed to end
in death of cells and visible necrosis. In this
study chlorosis was observed to precede death in the
folded leaves. However, there was leaf scorching
of the type described by Treshow (1970) observed in
unfolded young leaves. The third, fourth, and fifth
leaves could resist death due to heat stress because
they were more mature and had stopped active expansion.
Besides genotype V_3, genotypes V_5 and V_6 were observed
to be the more affected, in relative terms, by water
stress with respect to dry weights and plant heights.
Kaloyereas (1958) observed good positive correlations
between drought resistance and heat resistance in
various strains of Pinus taeda L. and this seems to
agree with the observation made in genotypes V_5 and
V_6 compared to the other genotypes. It is thus
suggested that drought resistance and heat resistance
are apparently positively related in pigeon pea
genotypes also.

5.1.2.   Plant height: The results of experiment I showed that
effects of interaction between genotypes and watering
regimes on plant height at harvest were significant
(P=0.01) such that whereas plant height decreased
consistently with decreasing frequency of watering
in genotypes V_3, V_4, V_5 and V_6, plants subjected to
W_3 watering regime had a higher mean plant height
per plant than W_2 plants in and genotype V_2, W_2 plants
had the highest mean height per plant.

El Nadi (1969a) obtained results which suggested that
severe water stress during part or whole of the
vegetative phase had a depressing effect on plant
height in broad beans. In this study the watering
treatments were started early in plant growth when
stem was still actively growing. It was, therefore
not suprising that plant height was consistently

reduced with decreasing frequency of watering in genotypes V_3, V_4, and V_6. It has been reported (Aspinall, et al., 1964) that the organ growing most rapidly at the time of moisture stress is the one most affected. Moreover, Wien _et al_. (1979) observed that drought stressed plants of cowpeas and soyabeans had significantly shorter stems only if stress began before the stems had ceased growing. The effects of drought stress on plant height can probably be attributed to its effects on cell division and enlargement. Slatyer (1969) reported that both cell **division** and cell enlargement are sensitive to water stress but the latter is often more sensitive thus being the first observable symptom of water deficits and is the main cause of the stunting which is perhaps that most common sign of water stress under field conditions. A more general response is that of a progressive decline in the rate of **cell enlargement** as water deficits develop. This could explain why there was a consistent decrease in mean height with decreasing frequency of watering since it can be expected that the longer the duration from a watering day the larger the water deficit for any one genotype and hence the more severely will plant cell enlargements be affected. Slatyer (1957a) suggested that the rate of cell enlargement is more or less proportional to turgor pressure but this is rarely a simple relationship (Loc'hart, 1965) and enlargement may cease when turgor pressure levels are still several bars (Boyer, 1963).

The fact that the mean height per plant in genotypes V_1 and V_2 did not decrease consistently as in the rest of the genotypes (Table 1) could perhaps be explained when it is considered that these were the shortest plants at any one time. It has been explained earlier that the smaller the plant the lower the water stress it could experience in any particular genotype and watering regime. It is probable, therefore, that the

degrees of stress to which the plants receiving
the various watering regimes in these genotypes were
never as different as to cause marked differences
in plant heights and that the marked differences could
be due to random error. These same genotypes were
among the least affected, in relative terms, with
respect to dry weight and even seed yield. Alternative-
ly the inconsistency could be due to inherent
heterogeneity within the genotypes.

In experiment II the effects of interaction between
genotypes and watering regimes on plant height at
harvest were not significant (P=0.01) nor were the
effects of watering regimes. The effects of genotypes
were, however, significant (P=0.01). Given the
overwhelming evidence available in support of the
fact that drought occurring during growing period
has depressing effects on plant height, for example,
El Nadi (1969a) and Wien et al. (1979) it becomes
difficult to explain the lack of response of plant
height to various watering regimes in experiment II.
However, as shown in figures 1 and 2, experiment II
was conducted during a cooler and more cloudy season
than experiment I and it is possible that the
temperature rather than moisture became the most
limiting factor. Oluoch (personal communication),
growing pigeon peas at Thika - Kenya, found that
pigeon pea plants were growing much slower during the
cool season and ended being much shorter on average
than plants which he had grown during the warmer
season. The results of experiment II seem to support
this finding by Oluoch as the plants planted in this
season also showed slower rate of development so that
they were only ready for harvest after 177 days
compared to plants in experiment I which were harvested
after 151 days. These plants were also shorter on
average than plants in experiment I in the better
watered treatments. In the less frequently watered
treatments, particularly W_4 watering regime, however,
the plants were taller on average in experiment II
than in experiment I and this seems to indicate that

plants grown during cool weather need lower soil
moisture than plants raised in hot weather for good
plant growth in height. It is possible that wet
soils create relatively cold environment around
the roots when ambient temperatures are low so
that root activity and plant growth are retarded.

It appears that the seasonal differences in
temperature and sunshine had almost proportionate
effects on the various genotypes since, although
the plants in experiment II were shorter on average,
the tallest genotypes in experiment I remained so
in experiment II with the other genotypes coming
behind in almost the same order in both experiments.

It has been stated (section 4.1.) that for any
particular watering regime and genotype, plants in
experiment II appeared to have experienced less
drought stress than those in experiment I. Thus,
while plants subjected to W_2 watering regime showed
signs of wilting in experiment I, their counterparts
in experiment II never showed such signs. This may
further prove that water stress was less limiting
in experiment II than in experiment I.

Weekly plant height measurements showed that the
difference among the plants subjected to the various
watering regimes increased as the plants grew bigger
in experiment I (Fig. 3). This is in keeping with the
result obtained in barley by Abd el Rahman et al.(1967);
they found that the difference in plant height during
various watering treatments were less pronounced during
the early stages of vegetative growth than at the
later stages of growth when cumulative effects of
water supply appeared. Besides the daily water
requirements which increases as a plant grows, water
stress affects many physiological factors of plant growth,

the extent of damage depending on the degree and
duration of water stress. It was, therefore, not
suprising that W_4 plants were the first to be
affected followed by W_3 and W_2 in that order.
The stepwise pattern of growth exhibited in later
stages by W_3 and W_4 plants represented periods of
suspended growth during moisture stress and resumed
growth upon elimination of the stress. That the
stepwise pattern of growth was more pronounced
during the later stages of growth further indicated
that water stress was more severe during these
stages, apparently a result of both change in size and
change in growth phase from vegetative to reproductive.

In experiment II there was no marked difference in
the weekly rate of increase in height among plants
subjected to the various watering regimes. It was,
however, noted that, though not very different,
plants subjected to the wettest regime exhibited the
lowest rate of increase in height during the entire
ten weeks (Fig. 5). These results further underscore
the contention that water stress was not the chief
factor limiting growth of plants during this season.

Comparison of weekly plant height increases among
the genotypes (Figs. 4 and 6) gave a very comparable
picture between the two seasons: In both seasons
plants of genotype V_3 emerged as the tallest on
average around the fifth week from the beginning of
watering treatments and V_5 which started with some
of the shortest plants on average managed to catch
up with the rest of the genotypes except genotype
V_3, by the time the weekly measurements were termina-
ted. Given that the plants in experiment II were
shorter on average for any particular genotype we
can only conclude that temperatures experienced in
the second season had almost proportionate effects
on the heights of all the genotypes.

5.1.3. Number of nodes and branches per plant

There were significant (P=0.01) interaction effects
between watering regimes and genotypes on the
number of nodes per plant in experiment I such that,
while the number of nodes per plant consistently
decreased with decreasing frequency of watering in
genotypes V_3 and V_5, the response was more
inconsistent in the rest of the genotypes (Table 2).
Genotypic differences in response to the watering
regimes was thus suggested. El Nadi (1969a), working
with broad beans, reported that cycles of water
stress during the whole of the vegetative period
had a depressing effect on number of nodes per plant
and results obtained with genotypes V_3 and V_5 seem
to suggest that progressively severe water stress
imposed on these genotypes produced plants with
progressively fewer nodes. In each genotype tall
plants tended to have higher number of nodes per
plant and even among the genotypes, tall ones, on
average, had higher number of nodes than short ones.
It was thus apparent that water stress may only
depress the number of nodes per plant through its
depressing effect on plant height and in experiment
II, when it was found that watering regimes had no
significant (P=0.01) effects on plant height, the
number of nodes per plant were also not significantly
(P=0.01) affected. Genotypes had significant (P=0.01)
effects on number of nodes per plant in experiment 2.
It was again noted that the taller genotypes tended
to have higher number of nodes per plant suggesting
that the number of nodes per plant is influenced,
at least partly by plant height.

The effects of watering regimes on number of branches
per plant were significant (P=0.01) in experiment I
but not in experiment II. In experiment I, plants
subjected to W_2 watering regime produced the highest

number of branches per plant on average although
this was not significantly (P=0.01) higher than that
of W_1 and W_3 plants. The mean number of branches per
plant in W_4 watering $\angle$ regime was, however, significantly (P=0.01) lower
than that of plants belonging to any of the other
regimes. Salter (1963a) found that the number of
pod-bearing branches, was significantly greater in
pea plants irrigated from germination to flowering
than in unirrigated plants. Similar observation was
made by El Nadi (1969c) for the number of tillers
in wheat. Slatyer (1969) observed that effects of
water deficits on primordial initiation appears to be
superficially similar to dormancy in the sense that
initiation can be completely suspended without the
potential for subsequent development being impaired
as long as the stress is not too severe or too
protracted. El Nadi (1969) found that plants of broad
beans produced more branches after an initial phase
of drought followed by a favourable water regime. In
experiment I it was noted that plants only started
showing signs of wilting after about 10 weeks of growth
and at this time a number of branches had already been
formed. This may explain why there was no significant
(P=0.01) difference on number of branches among W_1,
W_2 and W_3 plants. In addition, since the plants
were not subjected to continuous drought; they only
went through cycles of wet periods (soon after watering)
and dry periods (starting some time following a previous
watering), branch primordia which were dormant during
dry periods (Slatyer, 1969) could develop during the
wet periods so that little difference would appear
among the various watering regimes.

The first stress signs appeared in W_4 plants and
subsequently they were seen to be the most stressed
plants. Given these two points it may be suggested
that severe stress which could inhibit branch develop-
ment was likely to have first occurred in W_4 plants so
that they never had time to develop as many branches
as in the other treatments and the severity and duration
of the stress in these plants were such that recovery

of branch formation during the wet period was largely
precluded.

In any one watering regime plants in experiment II
had fewer branches than those in experiment I
(Tables 3 and 15). This difference between seasons
was probably the result of differences in temperature
and sunshine (Figs. 1 and 2) recorded between the
two seasons. The low temperatures apparently suppressed
development of lateral buds in plants subjected to
all watering regimes and was possibly a more limiting
factor to development of branches than water stress
and hence the lack of significant (P=0.01) differences
among the plants subjected to the various watering
regimes.

In both experiments the effects of genotypes on
number of branches per plant were significant (P=0.01)
indicating that there were genotypic differences in
growth habits which were not inhibited by seasonal
differences.

In field conditions, Akinola and Whiteman (1974)
reported a strong association between grain yield
per plant and number of pod bearing branches per plant
in pigeon peas. In this study it was found that some
genotypes produced more branches than others (Table 4).
It was also found that wetter regimes favoured the
production of more branches per plant (section
4.2.1.3.) but this effect was only significant (P=0.01)
in a warm season. It may therefore be concluded that
the best pigeon pea genotype to plant in a warm, wet
season is that which forms the highest number of
branches per plant.

5.1.4. Plant dry weights: The total dry weights included
the weights of vegetative shoot, root, pods and seeds.
Effects of interaction between watering regimes and
genotypes were significant (P=0.01), in experiment I,
such that, although the dry weight per plant decreased

with decreasing frequency of watering in all genotypes,
the decrease was more rapid and more pronounced in
some genotypes than others (Table 4).

In experiment II, the effects of interaction between
genotypes and watering regimes and those of genotypes
were not significant (P=0.01). As in experiment I,
however, there was a clear trend showing that the
total dry weight decreased with decreasing frequency
of watering (Table 16). The effects of watering
regimes were significant (P=0.01) and pairwise
comparison of mean dry weights for the various watering
regimes showed that the mean for any one watering
regime was significantly (P=0.01) different from that
of any other.

Reduction in plant dry weight as a result of water
stress has been reported in cowpeas (Wien et al., 1979)
and beans (El Nadi 1969a). It was stated earlier
(section 4.2.1.1.) that there was a consistent
decrease in plant height with a decrease in frequency
of watering in genotypes V_3, V_4, V_5 and V_6 in
experiment I. This could, at least partly, account
for the decrease in dry weight since Akinola and
Whiteman (1974) reported that total dry matter yield
in pigeon peas was strongly related to plant height.
The pods also contributed a large part of dry weight
in the wetter regimes (W_1 and W_2) as shown in Table
25 and thus provided an advantage for plants in these
regimes over those in W_3 and W_4 watering regimes
which on average had fewer or no pods.

In experiment II it was found that the effects of
watering   regimes on plant height were not significant
(P=0.01) nor were their effects on number of branches
per plant. However, the effects of watering regimes
on grain yield per plant were significant (P=0.01) and
grain yield decreased with decreasing frequency of
watering. Hence the effects of watering regimes
on total dry weight per plant in this experiment
could be largely attributed to its effects on grain
yield (Table 25).

Table 25: Percentage distribution of total dry
matter into various plant parts in the
4 watering regimes.

EXPERIMENT I

WATERING REGIME	VEGETATIVE SHOOT %	ROOT %	PODS (HUSK + SEEDS)%
W_1	58.3	7.7	34.0
W_2	55.3	9.3	35.4
W_3	62.4	12.2	25.4
W_4	69.4	16.9	13.7
MEAN	61.35	11.53	27.13

EXPERIMENT II

WATERING REGIME	VEGETATIVE SHOOT %	ROOT %	PODS (HUSK + SEEDS)%
W_1	30.8	8.7	60.5
W_2	36.6	14.7	48.7
W_3	61.1	19.6	19.6
W_4	66.2	21.5	12.3
MEAN	48.67	16.05	35.27

Plants showing signs of water stress had relatively
smaller photosynthetic surface as a result of vertical
leaf orientation and leaf shedding. Closure of
stomata is one method of reducing water loss but it
also reduces photosynthesis. Usually wilting leaves
have their stomatal aperture reduced if not totally
closed and thus not much dry matter would be produced
in such plants.

The shoot:root ratio was also found to decrease with
decreasing frequency of watering in both experiments
(Tables 7 and 19). This implies that the proportion
of total dry weight attributed to roots increased
with increasing water stress (Table 25). The effects
of watering regimes on shoot:root ratio were signi-
ficant (P=0.01) in both experiments while the effects
of genotypes were significant (P=0.01) in experiment
I but not in experiment II. Interaction between
watering regimes and genotypes was not significant
in both experiments.

These results support findings by other workers to
the effect that growth of roots is usually less
affected by water stress than that of aerial parts
so that the overall shoot:root ratio is often lower
in plants under water stress compared to their
better watered counterparts (Harris, 1914; Martin,
1940; Davis, 1942; Ronnike, 1957), in this study,
although the dry weight of roots generally decreased
with decreasing frequency of watering in both
experiments (Tables 6 and 18), the proportion of
total dry weight attributed to roots increased with
decreasing frequency of watering (Table 25). However,
the effects of watering regimes on root dry weights
were only significant (P=0.01) in experiment I and
not in experiment II thus suggesting that the decrease
in shoot:root ratio with decrease in frequency of
watering observed in experiment II was mainly a result
of reduction in shoot dry weight, root dry weight
remaining almost unchanged. In Table 25 it is shown

that the increase in proportion of total dry matter
which accompanied decrease in frequency of watering
was more marked in experiment I than experiment II.
It should be noted that the proportion of dry
matter attributed to root and that due to vegetative
shoot both increased with decreasing frequency of
watering in both experiments (Table 25) while the
proportion due to pods and seeds decreased. It
may hence be concluded that water stress favoured
deposition of dry matter in vegetative parts at
the expense of reproductive parts. The vegetative
shoot:root ratio also decreased with decreasing
frequency of watering thus suggesting that water
stress also favoured deposition of dry matter in
roots at the expense of vegetative aerial parts.

The genotypes could be divided into two groups. One
group included genotypes V_1, V_2 and V_4 which had
comparable shoot:root ratios. The other group
consisted of genotypes V_3, V_5 and V_6 which also
had comparable shoot:root ratios (Tables 7 and 19).
Plants in the first group had higher shoot:root
ratios on average, than those in the second group.
The genotypes belonging to the first group were also
relatively less affected by water stress with respect
to total dry weight, shootdry weight and grain yield
per plant. It was stated in Section 4.1. that plants
belonging to the first group tended to resist leaf
shedding more than those in the second group. These
leaves not only added to the shoot weight but
certainly also provided dry matter, through photo-
synthesis which was deposited in the later developed
parts such as pods and seeds even in the less
frequently watered treatments and these genotypes
actually gave better grain yields than those in the
second group in W_3 and W_4 watering regimes in spite
of the latter's better performance in W_1 watering

treatment. Table 26 shows that plants belonging
to genotypes V_1, V_2 and V_4 were also the most
efficient with respect to dry matter deposition
into seeds and pods in both experiments.

Following these findings it may be concluded that
the ability of a pigeon pea plant to give a good
yield under dry conditions rests on its ability to
maintain relatively high shoot weight and hence high
shoot:root ratio. Selection for genotypes of pigeon
peas which show relative drought resistance with
respect to shoot dry weight may thus be a useful
tool in breeding pigeon peas for more arid areas
as these plants also seem to be more efficient
with respect to deposition of dry matter into pods
and seeds   (Table 26).

From tables 25 and 26 it may also be concluded that
the low temperature and short sunshine hours which
prevailed during second season favoured deposition
of dry matter into vegetative shoot at the expense
of both pods and roots. Growing of pigeon peas in
cool climatic areas such as Kenya highlands would,
therefore not be advisable.

5.1.5.   Earliness to maturity: Duration to maturity was
expressed in terms of number of days from planting
to opening of the first flower in each plant.

Effects of watering regime on days to flowering were
not significant (P=0.01) in experiment II but it
was noted that W_3 plants flowered earliest followed
by W_2, W_4 and W_1 in that order. In experiment I the
effects of interaction between genotypes and watering
regimes on earliness to maturity were significant
(P=0.01) such that although the number of days to
flowering increased with decreasing frequency of
watering in genotypes V_3, V_4 and V_5 such a trend was
not clear in the other genotypes (Table 8).

Table 26:   Percentage distribution of total dry
matter into various plant parts
in the 6 genotypes.

EXPERIMENT I

| GENOTYPE | VEGETATIVE | | PODS |
	SHOOT %	ROOT %	HUSK + SEEDS)%
V_1	28.5	10.1	61.4
V_2	37.0	9.1	53.9
V_3	42.8	12.8	44.4
V_4	40.7	10.3	49.0
V_5	48.4	14.8	36.8
V_6	43.0	14.4	42.6
MEAN	40.07	11.92	48.02

EXPERIMENT II

	SHOOT %	ROOT %	HUSK + SEEDS)%
V_1	56.6	9.8	33.6
V_2	58.0	9.7	32.3
V_3	61.1	10.7	28.2
V_4	58.7	10.0	31.3
V_5	62.3	11.6	26.1
V_6	61.6	10.1	28.3
MEAN	59.72	10.32	30.0

Little evidence is available about the effects
of water stress on development. Cases have been
reported of hastened maturity in sorghum (Whiteman
and Wilson, 1965), cotton (El Nadi, 1974) and wheat
(Chinoy, 1960). Delayed maturity has also been
reported in a number of crops, for example,
Sorghum (Whiteman and Wilson, 1965)
and wheat (Chinoy, 1960; Angus and Moncur,
1977). Whether plant development is delayed or
hastened seems to depend on the degree of stress
to which it is subjected. Mild water deficits
between floral initiation and anthesis hastened
anthesis and maturity in some Medicago spp. (Clarkson
and Russell, 1976) but Angus and Moncur (1977)
found that whereas maturity was hastened in plants
which encountered mild stress, there was develop-
mental retardation in plants which had been severely
stressed.

It has been shown that water stress depresses
increase in plant height (El Nadi, 1969a; Wien et al.,
1979) and leaf area (Boyer, 1970; 1973; Hsiao,
1973; Wien et al., 1979) and work reviewed by Salter
and Goode (1967) showed that water stress during
periods of vegetative growth has general depressing
effects on vegetative growth of plant even though
grain yield may not be affected. It would therefore
be expected, and results of genotypes V_3, V_4 and V_5
in experiment I support this, that plants which were
subjected to drought stress should mature at a later
date due to cessation or reduction of shoot develop-
ment and cell enlargement. Moreover, Sax (1962)
emphasized that the age at first flowering, an
indication of achieving adult stage, shows great
variability among different genera of plants mainly
because the duration of the non-flowering juvenile
stage is greatly modified by environmental factors
which influence growth rate. He further noted that

vigorous trees reach adulthood before suppressed ones of the same species. Since water stress depresses plant vigour, it would, therefore, be expected that it delays maturity.

Given all the evidence in favour of the fact that water stress should delay maturity, it becomes difficult to explain cases where mild stress have been found to hasten maturity. Angus and Moncur (1977) suggested that the increase in leaf temperature which accompanies water stress may have an effect in hastening development similar to that of an increase in ambient temperature. However, this explanation would only be plausible where ambient temperatures are suboptimal.

The results of experiment I for genotypes V_1, V_2 and V_6 indicated that the earliest plants were those which received either W_2 or W_3 watering regime. Apparently the earliness increased with decreasing frequency of watering upto a point then started decreasing. This seems to support the concept that mild water stress hastened development while severe stress delayed it. It should, however, be noted here that some plant species · or cultivars develop drought avoiding mechanisms so that watering treatments which do not include actual measurement of plant water stress, as was the case in this study, may not provide actual information as to which plants are mildly or severely stressed. It may hence be suggested that future work on water relations in pigeon pea include measurement of plant water stress.

5.2. Effects of watering regimes and genotypes on grain yield and yield components per plant.

5.2.1. Total grain yield per plant:
The effects of interaction between genotypes and watering regimes on yield per plant were significant (P=0.01) in experiment I such that although there was a distinct drop in yield per plant resulting from decrease in frequency of watering in all genotypes, genotypes V_5, V_3 and V_6 were affected

more rapidly and to a relatively larger extent than
V_1, V_2 and V_4. The former genotypes, however,
yielded higher on average than the latter in the
wettest regime. Hence it appears that the decrease
in yield in response to water stress was more
drastic in genotypes which had higher yield potential
in the wettest regime. In experiment II, the
interaction was not significant (P=0.01) nor were
the effects of genotypes on grain yield per plant.
The effects of watering regimes were, however,
significant (P=0.01) and there was a decrease in grain
yield with decreasing frequency of watering. The
mean grain yield per plant in W_1 plants was the
highest but it was not significantly (P=0.01) higher
than that of W_2 plants. The mean yield for plants
in W_3 and W_4 watering regimes were, however, each
significantly (P=0.01) different from the mean yield
in any other watering regime.

It was shown in section 4.2.1.5. that, for any
watering regime, genotypes V_1, V_2 and V_4 matured
earlier than the other three genotypes with any of
them taking first second and third earliest flowering
dates in experiment I. This probably explains, at
least partly, why they did not yield very highly
in the wettest regime but yielded better than V_3,
V_5 and V_6 in the less frequently watered regimes:
Derera et al. (1969) observed strong consistent
negative correlation between grain yield and days
to first ear emergence in wheat under simulated
drought conditions and concluded that between 40
and 90 per cent of the variation in wheat yield under
drought are accountable by earliness. Chinoy (1960)
also showed that drought resistance was greater in
earlier lines of wheat than late ones even at same
intensity of drought and Fischer and Maurer (1978)
have provided evidence from 53 wheat and barley
cultivars in which yield increase owing to earliness
was greater when water deficits were more severe.
However, given an adequate water supply yield is
often positively correlated to maturity date in
determinate annual crops such as maize, sorghum, and

sunflower (Gunn and Chriestensen, 1965; Dalton, 1967; Goldsworthy and Colegrove, 1974). Results of this study show that these findings also hold for pigeon pea. Hence selection for earliness to avoid severe soil water deficits may mean lower yields in years of adequate rainfall but provide better assurance against total crop failure in dry years.

Early maturing cultivars are usually smaller than their later maturing counterparts. Smaller plants take up less soil moisture per unit time so that they can survive longer on moisture stored in the soil after the rains than their larger counterparts. Furthermore they would complete most of their vegetative growth earlier in the season and start depositing dry weights in the pods and seeds. This would be advantageous in the semi-arid areas of Kenya where the rains normally last for only a few weeks.

In this study it was observed that plants belonging to genotypes V_1, V_2 and V_4 were the shorter in any watering regime in experiment I and this could further explain the fact that they performed better under dry conditions; they could survive longer on moisture stored in the container.

The fact that genotype effects were not significant (P=0.01) in the second experiment could be attributed to the lower temperatures in this season. It has been stated in section 5.1.2.1. that the cool weather apparently affected plant heights in wetter treatments more than in the relatively dry treatments. Comparison of the result of grain yield per plant in experiment I (Table 9) and experiment II (Table 21) also show that, while the yields for W_1 plants were much lower in experiment II compared to experiment I, the mean yields for W_3 and W_4 plants

were actually higher in experiment II than in·
experiment I. Thus genotypes V_3, V_6 and V_5 which
were favoured by wet regimes were at a disadvantage
in experiment II whereas genotypes V_1, V_2 and V_4
which did not yield very highly in wet regimes
but still produced some grain even in the drier
watering regimes were actually at an advantage.
The mean yield for the various genotypes during
the second season were therefore not very different
from one another.

5.2.2. Yield components.

Yield of grain per plant of pigeon pea is a function
of number of pods per plant, number of grains per
pod and the individual grain weight often expressed
as 100 or 1000 grain weight. Akinola and Whiteman
(1974) also reported a strong association between
seed yield and number of pod producing branches
per plant of pigeon pea. This is an area which
should be investigated further since it suggests
that yield of pigeon pea was also influenced by
the number of sites available for pod formation
and would hence be useful in both breeding and
management of this crop.

There was a decrease in number of pods per plant
with decreasing frequency of watering in all genotypes
in experiment I. Genotypes V_3, V_5 and V_6 were,
however, affected more rapidly and to a relatively
larger extent than V_1, V_2 and V_4 so that the
interaction between watering regimes and genotypes
was significant (P=0.01). In experiment II, the
number of pods per plant decreased consistently with
decreasing frequency of watering in genotypes V_3, V_5
V_6 only. Genotypes V_1, V_2 and V_4 exhibited
an initial rise in number of pods per plant with
decreasing frequency of watering between W_1 and W_2
followed by a decrease between W_2 and W_4. Hence the
interaction between watering regimes and genotypes

was significant (P=0.01). It was observed in this
study that shedding of flower buds, flowers and young
pods was heavier in less frequently watered plants.
These factors led stressed plants to bear fewer
mature pods. Ogombe (1978) also found that competitive
stresses associated with high plant density reduced
number of pods per plant by reducing the number of
flower buds initiated and of open flowers while at
the same time increasing flower and pod abscissions.

The effects of watering regimes and those of genotypes
on the number of grains per pod were significant
(P=0.01) in experiment I. There was a decrease in
number of grains per pod with decreasing frequency
of watering (Table 11) Genotype V_2 had the highest
number of grains per pod while V_5 had the lowest.
In experiment II, the effects of interaction between
genotypes and watering regimes were significant
(P=0.01) since the number of grains per pod among
the various genotypes showed no general trend of
response to watering regimes. (Table 23). 100 seed
weight in the various genotypes tended to remain
unchanged : as the watering intervals widened. In
this study therefore, grain yield was influenced mainly
by number of pods per plant and to a lesser extent
by number of grains per pod in each genotype. This
confirms other reports that the number of pods per
plant is the most sensitive yield components in
pigeon peas (Munoz and Abrams, 1971;
        Beohar and Nigram, 1972; Akinola and Whiteman,
1975a; Ogombe, 1978).

Wien et al. (1979) reported that drought stress
reduced the number of pods per plant in cowpeas but
the stressed plants produced larger grains so that
there was no reduction in yield and that the number
of grains per pod was never affected. On the other
hand, El Nadi (1975) reported that number of seeds
per pod and their average weights decreased with
longer irrigation intervals in haricot bean (Phaseolus

vulgaris L.).   The discrepancy in these two
findings may be due to differences between crops
in response to water stress, differences in the
stages of development during which the stress is
imposed and differences in the intensity of stress
superimposed.

Wien et al. (1979) found that when water was withheld
from cowpea and soyabeans for two weeks, there
was no progressive decrease in leaf water potential
unlike in soyabeans in which leaf water potential
decreased from -11 to -22 bars by the end of the
stress period.   This shows differences in species
responses to low soil moisture content and it is
this kind of difference that may be reflected -----
in grain yield and yield components.   The influence
of stage of development during which stress occurs
has been reported by a number of workers, for
example, Sionit and Kramer (1977) found that stress
before or at flowering in soyabeans reduced pod
numbers while stress during pod filling reduced
seed size and Salter (1963a) reported that applying
water at the start of flowering increased yield by
30 per cent in Pisum sativum L. by increasing the
number of pods per plant and number of peas per
pod although the weight of individual seeds was
somewhat reduced.   On the other hand, when water was
applied during pod filling the weight per pea was
increased.   It thus appears that low soil water
deficit during flowering facilitates setting of pods
and seeds and watering during pod filling leads to
production of larger seeds.

While it is apparent that application of water
at certain stages of development influences one
yield component or other, the plants in this study
were subjected to cycles of water stress throughtout
their growing period so that each phase of develop-
ment experienced some period of water stress.   It is

thus not suprising that both number of pods per plant
and number of grains per pod were affected. It is,
however, difficult to explain the fact that the
weight per grain did not respond to water stress as
would be expected since the plants also experienced
drought during pod filling. A possible explanation
would be that, since grain filling occurred late
in plant development when most of the other sinks
were no longer active, the photosynthates available
at that time were mainly channelled to the grains.

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CHAPTER   7

A P P E N D I C E S

A.1. Analysis of variance for various
characters (Expt.I).

CHARACTERS	VARIANCE DUE TO:				
	TREATMENT df = 23	WATERING df = 3	GENOTYPES df = 5	INTER RACTION df = 15	ERROR df = 92
Days to flowering	1104.00**	2267.50**	3015.70**	234.1**	52.1
Final height per plant	1316.77**	3653.55**	3258.94**	202.02**	73.83
Number of nodes per plant	144.60**	154.15**	483.90**	29.58**	11.27
Number of branches per plant	13.34**	29.54**	27.02**	5.54 N.S.	2.68
Dry weight of whole plant	1197.13**	8039.49**	194.52**	162.86**	38.24
Shoot dry weight per plant	1057.58**	7121.80**	144.65**	149.05**	29.32
Root dry weight per plant	8.52 N.S.	31.86**	12.67	2.48 N.S.	4.70
Shoot:Root ratio per plant	67.36**	366.99**	52.02**	12.55 N.S.	5.76
Grain yield in grams per plant	252.00**	1796.63**	3.96 N.S.	25.85**	6.34
Number of pods per plant	3596.09**	24211.55**	209.46 N.S.	601.87**	114.47
Number of grains per pod	4.94**	32.27**	1.54**	0.61**	0.25

    **   = Significant at 1% level

  N.S. = Not significant at 1% level

A.2. Analysis of Variance for Various Characters (Expt. II).

CHARACTERS	VARIANCE DUE TO:				
	TREATMENT df = 23	WATERING df = 3	GENOTYPES df = 5	INTER-ACTION df = 15	ERROR df = 92
Days of flowering	357.15**	23.83 N.S.	1392.91**	78.55 N.S.	61.36
Height per plant at harvest	292.40**	82.90 N.S.	1165.40**	43.29 N.S.	93.16
Number of nodes per plant	84.34**	18.81 N.S.	327.52**	16.39 N.S.	14.06
Number of branches per plant	3.47**	4.15 N.S.	9.31**	1.38 N.S.	1.15
Dry weight of whole plant	165.42**	1053.33**	36.74 N.S.	30.73 N.S.	22.68
Shoot dry weight per plant	156.27**	1007.70**	27.96 N.S.	28.76 N.S.	
Root dry weight per plant	0.41 N.S.	0.56 N.S.	0.83 N.S.	0.23 N.S.	0.45
Shoot:root ratio per plant	50.05**	271.39**	21.64 N.S.	15.26 N.S.	9,17
Grain yield in grams per plant	39.22**	249.64**	3.44 N.S.	9.06 N.S.	5.44
Number of pods per plant	543.39**	2749.78**	232.62**	205.71**	46.62
Number of grains per pod	1.61**	5.91**	0.55 N.S.	1.10**	0.42

** = Significant at 1% level

N.S. = not significant at 1% level