VARIETAL REACTION TO NUTRIENT AND MOISTURE STRESS IN CASHEW

(*Anacardium occidentale* L.)

By

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THESIS

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Kerala, India

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DECLARATION

I hereby declare that the thesis entitled '**Varietal Reaction to Nutrient and Moisture Stress in Cashew (*Anacardium occidentale* L.)**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other University or Society.

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Introduction

INTRODUCTION

Cashew, one of the most important commercial crops of our country, is being grown in an area of 6.59 lakh hectares with a production of 4.3 lakh tonnes and productivity of 835 kg nuts per hectare (Balasubramanian, 1998). The present level of raw nut production in the country is far below the requirements of the processing industry. There are 825 processing units in the country demanding 8 lakh tonnes of raw nuts annually. The industrial demand for raw nuts by 2000 AD is estimated to be around 10 lakh tonnes.

At present, about 2.25 lakh tonnes of raw nuts are being imported annually costing a drain of foreign exchange to the tune of Rs.744 crores (Balasubramanian, 1998). In the consumer front, the annual demand for kernels increases at the rate of 13 per cent. Measures are therefore necessary to augment the internal production of raw nuts.

In India, cashew is grown almost entirely as a rainfed crop. About 70 per cent of the total cultivated area in the country is semi arid or arid receiving very low rainfall ranging from 500-800 mm (Katyal *et al.*, 1997). A large proportion of these drought prone areas are currently occupied with less remunerative species like acacia, casuarina, prosopis etc. Cashew can be a more remunerative crop in such areas provided suitable drought tolerant varieties are evolved. But no effort has been made so far to identify drought tolerant varieties of cashew which can be utilised for better exploitation of the drought prone environment. Such an effort can not only enhance the raw nut production but also sustain the cashew industry by providing regular employment to around 3 lakh workers of the processing sector. The foreign exchange earnings of the country can also be increased in addition to improving the socio - economic conditions of the farmers of drought prone area.

Irrigation during summer months is a production strategy capable of enhancing the productivity of cashew. Preliminary studies conducted in India and abroad indicate that irrigation can double nut yield in cashew. No attempt has been made so far to develop an irrigation schedule for cashew, for the state of Kerala.

Cashew is generally grown in marginal lands of extremely low fertility. Fertiliser application is seldom practiced in this crop. Varieties with ability to effectively utilise the native soil fertility would fit well in such environments. But no effort has been made so far to identify such varieties. Identification of efficient nutrient absorbing varieties will not only reduce the cost of cultivation but also enable fertiliser free agriculture.

It is in this context, the present project is designed with a specific objective of identifying drought tolerant cashew varieties and to study the physical, physiological and biochemical basis of drought tolerance in this crop. It is also intended to identify the optimum dose of N and irrigation schedule for cashew. The project also envisages to identify cashew varieties suitable for nutrient deficient soils (N, P and K deficient soils).

Review of Literature

REVIEW OF LITERATURE

Studies on drought tolerance of cashew varieties are not traceable in literature. Therefore available literature on drought tolerance in other crops is reviewed. Information available on the influence of major nutrients on the growth and productivity of cashew are also briefly reviewed below.

A. Drought Tolerance

Both physiologists and breeders have attempted to identify indirect selection criteria for drought tolerance in plants (Turner and Kramer, 1980). Morphological traits (Evans and Sorger, 1972), content of metabolic proline (Singh, 1973), and ABA (Quarrie, 1980), osmoregulation (Jones, 1979) and stomatal regulation (Jones, 1985) were used by various researchers to study the drought tolerance in different crops (acacia, *Eucalyptus*, cotton, wheat etc.). Sullivan (1971) suggested certain criteria to evaluate drought tolerance in plants. According to him, high leaf water potential, stomatal resistance to water loss and tolerance to heat are important characteristics to judge the drought tolerance of crops. A rapid method of screening for drought tolerance by measuring the leaf water potential was used in cacao accessions by Balasimha and Daniel (1988). Heat tolerance tests were used by Sullivan and Ross (1979) to select drought tolerant forest tree species.

a) Effect of water stress on growth

The general effect of water stress is to reduce the growth (Kramer, 1983). Significant difference in various growth parameters was noticed in cotton cultivars when subjected to increased levels of moisture stress (Singh *et al.*, 1996).

Height

One year old *Eucalyptus* hybrid showed a plant height of 19.2 cm when grown in a soil moisture regime of 22.5 per cent and the plant height was only 18.8 cm in a stressed soil containing 7.5 per cent of soil moisture (Rawat *et al.*, 1985). Restricted water supply decreased plant height by 20 per cent in *Eucalyptus maculata* and *E. brockwayi* seedlings (Myers and Landsberg, 1989). Irrigated seedlings of *Acacia mangium* had a height of 55.7 cm whereas the moisture stressed plant was only 40.2 cm tall (Awang and Chavex, 1993). *Eucalyptus* and *Casuarina* seedlings when subjected to a moisture stress for a period of 15 days, had a height of 100 cm but when these seedlings were allowed to grow under regular watering, they had a height of 140 cm (Nautyal *et al.*, 1994). The height of water stressed grapes was only 78-84 per cent of that of the regularly watered plants (Chartzoulakis *et al.*, 1993). Irrigated seedlings of *Acacia mangium* (1 year old) were 138.5 cm tall whereas moisture stressed seedlings were only 81.5 cm tall (Rajesh, 1996). Similar decrease in plant height due to moisture stress was noticed in seedlings of *Swietenia macrophylla* by Rajesh (1996).

Girth

The moisture stressed seedlings of *Eucalyptus* hybrid had a girth of 6 mm whereas the regularly watered ones had 12 mm girth (Nautiyal *et al.*, 1994). Similar effect of moisture stress on girth was noticed in *Casuarina equisetifolia* by Nautiyal *et al.* (1994). Rajesh (1996) studied the effect of moisture stress on seedlings of five forest tree species (*Tectona grandis, Acacia mangium, Ailanthus triphysa* and *Swietenia macrophylla*). He observed that the negative effect of moisture stress was less in *Acacia mangium* and more in *Tectona grandis.*

Leaves and leaf area

Irrigated seedlings of *Eucalyptus* had 273 leaves while moisture stressed ones had only 184 leaves. The leaf number of *Eucalyptus maculata seedlings* (one year old) grown under restricted water supply was five times lower compared to irrigated plants. The leaf size was also lower by 20 per cent due to restricted water supply (Myers and Landsberg, 1989). Regularly watered seedlings of *Eucalyptus* (one year old) had 200 leaves whereas moisture stressed seedlings had only 80 leaves. Similar effect of moisture stress on leaf number was noticed with seedlings of *Casuarina equisetifolia* by Nautiyal *et al.* (1994). Leaf area was reduced considerably due to water stress in *Eucalyptus* (Fisher and Hagan, 1965).

Biomass production

Regularly watered seedlings of *Acacia auriculiformis* (6 months old) had a biomass increment of 17.5 g whereas moderately and severely water stressed plants of the same age had biomass increment of 13.9 and 9.2 g respectively (Philips and Riha, 1993). Coconut trees under regular watering had a biomass 150 kg $palm^{-1}$, but when grown under moisture stress, it was only 100 kg $palm^{-1}$ (Rajagopal and Balasimha, 1994). The biomass production of *Eucalyptus* under moisture stress was five times lower compared to regularly watered plants and the corresponding reduction in *Casuarina* was 2.7 times (Nautiyal *et al.*, 1994).

Shoot dry matter production (SDMP)

The SDMP of regularly watered seedlings of *Eucalyptus* hybrid was 55.87 g pl^{-1} while in water stressed plants it was 17.25 g pl^{-1} (Rawat *et al.*, 1985). The SDMP of *Acacia mangium seedlings* (six month old) was 8.83 g pl^{-1} under regular watering, whereas the water stressed ones had a SDMP of 7.48 g pl^{-1} (Awang and Chavex, 1993) The SDMP of *Eucalyptus* hybrid seedlings grown under moisture stress was six times lower compared to irrigated ones, whereas the corresponding reduction in *Casuarina* was five times (Nautiyal *et al.*, 1994).

Root dry matter production (RDMP)

Acacia mangium seedlings (six month old) had a RDMP of 2.5 g pl^{-1} under regular watering whereas it was 1.65 g pl^{-1} in moisture stressed ones (Awang and Chavex, 1993). The RDMP of irrigated *Eucalyptus* seedlings was 20 g pl^{-1} whereas it was only 5 g pl^{-1} in water stressed plants. Similar effect of water stress on RDMP was also noticed with seedlings of *Casuarina* (Nautiyal *et al.*, 1994). Regularly watered seedlings of *Swietenia macrophylla* had a RDMP of 29.8 g pl^{-1} whereas it was only 7.0 g pl^{-1} in water stressed ones. The corresponding values in *Pterocarpus marsupium* was 36.7 and 9.3 g pl^{-1} respectively (Rajesh, 1996).

Root:shoot ratio

Robert and Cannon (1992) could not observe any difference in root:shoot ratio in *Picea glauca* seedlings due to change in soil moisture regimes. The root:shoot ratio did not change due to water stress in *Ailanthus triphysa, Acacia mangium* and *Swietenia macrophylla.* Irrigated seedlings of *Pterocarpus marsupium* had R:S ratio of 0.87, whereas under water stress it was 2.1 (Rajesh, 1996).

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Total dry matter production (TDMP)

The TDMP of *Eucalyptus* hybrid seedlings (six month old) under regular watering was 124.08 g pl^{-1} while it was 44.26 g pl^{-1} in water stressed ones (Rawat *et al.*, 1985). The TDMP of *Eucalyptus brockwayi* seedlings grown under restricted water supply was 3.5 times low compared to irrigated ones (Myers and Landsberg, 1989). The regularly watered *Acacia mangium* seedlings had a TDMP of 11.32 g pl^{-1} whereas it was 8.36 g pl^{-1} in moisture stressed ones (Awang and Chavex, 1993). The *Eucalyptus* seedlings under regular watering had a TDMP of 80 g pl^{-1} while, under water stress it was 20 g pl^{-1}. Similar effect of water stress on TDMP was also noticed with seedlings of *Casuarina* by Nautiyal *et al.* (1994).

b) Effect of water stress on physiological characters

Net photosynthesis (P_n)

The rate of net photosynthesis declined logarithmically with decrease in leaf water potential in *Ulnus americana* seedlings (Walters and Reich, 1989). The photosynthesis was significantly reduced in poplar clones during drought (Duckmann *et al.*, 1992). In rainfed cashew net photosynthesis was 5 µmol CO_2 $m^{-2}s^{-1}$ at 0900 hours (Kallarackal and Somen, 1992). Among the four plantation crops (arecanut, cocoa, cashew and coconut) cashew had the highest net photosynthesis (8.21 µmol CO_2 $m^{-2}s^{-1}$) and cocoa had the lowest (2.23 µmol CO_2 $m^{-2}s^{-1}$) (Rajagopal and Balasimha, 1994). Palanisamy *et al.* (1994) studied the P_n of thirteen hybrid cashew varieties [M-10/4, M-44/3 (Tamil Nadu), BLA-139-1, H-3-17, BLA-39-4, H-3-13 (Kerala), H-2/11, H-2/12, T.No.1, T.No.56, EPM-9/8 (Andhra Pradesh) Ullal-1 and purple (Karnataka) (twelve year old clonal trees) at NRCC, Puttur. The variety BLA-39-4 had the highest P_n (10.88 µmol CO_2 $m^{-2}s^{-1}$) under rainfed condition. The P_n of seven varieties (H-2/11, T.No.56, EPM 9/8, H-3-17, M-10/4, M-44/3 and Ullal-1) ranged between 9 and 10 μmol CO_2 $m^{-2}s^{-1}$. The P_n was lowest with the purple variety (6.2 μmol CO_2 $m^{-2}s^{-1}$). The P_n of regularly watered seedlings of *Pterocarpus marsupium* and *Ailanthus triphysa* were 8.4 and 3.4 μmol CO_2 $m^{-2}s^{-1}$ respectively. But under water stress the values of P_n were 1.5 and 1.2 μmol CO_2 $m^{-2}s^{-1}$ respectively (Rajesh, 1996). The seedlings of *Acacia auriculiformis* had a P_n of 11 μmol CO_2 $m^{-2}s^{-1}$ under regular watering while it was less than 3 μmol CO_2 $m^{-2}s^{-1}$ under water stress (Somen, 1998).

Transpiration

The transpiration rate of irrigated seedlings of *Eucalyptus* was 295.25 mg $cm^{-2}s^{-1}$ whereas it was 229.52 mg $cm^{-2}s^{-1}$ in water stressed plants (Rawat *et al.*, 1985). The drought tolerant accessions of cocoa (NC 23, NC 29 and NC 39) showed 54 to 59 per cent decrease in transpiration under stress compared to plants under irrigation (Balasimha *et al.*, 1987). The transpiration rate of *Acacia* species was low in drier soils (Lang *et al.*, 1987). The transpiration rate of water stressed *Eucalyptus maculata* seedlings was five times lower compared to irrigated ones. The effect of water stress on transpiration compared to irrigated ones was ten times lower in *E. brockwayi* seedlings (Myers and Landsberg, 1989). In rainfed cashew the transpiration rate was 4 mmol $m^{-2}s^{-1}$ at 0900 hours (Kallarackal and Somen, 1992). Water stress reduced the transpiration rate from 3.45 to 1.89 mmol $m^{-2}s^{-1}$ in tolerant hybrids (LO x COD) whereas in susceptible ones (COD x NICT) it decreased from 4.58 to 3.30 mmol $cm^{-2}s^{-1}$ (Rajagopal and Balasimha, 1994).

The transpiration rate of thirteen cashew varieties (12 year old clonal trees) ranged from 8.37 (H-2/12) to 9.4 (BLA-39-4) mmol $m^{-2}s^{-1}$ under rainfed conditions in Karnataka (Palanisamy *et al.*, 1994). Increase in soil moisture stress decreased the transpiration rate of *Pterocarpus marsupium* from 7.14 to

0.24 mmol $m^{-2}s^{-1}$. In *Acacia mangium* the reduction in transpiration rate due to moisture stress was from 2.47 to 0.15 mmol $m^{-2}s^{-1}$ in the laterite soils of Vellanikkara (Rajesh, 1996). In *Acacia auriculiformis* water stress decreased the transpiration rate by 14 mmol $m^{-2}s^{-1}$ (Somen, 1998).

Stomatal conductance

The increment in stomatal resistance in drought tolerant cocoa accessions (NC 23, NC 29) due to water stress was 56.6 per cent and in susceptible accessions it was thirty one percent (Balasimha *et al.,* 1987). The stomatal conductance of irrigated seedlings of *Fraxinus pennsylvanica* was 220 mmol $m^{-2}s^{-1}$ and in water stressed ones it was 80 mmol $m^{-2}s^{-1}$ (Abrams and Kubiske, 1990). The stomatal conductance decreased from 120 to 90 mmol $m^{-2}s^{-1}$ due to water stress in Eucaluptus seedlings (Smit and Driessche, 1992).

Among thirteen varieties of cashew (twelve year old clonal trees) tested at NRCC, Puttur, the variety BLA-39-4 maintained the highest stomatal conductance (460 mmol $m^{-2}s^{-1}$) and Tree No.1 maintained the lowest (310 mmol $m^{-2}s^{-1}$). Six varieties (H-2/11, EPM 9/8, H-3-17, H-3-13, M-10/4 and purple variety) maintained stomatal conductance above 400 mmol $m^{-2}s^{-1}$ (Palanisami *et al.*, 1994). Compared to coconut, arecanut and cocoa, cashew had the highest stomatal conductance (0.8 s cm^{-1}) (Rajagopal and Balasinha, 1994). The drought tolerant genotypes of coconut (LO x COD) had relatively high stomatal resistance (11.62 s cm^{-1}) compared to susceptible ones (7.00 s cm^{-1}) (Rajagopal and Balasimha, 1994).

Leaf temperature

When the plants are well supplied with water, the leaves will be relatively cool (Epstein, 1978). Leaf temperature of thirteen cahew varieties ranged from 33.2°C (BLA-39-4) to 35.7°C (T.No.56) (Palanisami *et al.*, 1994). Soil moisture stress did not decrease the leaf temperature in *Ailanthus triphysa* and *Acacia mangium* (Rajesh, 1996). But, water stress increased the leaf temperature from 38.08°C to 39.32°C in *Swietenia macrophylla* (Rajesh, 1996).

Leaf water potential (*Ψw*)

Under moisture stress condition,the drought tolerant accessions of cocoa showed a leaf water potential of -0.91 MPa whereas in susceptible ones it was -0.93 MPa (Balasimha *et al.*, 1987). In regularly watered plants, the leaf water potential decreased from -0.3 to -1.5 MPa due to a forty per cent decrease in moisture supply in *Eucalyptus maculata.* But in *E. brockwayi* the corresponding decrease was from -0.4 to -0.8 MPa (Myers and Landsberg, 1989). Rainfed cashew maintained relatively high leaf water potential even during the dry period (Kallarackal and Somen, 1992). While irrigated lytchee tree had a leaf water potential of -0.2 MPa,in unirrigated ones it was only -0.8 MPa (Batten *et al.*, 1994). Predawn *Ψw* ranged from -0.5 to -6.0 MPa in *four forest species (Thymus zygis, Halimium viscosum, Genita hirsuita* and *Juriperus oxyeedrus).* In *Quercus faginea* and *Retama sphacrocarpa* predawn *Ψw* ranged from -0.5 to -1.5 MPa (Lansac *et al.*, 1994).

The *Ψw* of WCT and GB genotypes of coconut was -1.48 MPa and -1.45 MPa respectively during March at Kasargod. The hybrid of these two genotypes had *Ψw* of -1.15 MPa (Rajagopal and Balasimha, 1994).

Chlorophyll content

The chlorophyll 'a', 'b' and total chlorophyll contents of cashew leaves (13 year old trees) were 0.39, 0.48 and 0.76 mg g^{-1} leaf tissue respectively (Latha, 1992). Bhaskar (1993) reported the chlorophyll 'a', 'b' and total chlorophyll contents of cashew leaves (5 year old trees) were 0.496, 0.492 and 0.926 mg g^{-1} leaf tissue respectively. The leaf chlorophyll content of cacao accessions was low under water stress compared to irrigated ones (Balasimha, 1988).

Moisture stress decrased chlorophyll 'a' content by 0.35, 0.11, 0.58 and 0.51 mg g^{-1} leaf tissue in *Ailanthus triphysa, Acacia mangium, Swietenia macrophylla* and *Pterocarpus marsupium* respectively (Rajesh, 1996). Moisture stress decreased the chlorophyll 'b' content by 0.16 mg g^{-1} leaf tissue in *Swietenia macrophylla* (highest reduction) and 0.08 mg g^{-1} leaf tissue in *Ailanthus triphysa* (Rajesh, 1996). Under water stress, in four species of Acacia(*Acacia holocericea, A. auriculiformis, A. mangium and A. aulacophora*) the chlorophyll 'a' content ranged from 0.868 to 1.221 mg g^{-1} leaf tissue, the chlorophyll 'b' content ranged from 0.3662 to 0.6812 mg g^{-1} leaf tissue and the total chlorophyll content ranged from 1.901 to 1.232 mg g^{-1} leaf tissue (Somen, 1998).

Chlorophyll Stability Index (CSI)

CSI was correlated with drought resistance in pines by Kalyoreas (1958) and in rice by Murty and Majumdar (1962). Among the four species of *Acacia*, the CSI was highest (96.6%) in *Acacia auriculiformis* (Sivasubramaniam, 1992). Sinha *et al.* (1996) observed the highest CSI (96.26%) in *A. crassicarpa* and lowest (84.28%) in *A. holocericea* under water stress in four species of *Acacia*. Somen (1998) observed that under water stress condition, the CSI was highest (54.03%) in *A. auriculiformis* and lowest in *A. holocericea, A. mangium* and *A. aulacocarpa* (Somen, 1998).

Relative Injury

According to Silva *et al.* (1974),the leaf membrane stability is disturbed due to moisture stress and the stability is indirectly measured by relative injury. In cotton, chloroplast membrane integrity was lost under water deficit condition. Martinean (1979) suggest that relative injury is useful to screen plants for thermo tolerance. Clarke and McGraig (1982) used membrane stability to evaluate drought tolerance. The drought tolerant clones of cotton wood (Platte and Tippicanoe) had reduced electrolyte leakage than susceptible ones (Ohio Red) under water stress (Gebre and Kuhns, 1991). In coconut, the drought tolerant genotypes showed electrolyte leakage of 20.19 per cent whereas in susceptible ones, it was 27.66 per cent under water stress (Rajagopal and Balasimha, 1994).

Dry weight fraction (DWF)

Helkvis *et al.* (1974) related the dry weight to turgid weight ratio of leaf laminae to drought tolerance. The DWF was high under drought in cotton (Cutler *et al.*, 1978), *Populus deltoides* (Kelliber and Tauer, 1980) and Seratro (Thomas, 1987).

Relative water content (RWC)

RWC is an alternative measure of plant water status (Sinclair and Ludlow, 1985). In cacao accessions the RWC ranged from 80.89 to 85.10 per cent under water stress. The drought tolerant accessions of cocoa had higher RWC (82.35%) compared to susceptible ones (79.43%) (Balasimha *et al.*, 1987). The moisture stressed seedlings of *Eucalyptus marginata* maintained a higher RWC (Stoneman *et al.*, 1994). The RWC in drought tolerant and susceptible genotypes of coconut were 82.35 and 79.43 per cent respectively under water stress (Rajagopal and Balasimha, 1994). The decrease in soil moisture content from 19 to 6 percent, decreased RWC from 88.52 to 61.49 per cent in *Acacia mangium* seedlings and from 59.28 to 35.32 per cent in *Pterocarpus marsupium* (Rajesh, 1996).

c. Effect of Water stress on Biochemical characters

Proline

Proline was first noted to accumulate in wilted plant tissue of perennial rye grass (Kemble and Mac Pherson, 1954). Proline accumulation during water stress is due to its synthesis from glutamase as well as due to the decreased rate of proline oxidation (Kramer, 1983). A greater amount of proline accumulation under water stress was noted in tea (Rajasekhar *et al.*, 1988), *Robinea pseudoacacia* seedlings (Hui-Jain and Bin, 1993) and durian clones (Razi *et al.*, 1994). Among seven forest species,(*Quercus faginea, Juniperus oxycedrus, Retama sphaerocarpa, Genista hirsuta, Lavandula pedunculata, Halimium viscosum* and *Thymus zygis*), the proline accumulation was lowest (0.77 µmol g^{-1}) in *Quercus faginea* and *Juniperus oxycedrus* and highest (35.44 µmol g^{-1}) in *Halimium viscasum* (Lansac *et al.*, 1994). Water stress increased the proline content of cocoa seedlings from 57 to 333 µmol g^{-1} fresh weight (Rajagopal and Balasimha, 1994). The negative effect of water stress on proline content of leaves was high in *Acacia mangium* and low in *Ailanthus triphysa* (Rajesh, 1996). Proline accumulation was highest (172 µmol g^{-1} leaf tissue) in *Acacia auriculiformis* and lowest (82 µmol g^{-1} leaf tissue) in *A. holocericea* under water stress (Somen, 1998).

Nitrate Reductase Activity (NRA)

The NRA decreased in moisture stressed poplar clones (Sinha and Nicholas, 1981). The NRA content of fenugreek was high in winter when temperature was very low (Despernier *et al.*, 1986). In irrigated cocoa plants, NRA was high from February to April and low during rainy season whereas in unirrigated plants the NR activity was low during dry period (Balasimha *et al.*, 1991). NR stability under drought was 0.59 and 0.53 in tolerant and susceptible species of cocoa respectively (Balasimha and Daniel, 1988) . In water stressed coconut, NR activity was 0.41 mmol NO_2 $h^{-1}g^{-1}$ while,in irrigated plants it was 1.1 mmol NO_2 $h^{-1}g^{-1}$ (Rajagopal and Balasimha, 1994). NRA in leaves of four cashew varieties (BLA-139-1, H-1600, H-1610 and H-1598) ranged from 0.133 (H-1598) to 0.210 (BLA-139-1) mmol NO_2 g^{-1} fresh weight h^{-1} (Salam *et al.*, 1993).

B. Response to irrigation

Drip irrigation was found useful for fruits and vegetables and thirty per cent saving of water and fifty per cent yield increase were reported (Sivanappan *et al.*, 1972). The amount of N applied was reduced approximately to one half through drip irrigation in fruit crops (Kenwarthy and Smith, 1977). Fertilizer application through trickle irrigation gave thirty six per cent increase in water use efficiency over conventional fertilizer application in oranges (Kanber et al., 1996). Drip irrigation increased yield from 13 to 55 per cent and water saving from 60 to 84 per cent compared to flood irrigation in vegetables (Sivanappan and Padmakumari, 1978). Drip irrigation was the best water management system in coconut (Raveendran, 1983). The irrigation requirement of coconut under drip method is 30 litres per day per palm (Varadan and Mohanachandran, 1988). The drip irrigated banana gives 12 per cent higher yield compared to basin irrigation (Clevik *et al.*, 1988). Coconut hybrid responded well to drip irrigation and the yield increased by 43 nuts per palm per year compared to basin irrigated trees (Dhanapal *et al.*, 1994). Drip irrigation increased the yield by 50 and 52 per cent in sweet orange and banana respectively compared to no irrigation (Upadhyay, 1995). In oil palm, the irrigation @ 180 litres of water per palm per week gave the highest yield of 149 kg per palm per year compared to no irrigation (119 kg per palm per year) (Vargheese, 1996). Increased productivity due to fertigation has been reported in several fruit crops like sapota, grapes, apple , coconut (Shivashankar and Khan, 1996) and cashew (Kumar *et al.*, 1998).

Ten irrigations at the rate of 200 litres per tree at fifteen days interval during November to March double the yield in cashew in Karnataka (13 year old) (NRCC, 1993). In cashew, application of 30 litres of water per tree at 15 days interval increased the nut yield by 393 per cent compared to unirrigated plants in West Bengal (Ghosh, 1995). In cashew drip irrigation @ 43 mm per week during April to October increased nut yield by 20 per cent in Australia (Schaper *et al.*, 1996). In cashew the highest nut yield (3.82 kg per tree) was obtained from trees provided with 80 per cent recommended dose of fertilizers in the form of water soluble fertilizers through drip irrigation, compared to trees supplied with recommended dose of NPK through soil without drip irrigation (Kumar *et al.*, 1998).

C. Nitrogen nutrition

a. Growth

Increase in levels of N from 200 to 1000 g per tree per year increased the height and girth of cashew (NRCC, 1980). Plant height increased linearly with increase in N application upto 1000 g per tree per year in sandy loam soils of

Bapatla (Nambiar, 1983). Cashew seedlings raised in Hoagland nutrient solution completely devoid of N, were short by 7.2 cm compared to seedlings grown in nutrient solution containing N. At the same time the leaf number decreased by 25 per cent in the absence of N in the nutrient solution (Gopikumar and Aravindakshan, 1988). Increasing N application from 500 to 1000 g per tree per year increased the tree height (Latha, 1992).

b. Leaf nutrient content

Leaf N content of cashew ranged from 1.52 to 1.98 per cent (Calton, 1961). Haag *et al.* (1975) reports that leaf N content ranging from 2.4 to 2.58 per cent indicate sufficiency whereas N content ranging from 0.98 to 1.38 per cent indicate N deficiency in cashew. Application of N @ 1000 g per tree per year resulted increased concentration of N in leaf and shoot (Kumar and Nagabhushanam, 1981). Increase of N level from 0 to 1500 g per tree per year increased leaf N content from 1.02 to 1.15 per cent during August. But N application decreased leaf P content from 0.149 to 0.124 per cent. Leaf K content decreased from 0.660 to 0.575 per cent due to increased levels of N application (Reddy *et al.*, 1982).

Increase in N application from 150 to 300 g per tree per year increased leaf N content from 2.04 to 2.53 per cent in cashew. But, leaf P decreased with increase in N application. Leaf K content decreased from 0.99 to 0.90 per cent when N level increased from 150 to 300 g per tree per year (Kumar, 1985). Variation in leaf N concentration ranging from 1.2 to 3.24 per cent was reported by Gopikumar and Aravindakshan (1989) in cashew seedlings. The leaf N content increased from 2.46 to 3.02 per cent with increase in N level from 250 to 1000 g per tree per year (Latha, 1992). The leaf N content decreased from 2.06 to 1.56 per cent with increase in age of the plant from 6 to 70 months (Richard, 1992).

The leaf N content varied with leaf position. It was highest (2.76%) in younger leaves and lowest (1.24%) in older leaves. The leaf N content varied with physiological phase. It was highest (2.76%) in flowering phase and lowest (1.24%) in pre flushing phase (Mathew, 1990). The leaf N content was highest (3.02%) at flowering and lowest (1.93%) at flushing phase (Latha, 1992). Bhaskar (1993) reported highest leaf N concentration at flushing an early flowering phases and lowest at fruiting and maturity phases.

D. Phosphorus nutrition

a. Growth

Plant height increased linearly with increase in P application upto 400 g P_2O_5 per tree per year in sandy loam soils of Bapatla (Nambiar, 1983). Increase in P application from 50 to 150 g P_2O_5 per tree per year increased plant height by twelve per cent (Kumar, 1985). Cashew seedlings raised in Hoaglands nutrient solution completely devoid of P were shorter by 8.63 cm compared to seedlings grown in nutrient solution containing P. At the same time the leaf number decreased by 27 per cent in the absence of P in the nutrient solution (Gopikumar and Aravindakshan, 1989). Increase in P application increased plant height upto 500 g P_2O_5 per tree per year (Latha, 1992).

b. Leaf nutrient content

According to Haag *et al.* (1975), leaf P content ranging from 0.16 to 0.2 per cent indicate sufficiency whereas P content ranging from 0.11 to 0.14 per cent indicate P deficiency in cashew. Falade (1978) observed highest growth at a leaf P concentration of 0.118 per cent in cashew seedlings. Increase in P application from 50 to 150 g per tree per year increased leaf P content from 0.11 to 0.16 per cent in cashew (Kumar, 1985). The leaf P content of cashew seedlings raised in Hoagland nutrient solution completely devoid of P was 0.11 per cent whereas it was 0.34 per cent in seedlings grown in nutrient solution containing P (Gopikumar and Aravindakshan, 1989). Increase in P application increased leaf P content from 0.072 to 0.16 per cent upto a dose of 500 g P_2O_5 per tree per year (Latha, 1992). The leaf P content increased from 0.045 to 0.136 per cent with increase in age of the plant from 6 to 70 months (Richard, 1992).

The leaf P content varied with leaf position. It was highest (2.76%) in seventh and eightth leaf and lowest (1.24%) in first leaf from the inflorescence (Mathew, 1990).

The leaf P content varied with physiological phase of the plant. It was highest (0.16%) in fruiting phase and lowest (0.072%) in flushing phase (Latha, 1992). Bhaskar (1993) reported the occurance of highest leaf P content at early flowering phase and lowest at fruiting phase.

E. Potassium nutrition

a. Growth

Plant height increased with increase in K application upto a dose of 150 g K_2O per tree per year (Kumar, 1985). Cashew seedlings raised in Hoaglands nutrient solution completely devoid of K were short by 7.03 cm compared to seedlings grown in nutrient solution containing K. At the same time the leaf number decreased by 25 per cent in the absence of K in the nutrient solution (Gopikumar and Aravindakshan, 1988). The plant height increased with increase in K application upto a dose of 1000 g K_2O per tree per year (Latha, 1992).

b. Leaf nutrient content

According to Haag *et al.* (1975), leaf K content ranging from 1.11 to 1.29 per cent indicate sufficiency whereas K content ranging from 0.20 to 0.26 per cent indicate K deficiency in cashew. The leaf K concentration for highest growth was determined as 0.342 per cent in cashew seedlings (Falade, 1978). Increase in K application from 50 to 150 g per tree per year increased leaf K content from 0.85 to 0.98 per cent in cashew (Kumar,1985). The leaf K content of cashew seedlings raised in Hoagland nutrient solution completely devoid of K was 1.06 per cent whereas it was 3.17 per cent in seedlings grown in nutrient solution containing K (Gopikumar and Aravindakshan, 1989). The leaf K content increased from 1.14 to 1.23 per cent when K level was increased from 0 to 1000 g K_2O per tree per year (Latha, 1992). The leaf K content decreased from 0.96 to 0.73 per cent with increase in age of the plant from 6 to 70 months (Richard, 1992).

The leaf K content varied with leaf position. It was highest (0.54%) in seventh and eighth leaf and lowest (2.74%) in first leaf from inflorescence (Mathew, 1990).

The leaf K content varied with physiological phase. It was highest (0.57%) in flowering phase and lowest (0.1.48%) in flushing phase (Latha,1992). Bhaskar (1993) reported the highest leaf K content at early flowering phase and lowest at fruiting phase.

F. Varietal variation on growth, leaf nutrient content and nutrient uptake

The growth parameters of cashew varied with varieties. Among 18 cashew varieties tested at Cashew research Station, Madakkathara, the variety V-3 was the tallest (8.03 cm) and M-44/3 the shortest (5.56 cm). The canopy spread was highest with the variety V-3 (10.35m) and lowest (7.97 cm) with M-44/3. The highest girth was noticed with the variety H-1610 and lowest with M-44/3 (CRS, 1997).

The leaf nutrient content in cashew varied with varieties. Among the six varieties (Vengurla-5, M-26/2, A-1, V-3, H-1600 and H-1598) tested, the leaf N content was highest in M-26/2 (3.26%) and lowest in V-5 (2.68%). The leaf P content and leaf K content were highest in M-26/2 and lowest in V-5 (Bhaskar, 1993).

Bhaskar (1993) quantified the nutrient offtake of cashew variety [4 year old trees yielding 4.08 kg nut and 4.15 kg apple (dry) per tree per year]. It was found that the nutrient offtake differed between varieties. The offtake was highest with the variety M-26/2 (439 g N, 13.9 g P and 184 g K per kg of nut along with its apple, respectively) and lowest in V-5 (82.7 g N, 2.23 g P and 36.1 g K per kg of nut along with its apple, respectively).

Material and Methods

MATERIALS AND METHODS

Experiments were conducted at Cashew Research Station, Kerala Agricultural University, Madakkathara, during 1996-'98 to identify drought tolerant varieties of cashew, to study the response of cashew to applied N at different levels of drip irrigation and to assess the tolerance of cashew varieties to nutrient (N, P and K) deficient soils. The experiments undertaken are:

Exp. I : Varietal variation in drought tolerance.

Exp. II : Response of cashew to applied N at different levels of irrigation (drip)

Exp. III : Tolerance of cashew varieties to N deficient soils

Exp. IV : Tolerance of cashew varieties to P deficient soils

Exp. V : Tolerance of cashew varieties to K deficient soils

Location

All the experiments were conducted at Cashew Research Station, Madakkathara (10° 31' N latitude and 76° 13' E longitude at an altitude of 22.25 m above mean sea level).

Soil

Exp.I was conducted in potting medium involving garden soil, sand and cowdung in the ratio of 1:1:1. The soil moisture characteristics and chemical properties of the potting medium are given in Table 1.

Exp.II was conducted in typical laterite soil belonging to the soil order oxisol. The mechanical composition, moisture characteristics and chemical properties of the soil are given in Table 2.

Table 1. Soil moisture characteristics and chemical properties of soil (Exp. I)

Soil moisture characters	Moisture content	Procedure
Field capacity (0.3 bars)	16.4%	Pressure plate apparatus (Richard, 1947)
Permanent wilting point (15 bars)	8.14%	Pressure plate apparatus (Richard, 1947)
Available water holding capacity	8.3%	

Nutrient content

Particulars	Value	Rating	Procedure
Total N	0.18%	High	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available P	0.07%	High	Bray I extractant - Ascorbic acid reductant method (Soil Survey Staff, 1992)
Available K	0.1%	High	1N neutral ammonium acetate extractant flame photometry (Jackson, 1973)

Table 2. Mechanical composition, soil moisture characteristics and chemical properties of soil (Exp. II)

Mechanical composition		
Coarse sand	27.2%	Robinson's International
Fine sand	23.8%	Pipette Method (Piper, 1968)
Silt	22.6%	
Clay	26.4%	

Soil moisture characters	Moisture content	Procedure
Field capacity (0.3 bars)	18.0%	Pressure plate apparatus (Richard, 1947)
Permanent wilting point (15 bars)	11.2%	Pressure plate apparatus (Richard, 1947)
Available water holding capacity	6.8%	

Chemical properties

Particulars	Value	Rating	Procedure adopted
Organic carbon	1.070%	Medium	Walkley and Black method (Soil Survey Staff, 1992)
Available N	331.5 kg ha^{-1}	Medium	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available P	4.8 kg ha^{-1}	Low	Bray I extractant - Ascorbic acid reductant method (Soil Survey Staff, 1992)
Available K	216 kg ha^{-1}	Medium	1N neutral ammonium acetate extractant flame photometry (Jackson, 1973)
pH	5.6	Moderately acidic	1:2.5 soil suspension using pH meter (Jackson, 1973)
Electrical conductivity	0.10 ds m^{-1}	Safe	Supernatant of 1:2.5 soil suspension using EC bridge (Jackson, 1973)
CEC	4.0 centi-moles kg^{-1}	--	Ammonium acetate method (Jackson, 1973)

Exp.III, IV and V were conducted in river sand. The chemical properties of the river sand used are given in Table 3.

Climate

The weather data recorded during January, 1996 to April, 1998 are given in Appendix-I. The weather data of 1996 and 1997 are graphically presented in Fig.1 and 2 respectively. The abstract of the weather data is given in Table 4.

During 1996, the daily maximum temperature ranged from 28.8 to 36.4°C with a mean of 31.7°C. During 1997, the daily maximum temperature ranged from 28.6 to 35.7°C with a mean of 32.2°C.

During 1996, the minimum temperature ranged from 21.8 to 25.2°C with mean of 23.5°C. During 1997, the minimum temperature ranged from 21.8 to 24.5°C with mean of 23.3°C.

During 1996, the monthly rainfall ranged from zero (during January to March) to 588.7 mm (July). During 1997, the monthly rainfall ranged from zero (during January to March) to 979 mm (July). The total rainfall of 1996 and 1997 were 2241.4 mm and 3042.8 mm respectively. In general the season commencing from December to May experienced moisture scarcity. The period January to May received no rainfall and this is the summer period of the region. The peak rainfall season coincided with June to August.

During 1996, the mean RH ranged from 53 to 90 per cent with a mean of 73.6 per cent. During 1997, the mean RH value ranged from 60 to 90 per cent with a mean of 74.2 per cent. January, February and March were the dry months (RH ranging

Table 3. Chemical properties of river sand (Exp. III, IV and V)

Chemical properties

Particulars	Value	Rating	Procedure adopted
Available N	8.60 kg ha^{-1}	Low	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available P	0.896 kg ha^{-1}	Low	Bray I extractant - Ascorbic acid reductant method (Soil Survey Staff, 1992)
Available K	5.3 kg ha^{-1}	Low	1N neutral ammonium acetate extractant flame photometry (Jackson, 1973)
pH	7.6	Slightly alkaline	pH meter (Jackson, 1973)

from 53 to 62%) and in July, August and September the humidity was more compared to other months (RH ranging from 82 to 90%).

During 1996 the monthly evaporation ranged from 88.9 to 219.2 mm with a mean of 137.8 mm. During 1997 the monthly evaporation ranged from 89.6 to 203 mm with a mean of 148.8 mm. The monthly evaporation was highest (157 to 219 mm) during January to April and lowest (88 to 95 mm) from July to November.

The sunshine hours per day ranged from 2.7 to 9.9 with a mean of 6.6 during 1996. During 1997 the sunshine hours per day ranged from 1.9 to 9.6 with a mean of 6.8. The number of of bright sunshine hours was low during July and August (ranging from 2.7 to 3.7 hours per day) and high during January to March (ranging from 9.4 to 9.9 hours per day). The area enjoys a warm humid tropical climate.

METHODS

Exp. I. Varietal variation in drought tolerance

The main objective of the experiment was to identify drought tolerant cashew varieties suitable for moisture stressed environments. For this purpose twenty one high yielding/promising varieties released by different research centres of the country (Table 5) were screened for drought tolerance. Screening was done at three stages viz., preliminary, secondary and final screening.

A. Preliminary screening

The preliminary screening was conducted during February to September 1996 using six month old seedings raised in polythene bags. The treatments involved 21 varieties with five replications. The experimental design was CRD. The seeds of twenty one varieties were collected during February-March, 1996, from Cashew

Table.4 Abstract of weather during 1996 and 1997

	1996		1997	
	Mean	Range	Mean	Range
Maximum temperature (°C)	31.7	28.8-36.4	32.2	28.6-35.7
Minimum temperature (°C)	23.5	21.8-25.2	23.3	21.8-24.5
Monthly rainfall (mm)	186.7	0-588.7	253,5	0-979
Total annual rainfall (mm)	2241.4		3042.8	
Mean RH (%)	73.6	53-90	74.2	60-90
Monthly evaporation (mm)	137.8	88.9-219.2	148.8	89.6-203
Sunshine hours per day	6.6	2.7-9.9	6.8	1.9-9.6

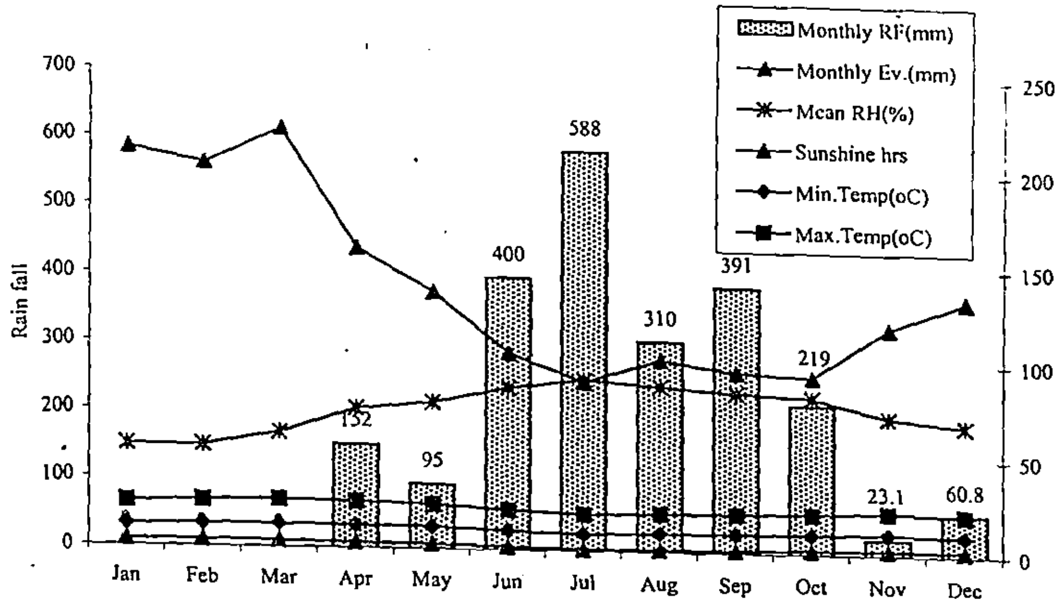

Fig.1 Meteorological data- 1996

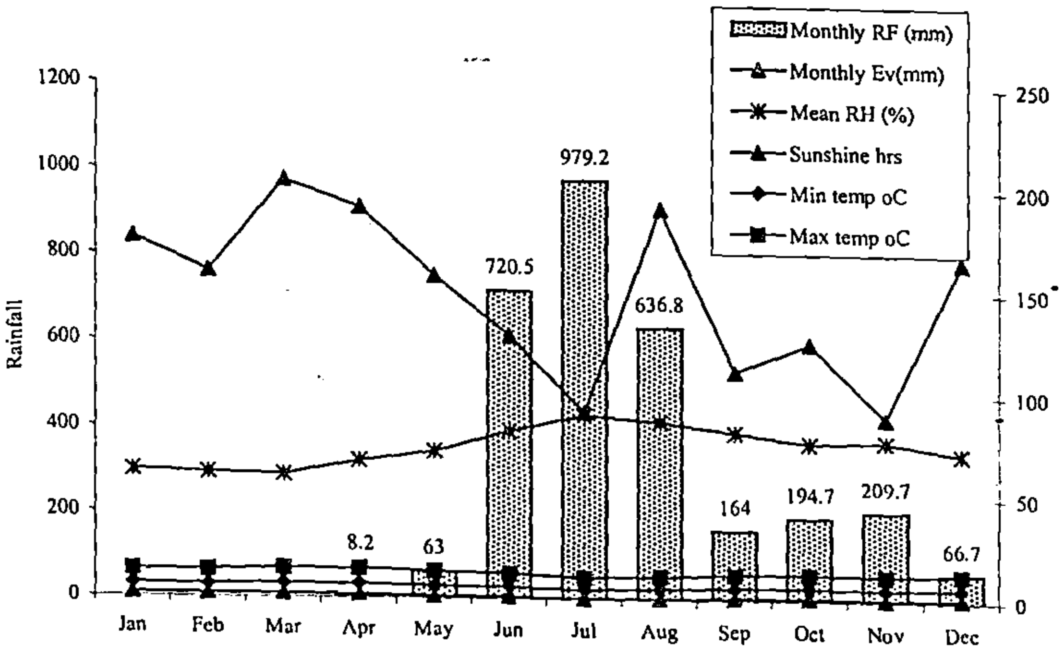

Fig 2 Meteorological data- 1997

Table 5. Details of varieties tested

Sl. No.	Name	Source	Reported yield potential (kg/tree)
1	H-1610	KAU	7.95
2	H-1608 (Dhana)	KAU	10.90
3	H-3-13	KAU	18.60
4	BLA-39-4 (MDK-1)	KAU	13.40
5	H-1598	KAU	12.80
6	H-3-17 (Dharasree)	KAU	18.60
7	NDR-2-1 (MDK-2)	KAU	17.00
8	A-1 (Anakkayam-1)	KAU	12.21
9	H-1591 (Priyanka)	KAU	16.90
10	H-1600	KAU	13.10
11	K-22-1	KAU	13.20
12	H-1596	KAU	15.70
13	M-26/2	TNAU	14.19
14	M-44/3	TNAU	10.50
15	M-33/3	TNAU	8.16
16	T-129	CRS, Bapatla	19.05
17	H-2/16	CRS, Bapatla	6.21
18	T-40	CRS, Bapatla	5.66
19	V5	CRS, Vengurla	12.72
20	VTH 30/4	CPCRI, Vittal	8.98
21	VTH 59/2	CPCRI, Vittal	6.91

KAU - Kerala Agricultural University, CRS - Cashew Research Station
TNAU - Tamil Nadu Agricultural University
CPCRI - Central Plantation Crop Research Institute

Research Station, Madakkathara. Twenty seeds of each variety were sown in polythene bags (25 cm x 30 cm) containing a mixture of garden soil, sand and cowdung (ratio 1:1:1) and kept in a green house with regular watering for six months. Five seedlings showing uniform growth were selected from each variety and subjected to moisture stress by withholding irrigation till all the seedlings dried. Observations such as dry weight fraction (DWF) and relative water content (RWC) were recorded at 3 days interval up to 20th day after withholding water.

Ten leaf discs of one cm diameter were taken from the youngest fully matured leaf (third leaf from the top) using a cork borer and its fresh weight recorded to 0.1 mg accuracy with the help of an analytical balance. The discs were floated in water, in covered petridishes, for 4 hours at room temperature and ambient light. The discs were then gently bloated with tissue paper and the turgid weight recorded. The leaf discs were then oven dried for 6 hours at 85°C and the dry weight recorded. DWF and RWC were calculated as follows

$$\text{DWF} = \frac{\text{Dry weight}}{\text{Turgid weight}}$$

(Helkvis *et al.*,1974)

$$\text{RWC} = \frac{\text{Fresh weight - dry weight}}{\text{Turgid weight - dry weight}} \times 100$$

(Barrs, 1968)

The experiment was repeated as such with same materials and methods during April to October 1996. Observation on percentage of dried leaves at fifteen days after withholding irrigation and the number of days took for complete drying of the plant were recorded. The number of leaves dried and total number of leaves present per plant were counted at fifteen days after withholding irrigation and the percentage of leaves dried was calculated.

Based on the data on DWF, RWC, percentage of dried leaves and number of days took for complete drying, six apparently tolerant varieties and four apparently sensitive varieties were selected for secondary screening.

B) Secondary Screening

The six apparently tolerant and four apparently sensitive varieties identified during preliminary screening were subjected to a secondary screening during June to December 1996 at two soil moisture regimes (regular watering and no watering), following the same methodology adopted in the preliminary screening. There were 20 treatment combinations (ten varieties x two moisture regimes). The experimental design was CRD with three replications.

Observations on physiological characters viz. photosynthetic rate 'P_n' (µmol of CO_2 assimilated m^{-2} leaf area s^{-1}), transpiration rate (mmol of H_2O m^{-2} leaf area s^{-1}), stomatal conductance 'g_s' (mmol of water vapour lost m^{-2} leaf area s^{-1}) and leaf temperature (°C) were recorded at 0900 hours, with a portable infrared gas analyser (IRGA model-LI-6200, Li-Cor, Nebraska, USA) using a one litre leaf chamber (Plate 1). The peak time of photosynthesis and transpiration in cashew was determined as 0900 hours by Kallarackal and Somen (1992) and therefore this time was chosen for recording observation. The measurements were made in the data logger attached to the instrument, using an inbuilt software. The data were transferred to a computer and processed further.

Leaf water potential (ψ_w)

The predawn leaf water potential was measured from the youngest fully matured leaf (3rd leaf from the top) of every plant around 0600 hours during December 1996, using (Plate 2) a Scholander type pressure bomb (Soil Moisture Equipment Corporation, Ohio, USA). The leaf water potential was measured from three plants per treatment, mean worked out and expressed in Mpa.

The leaf drying percentage was also recorded as done during the preliminary screening.

The experiment on secondary screening was repeated as such with the same materials and methods, during July 1996 to January 1997, to confirm the results. In this experiment, the observation on number of days took for complete drying of seedling was recorded.

Based on the data collected from the secondary screening, the number of varieties were further shortlisted from the ten varieties tested. Accordingly four apparently tolerant and two apparently sensitive varieties were selected for further intensive screening.

C) Final screening

Four apparently tolerant and two sensitive varieties selected from the secondary screening were further subjected to a final screening during August 1996 to February 1997 to study their response to six soil moisture regimes (Irrigation at 20% depletion of available water (DAW), 40% DAW, 60% DAW, 80% DAW, 90% DAW and life saving irrigation). There were 36 treatments (combinations of six

Plate 1. Field measurement of net photosynthesis, transpiration rate, stomatal conductance and leaf temperature using portable infrared gas analyser

Plate 2. Field measurement of leaf water potential using Scholander type pressure bomb

varieties x six soil moisture regimes) and the experimental design was CRD with five replications.

Seedlings were raised in polythene bags of size 25 cm x 30 cm (about 7.25 kg of potting mixture per bag) following the same procedure adopted for the Exp. IA. On attaining six months of age, seedlings of uniform size were chosen for imposing the irrigation treatment. At the beginning (before imposing treatments), a soaking irrigation was given uniformly to all the plants and it was assumed that the soil attained field capacity twenty four hours after the soaking irrigation. The quantity of water to be added after every irrigation to maintain the desired soil moisture regime (as per treatment) was calculated using the data on soil weight in each bag and available water holding capacity of the soil. By recording the daily weight loss of each polythene bag, water was added regularly to maintain the intended soil moisture regimes. The plants were retained as such for a month and the following observations were recorded.

a. Growth characters

Observations on plant height, stem girth, internodal length, biomass production, total dry matter production and root:shoot ratio were recorded following standard procedures.

Height of the plant (cm) was measured from ground level to the tip of the topmost leaf using a metre scale. The girth of the plant (cm) was measured at 10 cm above the ground level using a thread and the length of the thread was measured using a metre scale. The distance between the point of attachment of first fully opened leaf from the top and that of just below was measured and recorded as internodal length. After recording the above observations, the plants were uprooted carefully with least damage to the root system. The root portion was washed well and after allowing the free water to go, the fresh weight of the plant was recorded (g). The plants were then separated into shoots and roots and kept in a hot air oven at 70°C for 48 hours and dry weight recorded to constant weight (g). The total dry matter production (TDMP) and root:shoot ratio were determined.

b. Physiological characters

Physiological characters such as photosynthetic rate, transpiration rate, stomatal conductance, leaf temperature and leaf water potential were recorded following the same procedure explained under the Exp. IB.

i) Leaf area per seedling

The leaves of the seedlings were grouped based on size (large, medium and small), 100 leaves from each group were taken and their maximum length (l) and maximum breadth (b) were measured. The area of these leaves was also measured using a leaf area meter. Based on the relation between length and breadth, a correction factor (K) was worked out for each size group and it was correlated with planimetric observations. The K factors identified for leaves of large, medium and small size groups were 0.675,0.685 and 0.925 respectively. Using the relationship l x b x K, the leaf area per seedling was worked out and expressed in cm^2.

ii) Chlorophyll content of leaves

Fresh leaves of six month old seedlings were collected for chlorophyll analysis. The leaves were made into pieces, one gram of the leaf was weighed into a mortar and ground with a pestle. The chlorophyll was extracted using 80 per cent acetone. The extract was filtered (Wattman No.1) and made up to 25 ml using 80 per cent acetone. The absorbance was read in a Spectrophotometer at 663 and 645 nm wave length. The chlorophyll `a', chlorophyll `b' and total chlorophyll contents were calculated using the following formula and expressed in mg g^{-1} of fresh leaf.

Chlorophyll 'a' = 12.7 (OD at 663 nm) - 2.69 (OD at 645 nm) x V/W x 1000

Chlorophyll 'b' = 22.9 (OD at 645 nm) - 4.68 (OD at 663 nm) x V/W x 1000

Total chlorophyll = 20.2 (OD at 645 nm) + 8.02 (OD at 663 nm) x V/W x 1000

(Starner and Hardley, 1967).

OD - optical density

V - final volume of 80 per cent acetone extract

W - fresh weight of leaf (g)

iii) Chlorophyll Stability Index (CSI)

One gram (W) each of two fresh leaf samples were weighed separately and kept in two test tubes, each containing 50 ml of distilled water. One sample was subjected to a temperature of 55 ± 1°C for 30 minutes by keeping in a hot water bath (**treated**) and the other sample was left at room temperature (**control**). The samples were removed after 30 minutes, blotted with a filter paper and ground with 10 ml of aqueous acetone (80%) using a mortar and pestle. The homogenate was centrifuged at 3000 rpm for 10 minutes. The supernatant was made up to 25 ml (V) with 80 per cent acetone and the absorbance at 652 nm (A_{652}) was recorded. The difference in chlorophyll contents (mg g^{-1} of fresh tissue) of the two samples (control and treated) were estimated as shown below.

Chlorophyll content = A_{652}/34.2 x 1000 x V/1000 x W

The chlorophyll stability index was worked out using the following formula (Kaloyereas, 1958).

$$CSI = \frac{\text{(Chlorophyll in Control - Chlorophyll in treated)}}{\text{Chlorophyll in Control}} \times 100$$

iv) DWF, RWC and leaf drying percentage

The DWF and RWC of the leaf and the leaf drying percentage (at one month after imposing treatment) were recorded following the same method explained for the Exp. IA.

v) Relative Injury (RI)

Forty leaf discs (uniform size 1 cm^2) were taken and washed three times with distilled water to wash out the contents of cut cells at the periphery of leaf discs. 20 leaf discs each, were put in two test tubes containing 20 ml of distilled water. One test tube was kept in a water bath at 45°C for 30 ninutes, cooled to room temperature quickly with tap water and kept as such at 6-10°C in a temperature controlled refrigerator for 18 hours (for diffusion of electrolyte into medium). Then it was kept in a water bath at 25°C for one hour and electrical conductivity (EC) of the medium was measured at this temperature (T_1). This test tube was then boiled at 100°C for 20 minutes, cooled to room temperature, volume adjusted to 20 ml and EC of the medium was measured at 25°C (T_2).

The other test tube containing 20 leaf discs was kept at 25°C for 30 minutes (instead of 45°C with the first test tube) and the EC was measured at 25°C (C_1). Following the same steps adopted with the first test tube, EC at 100°C (C_2) of the medium in the second tube was also recorded. RI was calculated as follows (Clarke and McGraig, 1982).

$$\text{Relative Injury (RI)} = 1 - \frac{(1 - T_1/T_2)}{(1 - C_1/C_2)} \times 100$$

T_1 - EC of the medium at 45°C

T_2 - EC of the medium at 100°C

C_1 - EC of the medium at 25°C

C_2 - EC of the medium at 100°C

c) Biochemical characters

Proline

Proline was estimated spectrophotometrically following the ninhydrin method described by Bates *et al.* (1973) using pure proline as the standard. Fresh leaf samples were collected and cut into pieces. 0.5 g of the leaf material was homogenised with 10 ml of three per cent sulfo salicylic acid and centrifuged at 3000 rpm for 10 minutes. Two ml of supernatant liquid was taken and added with two ml of glacial acetic acid, two ml of acid ninhydrin mixture and two ml of 6 N orthophosphoric acid. The contents were allowed to react at 100°C for one hour and the reaction was terminated by keeping it in an ice bath for 10 minutes. The reaction mixture was mixed vigorously with 4 ml of toluene using a mixer, for 10 to 20 seconds. The upper coloured chromophore containing toluene was aspirated from the aqueous phase and warmed at room temperature and the optical density was read at 520 nm in a spectrophotometer. The proline content was determined from the standard curve of pure proline and expressed in mg g^{-1} of fresh leaf.

Nitrate Reductase Activity (NRA)

The fresh leaf samples were made into discs of approximately 0.5 mm diameter and 0.3 g of samples were taken in an injection bottle containing 5 ml of infiltration medium (0.2 M KNO_3 and 1 mM potassium phosphate at pH 7.5). The injection bottle containing the media and leaf were evacuated at 6 mm mercury pressure for 30 seconds, the vaccum released and the process repeated. The bottles were incubated in a BOD for one hour at 33°C, with shaking at 30 minutes interval. After one hour, the bottles were placed in a hot water bath for 5 minutes to arrest the reaction. After cooling, 0.4 ml of the colouring agent (one per cent sulphanilamide in 3 M HCl and 0.2 per cent naphthyl ethylene diamine dihydro chloride in equal volumes) was added to this medium and made up to 6 ml. The absorbance of the supernatant was read at 540 nm in spectrophotometer. Enzyme activity was expressed as mmol NO_2^- produced g^{-1} fresh leaf h^{-1} (Klepper *et al.*, 1971).

d) Anatomical characters

Observations on stomatal index, leaf thickness, cuticle thickness and bark thickness were measured following standard procedures.

(i) Stomatal Index (SI)

The SI was recorded following the method suggested by Johansen (1940). Leaf peeling of the youngest fully matured leaf (third or fourth leaf from the top) were taken from upper and lower surface of six month old seedlings using a sharp blade. The peelings were dipped in 100 per cent acetone for 24 hours and were made chlorophyll free. The peelings were then washed in water and stained with safranine for one minute. The stained samples were washed in water and mounted on a slide with glycerol. Stomatal counts per unit leaf area were taken from 20 spots, from upper and lower surfaces, with the help of Leitz Dialux-20 microscope and the mean worked out.

ii) Leaf thickness (mm)

The leaf thickness of youngest fully matured leaf from the top (third or fourth leaf from the top) of six month old seedling was measured in mm using Vernier-

Calipers. The measurements were taken from 10 samples per treatment and the mean worked out.

iii) Cuticle thickness (μm)

Leaf sections were prepared from the youngest fully matured leaf (third or fourth leaf from the top) and the sections were stained by Sudan-IV prepared by dissolving 0.5 g of the dye in 100 ml of 70 per cent alcohol (Loequin and Langerson, 1978). The sections were kept in the stain for 20 minutes and mounted on a slide with glycerol (Johansen, 1940). The measurements on cuticle thickness (upper and lower surfaces) were made with calibrated eyepiece micrometer, in the region of intense red stained cuticle overlying the epidermal cell wall. Thirty measurements were taken from different spots of every section, both on the upper and lower surfaces and the means worked out. Photomicrographs were also taken with a Leitz Dialux-20 microscope fitted with vario-orthomat camera.

iv) Bark thickness (mm)

Sections from the stem portion adjacent to the youngest fully matured leaf (third or fourth leaf from the top) were taken and the bark thickness measured with the help of a Vernier Calipers and expressed in millimetres. Ten measurements were taken from ten samples and mean worked out.

D) Field monitoring of cashew trees

The three stage screening of varieties using six month old seedling in green house enabled to identify certain tolerant and sensitive varieties to moisture stress. In order to assess the performance of adult trees of these varieties to moisture stress under field condition, their physiological characters were monitored during peak summer months (March, 1998). For this purpose, an existing 10 year old clonal plantation containing these tolerant and sensitive varieties, at Cashew Research Station, Madakkathara was selected. The trees were planted during 1987 with soft wood grafts, at a uniform spacing of 7.5 m x 7.5 m. The plants were raised rainfed and maintained well as per the package of practice of recommendations of Kerala Agricultural University (KAU, 1996). Fertilizer application, weeding, plant protection etc. were done uniformly to all the plants in all the years. Physiological characters such as net photosynthesis, transpiration rate, stomatal conductance, leaf temperature and leaf water potential were recorded using infra red gas analyser and Scholander pressure bomb following the method explained for Exp. IB. The index leaf (fully matured youngest leaf of the current season flush) was used for the above measurements. The weather data of the period (March,1998) are given in Appendix I. The yield data of these varieties are presented in Table 23.

Exp. II. Response of cashew to applied N at different levels of irrigation (drip)

The main objective of the experiment was to study the differential response of cashew trees to applied N at different levels of irrigation through drip. For this purpose, an existing three year old graft raised plantation (variety -H-3-17) was selected. The trees were planted during 1992 with softwood grafts, following a uniform spacing of 7.5 m x 7.5 m. The trees were raised rainfed and maintained well as per the package of practice recommendations of Kerala Agricultural University (KAU, 1996). All the operations such as fertilizer application, weeding, plant protection etc. were done uniformly in all the years.

Twenty seven trees of uniform growth and size (measured in terms of height, girth and canopy spread) were chosen for the study. The experiment involved combinations of three levels of applied N (N_0 - no N application, N_1 - N @ 750 g per tree per year and N_2 - N @ 1500 g per tree per year) and three levels of irrigation (I_0 - no irrigation, I_1 - drip irrigation @ 40 litres of water per tree per day and I_2 - drip irrigation @ 80 litres of water per tree per day).

Nitrogen was applied as urea (46.2% N) in two equal split doses (during May and October). A uniform dose of P and K @ 325 g P_2O_5 per tree per year and 750 g K_2O per tree per year through rock phosphate and muriate of potash was also received by all the trees in both the years. Weeding and plant protection were given uniformly to all plants during the experimental period. The experimental design was RBD with nine treatment combinations and three replications. Single tree formed a replication. The treatments were imposed during 1995-96 and 1996-97. To provide irrigation, five drippers were given at a radius of 50 cm from the trunk in the basin of the tree. The irrigation was given from December 15th of to April 15th in both the years. The following observations were recorded.

a) Growth characters

Observations on growth characters (tree height, tree girth, leaf area index and canopy spread) were recorded during September 1996 (one year after irrigation) and September 1997 (two years after irrigation) following standard procedures.

The tree height was measured from ground level to the point where highest growth was observed and expressed in metre (m). The girth of the tree was measured at a height of 50 cm from the ground level and expressed in cm. The LAI was measured using canopy analyser (model - LAI-2000, Li-Cor, Nebraska, USA). The canopy spread in East-West and North-South directions were recorded and mean worked out. The number of flushes were counted at five randomly selected positions in the canopy using a quadrant of one square metre, during September 1996 and September 1997, and the average worked out.

b) Yield characters and yield

The number of panicles were counted at five randomly selected positions in the canopy using a quadrant of one square metre during January 1996 and January 1997 and the average worked out. Nuts were collected separately from each tree during different harvests, sundried for 3 days and the total nut yield (kg per tree) recorded.

Exp. III. Tolerance of cashew varieties to N deficient soils

This experiment was conducted during March to September, 1997 to identify cashew varieties suitable for N deficient soils. Ten high yielding varieties released by different cashew research centres of the country were subjected to the tolerance test. The details regarding their names, source and yield potential are given below.

Table a. Details of varieties (Exp. III, IV and V)

SlNo.	Name	Source	Yield potential (kg tree^{-1})
1	H-1591 (v_1)	KAU	16.90
2	M-26/2 (v_2)	TNAU	14.19
3	H-1598 (v_3)	KAU	12.80
4	MDK-1 (v_4)	KAU	13.40
5	H-1608 (v_5)	KAU	10.90
6	M-44/3 (v_6)	TNAU	10.50
7	V-5 (v_7)	CRS	12.72
8	MDK-2 (v_8)	KAU	17.00
9	A-1 (v_9)	KAU	12.21
10	K 22-1 (v_{10})	KAU	13.20

CRS-Cashew Research Station, Vengurla
KAU- Kerala Agricultural University
TNAU-Tamil Nadu Agricultural University

For conducting tolerance test, river sand containing extremely low level of N (8.6 kg available N ha^{-1}) was used. In this medium nine soil N regimes were created by applying nine doses of N (n_1 - 0 kg N ha^{-1}, n_2 - 25 kg N ha^{-1}, n_3 - 50 kg N ha^{-1}, n_4 - 75 kg N ha^{-1}, n_5 - 100 kg N ha^{-1}, n_6 - 125 kg N ha^{-1}, n_7 - 150 kg N ha^{-1}, n_8 - 175 kg N ha^{-1}, n_9 - 200 kg N ha^{-1}). The experimental design was CRD with ninety treatment combinations (10 varieties x 9 N regimes) and three replications.

Sufficient seeds were sown in polythene bags of size 25 cm x 30 cm (to hold 5 kg of sand per bag). On attaining two months of age, seedlings showing uniform growth (assessed based on number of leaves, seedling height and seedling girth) were selected for imposing treatments. The N regimes were created by adding urea solution (0.2% N), based on the soil weight in the polythene bag (5 kg) and the treatment (assuming that six inch furrow slice of a hectare weighs 20,00,000 kg). The plants were kept in a green house with regular watering for a period of four months. The following observations were recorded.

a) Growth characters

Observations on growth characters (seedling height, stem girth, leaf number, leaf area per plant, TDMP and root:shoot ratio) were recorded following the procedure explained under Exp. IC.

b) Content and uptake of nutrients (N, P and K)

The nitrogen content of the leaf was determined using kjeldahl digestion and distillation method (Jackson, 1973). For the determination of phosphorus and potassium, a known weight of the sample was digested in a 10:4:1 mixture of nitric, perchloric and sulphuric acid. The phosphorus content of this digest was determined colorimetrically by vanado molybdo phosphoric yellow colour method in nitric acid medium and potassium content was determined using a flame photometer (Jackson, 1973).

To estimate the nutrient uptake, the entire plant parts (root and shoot) were ground well and the nutrient contents (N, P and K) of the sample was determined as indicated above. The nutrient uptake was arrived as a product of nutrient content and total dry matter.

c) Response of varieties to N

The response of cashew varieties to different levels of N was determined by fitting a second order regression equation

d) N use efficiency

N use efficiency was determined using the following formula

$$\text{N use efficiency} = \frac{\text{N uptake in treatment - N uptake in control}}{\text{Quantity of N applied}} \times 100$$

Exp.IV. Tolerance of cashew varieties to P deficient soils.

This experiment was conducted during March to September, 1997 to identify cashew varieties suitable for P deficient soils. Ten high yielding varieties used for Exp.III (Table a) were utilised for the study.

For conducting tolerance test, river sand containing extremely low level of P (0.896 kg available P ha^{-1}) was used. In this medium, nine soil P regimes were created by applying nine doses of P (p_1 - 0 kg P_2O_5 ha^{-1}, p_2 - 10 kg P_2O_5 ha^{-1}, p_3 - 20 kg P_2O_5 ha^{-1}, p_4 - 30 kg P_2O_5 ha^{-1}, p_5 - 40 kg P_2O_5 ha^{-1}, p_6 - 50 kg P_2O_5 ha^{-1}, p_7 - 60 kg P_2O_5 ha^{-1}, p_8 - 70 kg P_2O_5 ha^{-1}, p_9 - 80 kg P_2O_5 ha^{-1}).

The experimental design was CRD with ninety treatment combinations (10 varieties x 9 P regimes) and three replications. Sufficient seeds were sown in polythene bags of size 25 cm x 30 cm (to hold 5 kg of sand per bag). On attaining two months of age, seedlings showing uniform growth (assessed based on number of leaves, seedling height and seedling girth) were selected for imposing treatments. The P regimes were created by adding mono calcium phosphate solution (0.05% P). To calculate the quantity of phosphorus to be applied per bag, the same method adopted in Exp. III was used. The plants were kept in a green house with regular watering for a period of four months. Observations on growth characters (seedling height, seedling girth, leaf number, leaf area per plant, TDMP and root:shoot ratio), content and uptake of nutrients (N, P and K), response of varieties to P and P use efficiency were recorded following the same methods and techniques used for Exp. III.

Exp.V. Tolerance of cashew varieties to K deficient soils.

This experiment was conducted during March to September, 1997 to identify cashew varieties suitable for K deficient soils. Ten high yielding varieties used for Exp. III (Table a) were utilised for the study.

For conducting the tolerance test, river sand containing extremely low level of K (5.3 kg available K ha^{-1}) was used. In this medium, nine soil K regimes were created by applying nine doses of K (k_1 - 0 kg K_2O ha^{-1}, k_2 - 25 kg K_2O ha^{-1}, k_3 - 50 kg K_2O ha^{-1}, k_4 - 75 kg K_2O ha^{-1}, k_5 - 100 kg K_2O ha^{-1}, k_6 - 125 kg K_2O ha^{-1}, k_7 - 150 kg K_2O ha^{-1}, k_8 - 175 kg K_2O ha^{-1}, k_9 - 200 kg K_2O ha^{-1}). The experimental design was CRD with ninety treatment combinations (10 varieties x 9 K regimes) and three replications. Sufficient seeds were sown in polythene bags of size 25 cm x 30 cm (to hold 5 kg of sand per bag). On attaining two months of age, seedlings showing uniform growth (assessed based on number of leaves, seedling height and seedling girth) were selected for imposing treatments. The K regimes were created by adding KCl solution (0.2% K). To calculate the quantity of K to be applied per bag, the same method adopted in Exp. III was used. The plants were kept in a green house with regular watering for a period of four months.

Observations on growth characters (seedling height, seedling girth, leaf number, leaf area per plant, TDMP and root:shoot ratio), content and uptake of nutrients (N, P and K), response of varieties to K and K use efficiency were recorded following the same methods used in Exp. III.

Statistical Analysis

The data collected for different experiments were tabulated and subjected to analysis of variance technique (Panse and Sukhatme, 1985). The data generated under Exp.I, III, IV and V were subjected to principal component analysis to classify the varieties under different tolerance groups.

Principal component analysis

In order to rate the varieties based on their relative tolerance to drought, the technique of principal component analysis was used. For this purpose, simultaneous influence of 10 characters (net photosynthesis, transpiration rate, leaf water potential, stomatal conductance at 5 days after withholding water, total dry matter production, leaf area, relative injury, chlorophyll stability index, proline and nitrate reductase activity at one month after withholding water of six month old seedlings) which can explain the extent of drought tolerance were considered.

Principal component analysis reduced the dimensionality of the problem. The first principal component expressed as a linear function of 10 characters that will explain maximum variation (R^2= 0.9628) and is totally uncorrelated of the second principal component which is also expressed likewise. Principal components were extracted based on the correlation matrix. If the first principal components explains a good amount of variation, that alone need be considered for further analysis. In such a way the dimensionality of the problem was reduced to one from ten. In this way, these 10 characters represented by 10 variables were reduced to one linear combination of variables which may be regarded as a single value.

The component scores (based on the first principal component) were worked out for 54 plants (6 varieties x 3 moisture regimes (20% DAW, 40% DAW and life saving irrigation x 3 replications) and were grouped as a frequency distribution. The **median** of this frequency distribution was worked out and designated as the index (demarcating point). The criterion for judging as to whether a variety is sensitive or tolerant is that if its score based on the first principal component fall below the index, it would be judged as sensitive and otherwise tolerant.

Multiple regression equation was develop to calculate the index (y). For this purpose, the corresponding eigen vector, overall mean and standard deviation of each character were utilised. The relationship can be expressed as follows.

$$y = EV(x_1)\frac{x_1 - mx_1}{S.D.\ of\ x_1} + EV(x_2)\frac{x_2 - mx_2}{S.D.\ of\ x_2} + \ldots\ldots + EV(x_{10})\frac{x_{10} - mx_{10}}{S.D.\ of\ x_{10}}$$

where y - drought tolerance index

x_1 to x_{10} - characters selected

EV - Eigen vector

m - overall mean of the character

SD - standard deviation

As the 10 characters explain the drought tolerating ability of the plant, the index (y) forms a measure of the drought tolerance. The tolerance rating of varieties to N, P and K the deficient soils were also done as explained above.

Results

RESULT

Exp.I. Varietal variation in drought tolerance

A. Preliminary screening

Six month old seedlings of twenty one varieties were subjected to moisture stress by with-holding water. Observations on DWF and RWC (at 3 days interval), percentage of dried leaves at 15 days after with-holding water and number of days took for complete drying were recorded. The results of the study are presented below.

Dry Weight Fraction (DWF)

The DWF differed significantly between varieties and durations of stress (Table 6). Between varieties, the DWF varied from 0.313 (H-1598) to 0.446 (M-44/3). The DWF of M-26/2 and M-44/3 were above 0.4 and H-1598 and T-40 were less than 0.32 (Fig.3). The DWF of the remaining 17 varieties ranged between 0.32 and 0.40.

DWF increased with increase in duration of moisture stress. The DWF was lowest (0.334) at 3 DAWW and it was on par with the DWF at 6 DAWW and highest (0.380) at 13 DAWW.

Relative Water Content (RWC)

The RWC varied considerably between varieties and durations of stress (Table 7). The mean RWC was lowest with the variety K-22-1 (65.88%) and highest with the variety T-129 (89.80%). RWC of six varieties (H-1610, M-26/2, V-5, M-44/3, T-129 and H-1591) were above 85 per cent and four varieties (H-3-13, H-2/16, A-1 and K-22-1) were below 75 per cent (Fig.4).

Table 6. DWF in relation to varieties and duration of stress

Varieties	3 DAWW	6 DAWW	9 DAWW	13 DAWW	Mean
H-1610	0.308	0.320	0.317	0.402	0.337
T-129	0.334	0.353	0.343	0.384	0.354
H-1608	0.349	0.298	0.441	0.506	0.398
M-26/2	0.421	0.360	0.449	0.524	0.438
V-5	0.267	0.296	0.373	0.462	0.350
M-44/3	0.364	0.353	0.566	0.501	0.446
H-3-13	0.327	0.305	0.316	0.370	0.329
BLA-39-4	0.313	0.315	0.351	0.338	0.329
H-2/16	0.309	0.379	0.240	0.354	0.321
H-1598	0.289	0.259	0.298	0.407	0.313
H-3-17	0.378	0.364	0.346	0.395	0.371
NDR-2-1	0.300	0.345	0.330	0.300	0.325
A-1	0.239	0.287	0.408	0.383	0.329
H-1591	0.276	0.319	0.464	0.535	0.399
H-1600	0.360	0.348	0.345	0.400	0.363
M-33/3	0.367	0.343	0.389	0.410	0.377
T-40	0.315	0.349	0.346	0.357	0.314
VTH-30/4	0.376	0.385	0.346	0.357	0.341
VTH-59/2	0.391	0.390	0.404	0.405	0.397
K-22-1	0.325	0.362	0.369	0.370	0.356
H-1596	0.312	0.391	0.364	0.406	0.368
Mean	0.334	0.338	0.365	0.380	
	SEm±	CD (0.05)			
Varieties	0.021	0.060**			
Duration of stress	0.009	0.022**			

DAWW - days after withholding water
** Significant at 1 per cent level

RWC decreased with increase in duration of stress, the highest at 3 DAWW (89.42%) and the lowest at 13 DAWW (72.51%).

Leaf drying percentage

There was considerable variation in the leaf drying percentage recorded at 15 DAWW, between varieties (Fig.5). The leaf drying percentage ranged from 20.2 (H-1591) to 93.4 per cent (H-3-13) between varieties. The leaf drying percentage of five varieties (H-1591, M-44/3, V-5, M-26/2 and H-1608) was less than 55. Over 90 per cent of leaves dried in three varieties (NDR-2-1, K-22-1 and H-3-13) in 15 days of moisture stress. The lowest leaf drying percentage(20.2%) was noticed with H-1591 and highest (93.4%) with H-3-13.

Number of days took for complete drying of seedling

Number of days took for complete drying of seedlings varied considerably between varieties (Fig.6). Three varieties (H-3-13, K-22-1 and NDR-2-1) took less than 20 days for complete drying whereas, four varieties (V-5, M-44/3, M-26/2 and H-1591) took over 35 days to die. The duration of life under moisture stress was longest with the variety H-1591 (42 days) followed by M-26/2 (40 days) and then M-44/3 (39 days). The variety H-3-13 was the first one died in the shortest duration of stress (16 days).

Based on the data on DWF, RWC, leaf drying percentage and number of days took for complete drying, the varieties were short listed. Varieties having the highest DWF, RWC, lowest percentage of dried leaves and longest duration of life under stress were treated as apparently tolerant varieties and those with opposite characteristics were treated as apparently sensitive varieties. As such six apparently tolerant varieties (H-1591, M-44/3, M-26/2, V-5, H-1608 and VTH-30/4) and four

Table 7. RWC (%) in relation to varieties and duration of stress

Varieties	3 DAWW	6 DAWW	9 DAWW	13 DAWW	Mean
H-1610	92.28	89.00	83.00	75.77	85.01
T-129	93-96	91.64	89.09	84.51	89.80
H-1608	92.75	88.90	78.78	74.87	83.82
M-26/2	93.80	90.00	89.52	81.56	88.71
V-5	93.75	88.84	82.85	80.47	86.47
M-44/3	94.34	90.00	88.31	81.81	88.61
H-3-13	85.23	78.32	69.59	65.41	74.63
BLA-39-4	89.39	78.94	75.83	72.75	79.22
H-2/16	86.31	75.00	72.08	65.50	74.72
H-1598	92.10	88.80	80.78	70.09	82.91
H-3-17	90.90	86.92	79.09	75.08	82.99
NDR-2-1	92.00	77.72	68.48	65.21	75.85
A-1	83.33	76.72	68.59	55.22	70.96
H-1591	94.39	86.25	85.36	84.28	87.59
H-1600	90.38	89.01	77.93	65.04	80.59
M-33/3	87.78	82.30	80.00	69.51	79.89
T-40	88.57	82.68	78.68	65.86	78.94
VTH-30/4	88.31	80.26	78.09	73.70	80.09
VTH-59/2	81.42	80.25	76.66	72.42	77.68
K-22-1	77.14	62.64	62.75	58.02	65.88
H-1596	89.27	83.63	82.55	78.50	83.48
Mean	89.42	83.23	78.47	72.51	
	SEm±	CD(0.05)			
Varieties	1.020	2.570**			
Duration of stress	2.120	5.960**			

DAWW - days after withholding water
** Significant at 1 per cent level

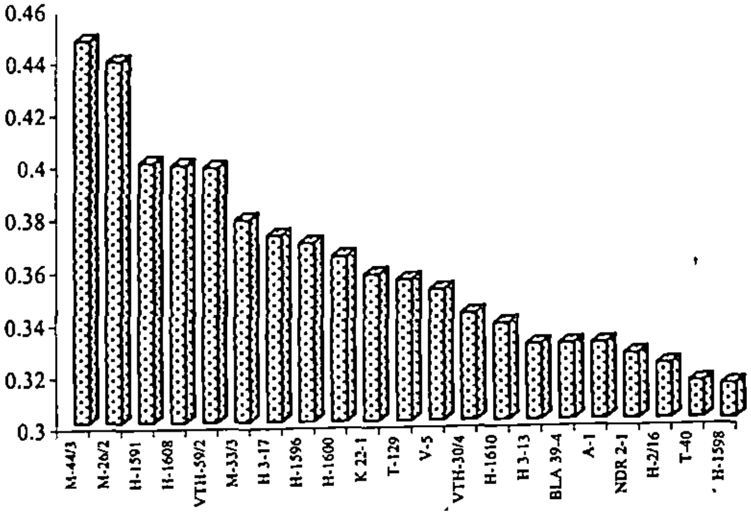

Fig.3 Dry weight fraction of 21 cashew varieties

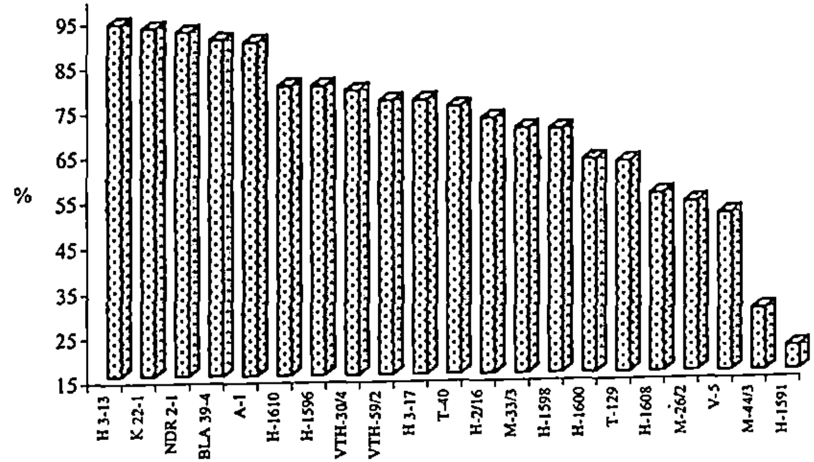

Fig5 Leaf drying percentage of 21 cashew varieties at 15 days after withholding water

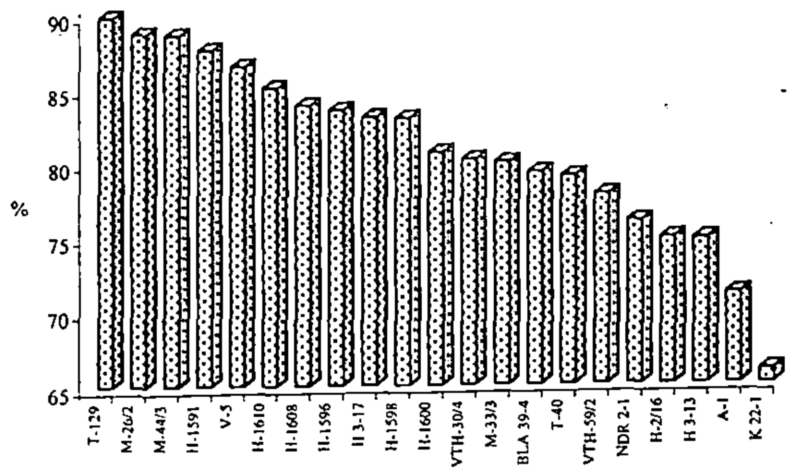

Fig.4 Relative water content of 21 cashew varieties

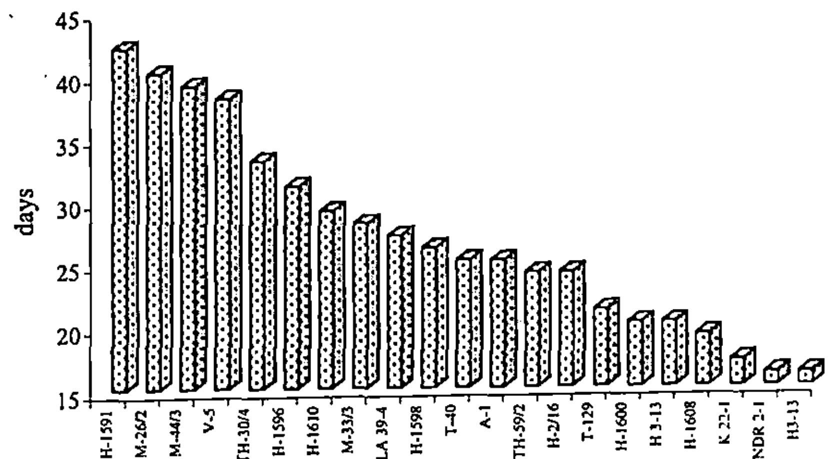

Fig.6 Number of days took for complete drying of seedlings of 21 cashew varieties

apparently sensitive varieties (K-22-1, H-3-13, T-129 and H-1600) were identified for a secondary screening.

B. Secondary screening

Six month old seedlings of six apparently tolerant and four apparently sensitive varieties identified in the preliminary screening were subjected to moisture stress by with-holding water during June to December, 1996. Observations on net photosynthesis, transpiration rate, stomatal conductance, leaf temperature, leaf water potential, leaf drying percentage at 15 days after with-holding water and number of days took for complete drying of the seedlings were recorded. The results obtained are presented below.

Net photosynthesis (P_n)

There was considerable difference in net photosynthesis (P_n) between the ten varieties tested and this was consistently noticed in the water stressed plants at different durations of stress (2, 5 and 10 DAWW) as well as in the regularly watered plants (Table 8). When all the varieties were kept under uniform and regular irrigation, P_n was highest in the variety V-5 (9.551 μmol $m^{-2}s^{-1}$) followed by H-1608 (6.27 μmol $m^{-2}s^{-1}$) and lowest in the variety H-1600 (3.88 μmol $m^{-2}s^{-1}$). At 2 DAWW, P_n was highest (11.02 μmol $m^{-2}s^{-1}$) with the variety H-3-13 and lowest (2.990 μmol $m^{-2}s^{-1}$) with the variety H-1600. The P_n of H-3-13 declined drastically to zero at tenth day after withholding water. The variation in P_n values of varieties in relation to durations of stress were not consistent. Therefore the mean P_n of 2, 5 and 10 DAWW was compared. The mean P_n was highest (4.228 μmol $m^{-2}s^{-1}$) in the variety H-3-13 followed by VTH-30/4 (3.636 μmol $m^{-2}s^{-1}$) and K-22-1 (3.562 μmol $m^{-2}s^{-1}$) and lowest (1.519 μmol $m^{-2}s^{-1}$) in the variety H-1600 (Fig.7).

Between durations of stress, the mean P_n was highest (6.580 μmol $m^{-2}s^{-1}$) at 2 DAWW and lowest at 10 DAWW (0.079 μmol $m^{-2}s^{-1}$) (Fig. 8). The mean P_n at 2 DAWW was higher than that of regularly watered plants (5.330 μmol $m^{-2}s^{-1}$).

Transpiration rate

The transpiration rate differed considerably between varieties (Table 9). Under regular watering, the transpiration rate was highest with the variety V-5 (6.143 mmol $m^{-2}s^{-1}$) followed by H-1600 (5.332 mmol $m^{-2}s^{-1}$) and VTH-30/4 (4.826 mmol $m^{-2}s^{-1}$) and lowest with the variety T-129 (2.643 mmol $m^{-2}s^{-1}$). At 2 DAWW, the transpiration rate was highest with the variety H-3-13 (8.067 mmol $m^{-2}s^{-1}$) followed by VTH-30/4 (5.611 mmol $m^{-2}s^{-1}$) and lowest with the variety M-26/2 (3.374 mmol $m^{-2}s^{-1}$). The variation in transpiration rate of varieties in relation to durations of stress was not consistent. Therefore the mean transpiration rate of 2, 5 and 10 DAWW, was compared. The mean transpiration rate was highest with the variety H-3-13 (5.125 mmol $m^{-2}s^{-1}$) followed by H-1600 (3.5 mmol $m^{-2}s^{-1}$) and VTH-30/4 (3.215 mmol $m^{-2}s^{-1}$) and lowest with the variety M-44/3 (1.893 mmol $m^{-2}s^{-1}$) followed by K-22-1 (1.893 mmol $m^{-2}s^{-1}$). Mean transpiration rate was below 2.5 mmol $m^{-2}s^{-1}$ (Fig. 9) in six varieties (V-5, H-1608, M-44/3, M-26/2, K-22-1 and T-129).

Between durations of stress, mean transpiration rate was highest (4.754 mmol $m^{-2}s^{-1}$) at 2 DAWW, it declined to 2.111 mmol $m^{-2}s^{-1}$ at 5 DAWW and further declined to 0.503 mmol $m^{-2}s^{-1}$ at 10 DAWW (Fig. 10).

Stomatal conductance (g_s)

The stomatal conductance differed considerably between varieties (Table 10). In seedlings under regular watering, the g_s was highest in the variety H-1600 (202 mmol $m^{-2}s^{-1}$) followed by V-5 (199 mmol $m^{-2}s^{-1}$) and VTH-30/4 (158 mmol $m^{-2}s^{-1}$). The

Table 8. Variation in net photosynthesis (μmol m^{-2} s^{-1}) in relation to varieties and duration of moisture stress

Varieties	2 DAWW	5 DAWW	10 DAWW	*Mean	Regular watering
VTH-30/4	7.654	3.222	0.033	3.636	4.841
V-5	6.837	0.071	0.287	2.398	9.551
H-1591	7.019	1.887	0.000	2.968	4.072
H-1608	5.588	1.528	0.065	2.393	6.270
M-44/3	7.841	0.371	0.120	2.773	5.262
M-26/2	4.155	0.000	0.000	2.077	5.020
K-22-1	5.036	0.268	0.078	3.562	5.017
T-129	7.691	1.623	0.211	3.175	4.400
H-3-13	11.02	1.655	0.000	4.228	5.021
H-1600	2.990	1.568	0.000	1.519	3.880
Mean	6.580	1.220	0.079		5.330
	SEm±	CD(0.05)			
Varieties	0.292	0.852**			
Duration	0.160	0.465**			

DAWW - days after withholding water

** Significant at 1 per cent level

* Mean of values at 2, 5 and 10 DAWW

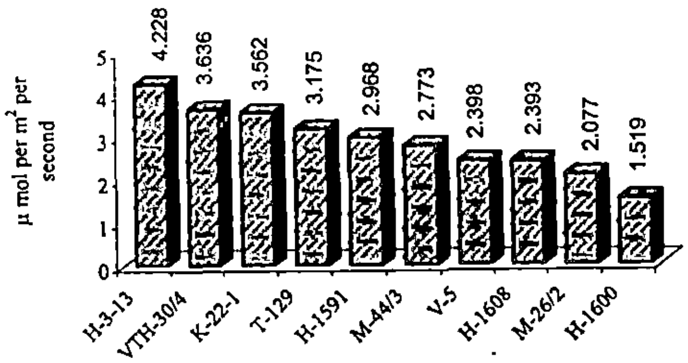

Fig7 Net photosynthesis of ten cashew varieties (six month old seedling)

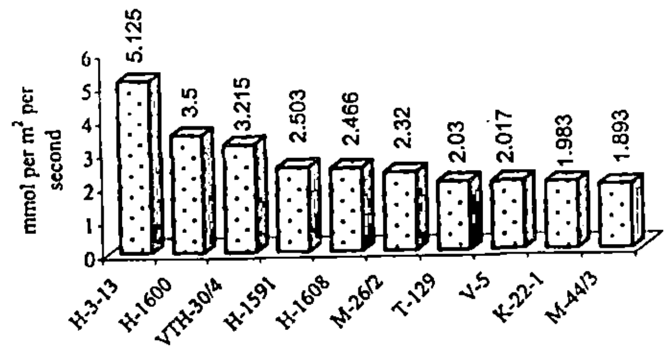

Fig 9 Transpiration rate of ten cashew varieties (six month old seedlings)

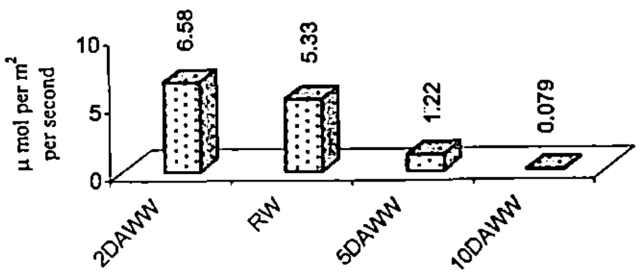

Fig 8 Net photosynthetic rate (6 month old seedling) at four soil moisture regimes

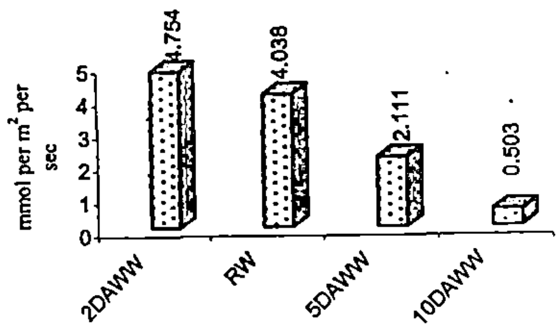

Fig10 Transpiration rate (six month old seedling) at four soil moisture regimes

Table 9. Variation in transpiration rate (mmol $m^{-2}s^{-1}$) in relation to varieties and duration of stress

Varieties	2 DAWW	5 DAWW	10 DAWW	*Mean	Regular watering
VTH-30/4	5.611	3.640	0.394	3.215	4.826
V-5	3.795	1.637	0.620	2.017	6.143
H-1591	4.201	2.636	0.674	2.503	3.320
H-1608	5.122	1.841	0.437	2.466	4.231
M-44/3	4.538	0.889	0.254	1.893	4.115
M-26/2	3.374	1.276	0.000	2.320	3.466
K-22-1	4.483	1.082	0.386	1.983	3.291
T-129	4.171	1.679	0.240	2.030	2.643
H-3-13	8.067	2.184	0.000	5.125	3.018
H-1600	4.176	4.302	2.022	3.500	5.332
Mean	4.754	2.111	0.503		4.038
	SEm±	CD(0.05)			
Varieties	0.222	0.648**			
Duration	0.122	0.355**			

DAWW - days after withholding water

** Significant at 1 per cent level

* Mean of values at 2, 5 and 10 DAWW

lowest g_s was noticed in the variety T-129 (70 mmol $m^{-2}s^{-1}$) followed by H-3-13 (83 mmol $m^{-2}s^{-1}$) and M-26/2 (95 mmol $m^{-2}s^{-1}$). In stressed plants, at 2 DAWW, g_s was highest in the variety H-3-13 (295 mmol $m^{-2}s^{-1}$) followed by VTH-30/4 (277 mmol $m^{-2}s^{-1}$). The lowest g_s was noticed in the variety M-26/2 (109 mmol $m^{-2}s^{-1}$) followed by T-129 (124 mmol $m^{-2}s^{-1}$). More or less the same trend was noticed at 5 and 10 DAWW.

An attempt was also made to compare the mean g_s of 2, 5 and 10 DAWW. It was found that the g_s was highest in the variety H-3-13 (171 mmol $m^{-2}s^{-1}$) followed by H-1600 (166 mmol $m^{-2}s^{-1}$) and VTH-30/4 (136 mmol $m^{-2}s^{-1}$). The lowest g_s was noticed (Fig.11) in the variety T-129 (54 mmol $m^{-2}s^{-1}$) followed by K-22-1 (55 mmol $m^{-2}s^{-1}$).

There was drastic decline in g_s with increase in duration of stress. The g_s was 183 mmol $m^{-2}s^{-1}$ at 2 DAWW, it decreased to 61 mmol $m^{-2}s^{-1}$ at 5 DAWW and further decreased to 18 mmol $m^{-2}s^{-1}$ at 10 DAWW (Fig. 12).

Leaf Temperature

The leaf temperature differed considerably between varieties (Table 11). In regularly watered plants, leaf temperature was highest (35.5°C) in the variety M-26/2 and it was on par with M-44/3 (35.43°C) and lowest in the variety H-1600 (33.39°C). In stressed plants, at 2 DAWW, the leaf temperature was highest in the variety K-22-1 (37.07°C) and it was more or less same with H-3-13 (36.41°C) and lowest in the variety H-1600 (33.14°C). More or less the same trend was noticed at 5 DAWW. At 10 DAWW, the leaf temperature was highest in the variety V-5 (37.33°C) and lowest in the variety T-129 (32.59°C).

An attempt was made to compare the mean leaf temperature of 2, 5 and 10 DAWW (Fig.13). The leaf temperature was highest in the variety H-3-13 (37.27°C) followed by M-26/2 (37.15°C) and lowest in H-1600 (33.42°C) followed by VTH-30/4 (34.54°C).

Table 10. Variation in stomatal conductance (mmol $m^{-2}s^{-1}$) in relation to varieties and duration of stress

Varieties	2 DAWW	5 DAWW	10 DAWW	*Mean	Regular watering
VTH-30/4	277	121	10	136	158
V-5	136	55	15	67	199
H-1591	143	69	16	76	101
H-1608	191	41	29	87	126
M-44/3	168	21	30	73	118
M-26/2	109	23	00	66	95
K-22-1	134	23	9	55	97
T-129	124	32	7	54	70
H-3-13	295	47	0	171	83
H-1600	254	182	63	166	202
Mean	183	61	18		125
	SEm±	CD(0.05)			
Varieties	16.5	48.0**			
Duration	9.0	26.2**			

DAWW - days after withholding water

** Significant at 1 per cent level

* Mean of values at 2, 5 and 10 DAWW

The leaf temperature varied with durations of stress. At 2 DAWW the leaf temperature was 35.41°C, it increased to 36.35°C at 5 DAWW and then decreased to 34.98°C at 10 DAWW (Fig. 14).

Leaf water potential (Ψ_w)

The Ψ_w showed considerable difference between varieties (Table 12). In regularly watered plants, the Ψ_w was highest in the variety V-5 (-1.20 MPa) followed by K-22-1 (-1.33 MPa) and lowest in the variety H-1600 (-1.87 MPa). In stressed plants, at 2 DAWW, the variety H-1591 had the highest Ψ_w (-2.20 MPa) followed by V-5 (-2.27 MPa) and lowest in the variety K-22-1 (-2.94 MPa) followed by VTH-30/4 (-2.93 MPa). Almost the same trend was noticed at 5 and 10 DAWW. An attempt was made to compare the mean Ψ_w of 2, 5 and 10 DAWW (Fig.15). The variety H-1591 had the highest Ψ_w (-2.56 MPa) followed by M-44/3 (-2.65 MPa) and M-26/2 (-2.67 MPa). The mean Ψ_w was lowest in the variety K-22-1 (-3.61 MPa) followed by H-3-13 (-3.37 MPa). Four varieties (V-5, M-26/2, M-44/3 and H-1591) had Ψ_w above -3.2 MPa and six varieties (K-22-1, T-129, H-3-13, H-1600, H-1608 and VTH-30/4) had Ψ_w below -3.2 Mpa.

Ψ_w decreased with increase in duration of stress. Ψ_w was highest at 2 DAWW (-2.62 MPa), it decreased to -3.08 MPa at 5 DAWW and further decreased to -3.42 MPa at 10 DAWW (Fig. 16).

Leaf drying percentage

Leaf drying percentage differed considerably between varieties (Fig.17). The leaf drying percentage of four varieties (H-1591, M-44/3, V-5 and M-26/2) was below 55 and four varieties (T-129, H-3-13, VTH-30/4 and K-22-1) was above 65. The

Table 11. Variation in leaf temperature (°C) in relation to varieties and duration of stress

Varieties	2 DAWW	5 DAWW	10 DAWW	*Mean	Regular watering
VTH-30/4	34.13	33.80	35.70	34.54	34.30
V-5	35.03	34.60	37.33	35.65	34.53
H-1591	35.87	36.07	36.50	36.14	34.50
H-1608	35.63	38.03	35.07	36.24	35.23
M-44/3	34.90	36.30	33.47	34.89	35.43
M-26/2	35.64	38.67	--	37.15	35.50
K-22-1	37.07	38.80	34.23	36.70	34.83
T-129	36.27	36.93	32.59	35.25	35.40
H-3-13	36.41	38.13	--	37.27	35.20
H-1600	33.14	32.13	35.00	33.42	33.39
Mean	35.41	36.35	27.98		34.83
	SEm±	CD(0.05)			
Varieties	0.358	1.043**			
Duration	0.196	0.493**			

DAWW - days after withholding water

** Significant at 1 per cent level

* Mean of values at 2, 5 and 10 DAWW

Table 12. Variation in leaf water potential (MPa) in relation to varieties and durations of stress

Varieties	2 DAWW	5 DAWW	10 DAWW	*Mean	Regular watering
VTH-30/4	-2.93	-3.23	-3.61	- 3.25	-1.80
V-5	-2.27	-2.81	-3.04	- 2.70	-1.20
H-1591	-2.20	-2.60	-2.93	- 2.56	-1.43
H-1608	-2.73	-3.28	-3.69	- 3.23	-1.47
M-44/3	-2.40	-2.61	-2.95	- 2.65	-1.60
M-26/2	-2.47	-2.74	-2.81	- 2.67	-1.50
K-22-1	-2.94	-3.35	-3.85	- 3.61	-1.33
T-129	-2.64	-3.43	-3.67	- 3.24	-1.47
H-3-13	-2.85	-3.35	-3.91	- 3.37	-1.47
H-1600	-2.74	-3.46	-3.81	- 3.33	-1.87
Mean	-2.62	-3.08	-3.42		-1.51
	SEm±	CD(0.05)			
Varieties	0.084	0.254**			
Duration	0.046	0.133**			

DAWW - days after withholding water

** Significant at 1 per cent level

* Mean of values at 2, 5 and 10 DAWW

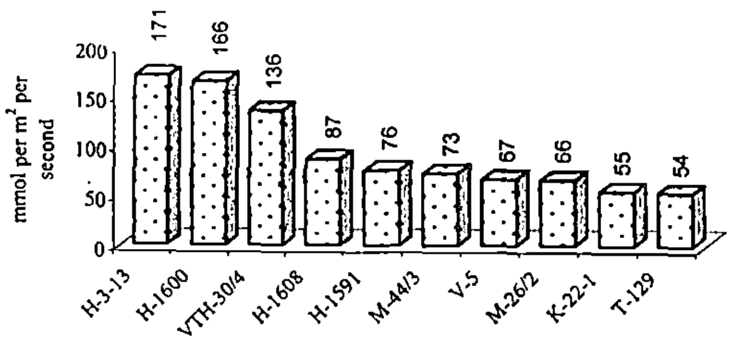

Fig 11 Stomatal conductance of ten cashew varieties (six month old seedling)

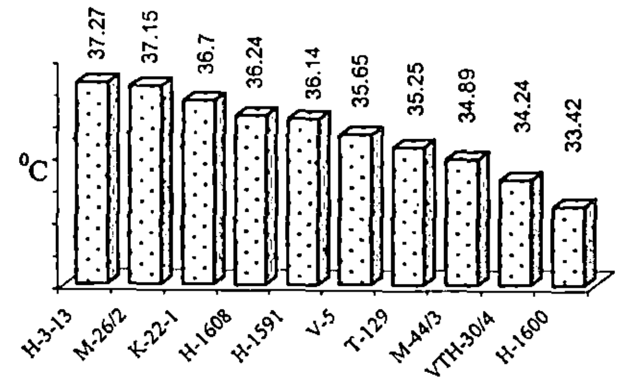

Fig13 Leaf temperature of ten cashew varieties (six month old seedling)

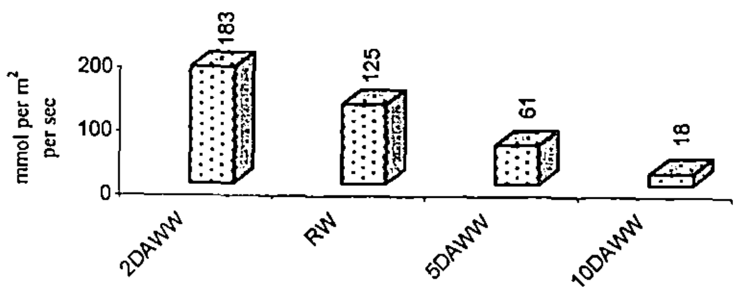

Fig12 Stomatal conductance (six month old seedling) at four soil moisture regimes

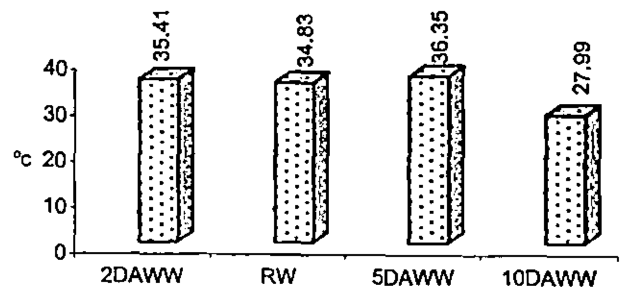

Fig14 Leaf temperature (six month old seedling) at four soil moisture regimes

percentage of dried leaves was lowest (23.7%) with the variety H-1591 followed by M-44/3 (33.5%) and V-5 (51.3%) and highest (88%) with the variety K-22-1.

Number of days took for complete drying

Number of days took for complete drying of seedlings varied considerably between varieties (Fig.18). The seedlings of H-3-13, K-22-1, T-129 and H-1600 took less than 25 days for complete drying whereas seedlings of four varieties(M-26/2, V-5, H-1591 and M-44/3) took over 40 days to die. The duration of life under moisture stress was longest (45 days) with the variety M-44/3 followed by H-1591 (43 days) and V-5 (41 days). The variety H-3-13 was the first one died in the shortest duration of stress (17 days).

Based on the data on net photosynthesis, transpiration rate, stomatal conductance, leaf temperature, leaf water potential, leaf drying percentage and number of days took for complete drying of seedlings, the varieties were further short listed. Varieties having the highest Ψ_w, lowest leaf drying percentage and longest duration of life under drought were treated as apparently tolerant and the varieties with opposite characters were treated as apparently sensitive. As such four apparently tolerant varieties (H-1591, M-44/3, M-26/2 and V-5) and two apparently sensitive varieties (K-22-1 and H-3-13) were identified for final screening.

C. Final screening

Six month old seedlings of four apparently tolerant and two sensitive varieties identified in the secondary screening were subjected to a final screening during August 1996 to February 1997 to study their response to different soil moisture regimes. The results obtained are presented below.

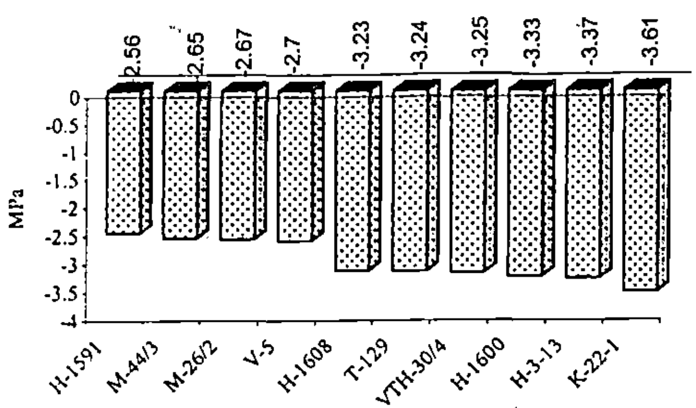

Fig15 Leaf water potential of ten cashew varieties (six month old seedling)

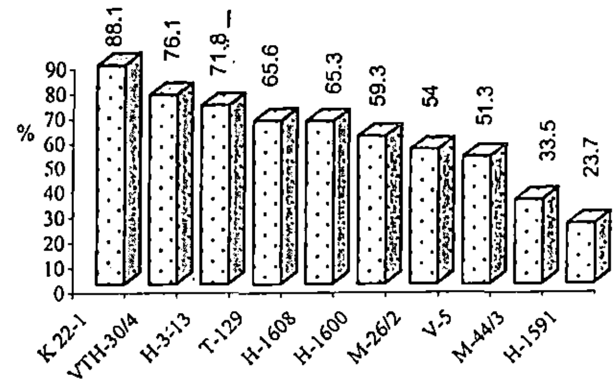

Fig17 Leaf drying percentage of ten cashew varieties at 15 days after withholding water

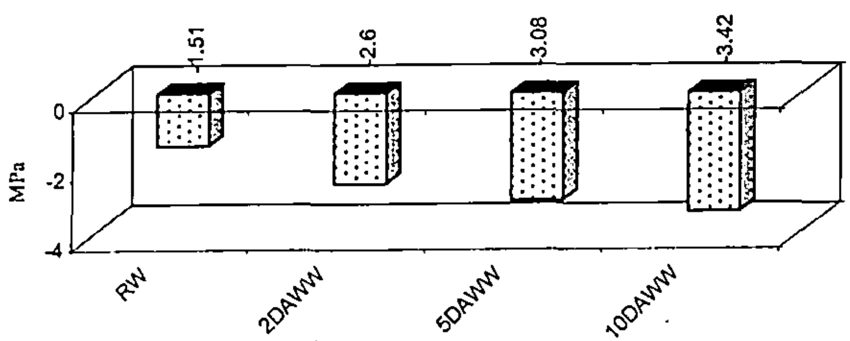

Fig16 Leaf water potential (six month old seedling) at four soil moisture regimes

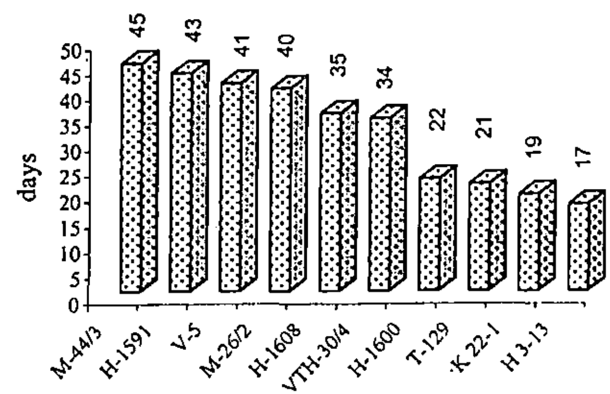

Fig.18 Number of days taken for complete drying of seedlings of ten cashew varieties

a) Growth characters

Seedling height

Seedling height differed with variety as well as soil moisture regimes (Table 13). The seedlings of H-1591 were tallest (40.3 cm) followed by M-26/2(36.5 cm). The seedlings of K-22-1 were the shortest (24.88 cm).

The seedlings raised under regular watering (20% DAW) were the tallest (34.8 cm). Increase in soil moisture stress resulted a decrease in seedling height. The shortest seedlings were noticed with the plants kept under life saving irrigation (32.56 cm).

Seedling girth

There was considerable difference in seedling girth between varieties (Table 13). Seedlings of K-22-1 had the highest girth (3.51 cm) and those of M-26/2 had the lowest (2.87 cm). Variation in soil moisture regime did not change seedling girth.

Number of leaves

The leaf production was highest with seedlings of H-3-13 (25.00) followed by M-44/3 (20.47) and lowest with K-22-1 (18.87) followed by H-1591 (Table 13).

The leaf production was highest (28.13) with seedlings raised under regular irrigation (20% DAW) and lowest (17.83) with seedlings kept under life saving irrigation.

Internodal length

The internodal length differed considerably between varieties (Table 13). It was highest with the variety M-44/3 (2.64 cm) followed by M-26/2 (2.62 cm) and lowest with K-22-1 (1.44 cm).

The plants grown under regular watering (20% DAW) had the longest internode (2.55 cm). Internodal length decreased with increase in soil moisture stress. The lowest internodal length was seen with seedlings grown under life saving irrigation (1.86 cm).

Root dry matter production (RDMP)

The root production measured in terms of RDMP did not differ between varieties (Table 13). But this character was affected by change in soil moisture regime. The RDMP was highest (2.86 g) with seedlings raised under regular irrigation (20% DAW). RDMP decreased with increase in soil moisture stress. The lowest RDMP was noticed with seedlings grown under life saving irrigation (1.87 g).

Shoot dry matter production (SDMP)

The SDMP differed between varieties and soil moisture regimes (Table 13). The SDMP was highest with M-26/2 (9.13 g pl^{-1}) followed by H-3-13 (8.46 g pl^{-1}) and lowest with M-44/3 (6.11 g pl^{-1}).

Highest SDMP was noticed with seedlings grown under regular irrigation (8.99 g pl^{-1}). Increase in soil moisture stress decreased SDMP and it was lowest (6.61 g pl^{-1}) with seedlings under life saving irrigation.

Root:shoot ratio (R:S ratio)

The R:S ratio varied between varieties and soil moisture regimes (Table 13). R:S ratio was highest (0.39) with M-44/3 followed by K-22-1 (0.36) and lowest (0.27) with H-3-13.

The seedlings grown in the soil moisture regime of 40% DAW had the highest R:S ratio (0.33) and those grown under life saving irrigation had the lowest R:S ratio (0.28).

Biomass production (BMP)

The BMP differed considerably between varieties and soil moisture regime (Table 13). BMP was highest with H-1591 (16.34 g pl^{-1}) followed by M-26/2 (14.98 g pl^{-1}) and M-44/3 (13.76 g pl^{-1}) and lowest with K-22-1 (11.51 g pl^{-1}).

The seedlings raised under regular irrigation (20% DAW) had the highest BMP (15.73 g pl^{-1}) and it decreased with increase in soil moisture stress. The BMP was lowest in seedlings raised under life saving irrigation (12.3 g pl^{-1}).

Total dry matter production (TDMP)

The TDMP varied between varieties and soil moisture regimes (Table 13). TDMP was highest with the variety H-1591 (12.82 g pl^{-1}) followed by V-5 (10.06 g pl^{-1}) and M-44/3 (9.97 g pl^{-1}) and lowest with K-22-1 (7.12 g pl^{-1}).

TDMP was highest (11.85 g pl^{-1}) with plants grown under regular irrigation. TDMP decreased with increase in soil moisture stress and lowest TDMP(8.48 g pl^{-1}) was observed with plants raised under life saving irrigation (Fig. 19a).

Table 13. Variation in growth characters in relation to varieties (six month old seedling) and soil moisture regimes

Treatments	Height (cm)	Girth (cm)	No. of leaves	Internodal length (cm)	RDMP ($g\ pl^{-1}$)	SDMP ($g\ pl^{-1}$)	Root:Shoot ratio	BMP ($g\ pl^{-1}$)	TDMP ($g\ pl^{-1}$)
a) Variety									
V5	32.54	2.92	19.70	2.04	2.34	7.68	0.29	13.36	10.06
M-26/2	36.55	2.87	19.13	2.62	2.63	9.13	0.33	14.98	9.02
M-44/3	25.93	2.92	20.47	2.64	2.20	6.11	0.39	13.76	9.97
H-1591	40.30	3.20	18.90	2.50	2.22	7.60	0.35	16.34	12.82
K-22-1	24.88	3.51	18.87	1.44	2.34	7.34	0.36	11.51	7.12
H-3-13	35.38	3.45	25.00	2.43	2.14	8.46	0.27	13.71	8.20
SEm±	0.278	0.017	0.247	0.027	0.034	0.120	0.010	0.144	0.124
CD(0.05)	0.780**	0.050**	0.720**	0.080**	NS	0.350**	0.029**	0.420**	0.360**
b) Soil moisture regimes									
20% DAW	34.80	3.41	28.13	2.55	2.86	8.99	0.32	15.73	11.85
40% DAW	32.61	3.19	21.00	2.39	2.81	8.45	0.33	14.67	11.26
60% DAW	32.00	3.16	19.07	2.37	2.21	7.08	0.31	14.25	10.49
80% DAW	33.28	3.06	19.40	2.29	1.92	7.07	0.31	13.77	9.25
90% DAW	32.83	3.05	18.63	2.22	1.87	6.91	0.31	12.95	8.83
Life saving	32.56	2.99	17.83	1.86	1.87	6.61	0.28	12.30	8.48
SEm±	0.278	0.017	0.247	0.027	0.034	1.120	0.010	0.144	0.124
CD(0.05)	0.780**	NS	0.720**	0.080**	0.100**	0.350**	0.029**	0.420**	0.360**

DAW - Depletion of available water ** Significant at 1 per cent level; BMP - Biomass production
RDMP - Root dry matter production; SDMP - Shoot dry matter production; TDMP - Total dry matter production

Response of varieties to irrigation

The response of six varieties to irrigation measured in terms of increase in TDMP over unirrigated control is presented in Fig.19b. The highest response was observed with K-22-1 (90.06%) followed by H-3-13 (87.01%) and M-44/3 (81.9%). The response was lowest with the variety M-26/2 (29.29%).

b) Physiological characters

Net photosynthesis (P_n)

The P_n varied between varieties and soil moisture regimes (Table 14). At 2 days after imposing treatment (DAIT), the P_n was highest in the variety V-5 (2.207 μmol $m^{-2}s^{-1}$) followed by M-26/2 (2.15 μmol $m^{-2}s^{-1}$). The lowest P_n was noticed in H-3-13 (1.457 μmol $m^{-2}s^{-1}$). More or less the same trend was noticed at 5 and 10 DAIT.

An attempt was made to compare the mean P_n during stress periods between varieties (Fig.20). The mean P_n was highest with the variety H-1591 (1.844 μmol $m^{-2}s^{-1}$) followed by M-26/2 (1.650 μmol $m^{-2}s^{-1}$) and V-5 (1.339 μmol $m^{-2}s^{-1}$). The lowest P_n was observed in seedlings of K-22-1 (0.772 μmol $m^{-2}s^{-1}$).

At 2 DAIT, the P_n was highest with plants grown under regular irrigation (1.964 μmol $m^{-2}s^{-1}$) and lowest (1.042 μmol $m^{-2}s^{-1}$) with plants kept under life saving irrigation. The same trend was noticed at 5 and 10 DAIT. The mean data on P_n also showed a similar trend between soil moisture regimes (Fig. 21).

Transpiration rate

The transpiration rate differed considerably between varieties and soil moisture regimes (Table 15). At 2 DAIT, the transpiration rate was highest in the variety

Table 14. Variation in net photosynthesis ($\mu mol\ m^{-2}s^{-1}$) in relation to varieties (six month old seedling) and soil moisture regimes at different intervals

Treatments	2 DAIT	5 DAIT	10 DAIT	Mean
a) Variety				
V-5	2.207	1.167	0.642	1.339
M-26/2	2.150	1.735	1.064	1.650
M-44/3	1.800	0.962	0.748	1.170
H-1591	2.084	2.315	1.134	1.844
K-22-1	1.951	0.364	0.000	0.772
H-3-13	1.457	0.903	0.627	0.996
Mean	1.941	1.274	0.703	
b) Soil moisture regimes				
20% DAW	1.964	2.487	1.373	1.941
60% DAW	1.681	1.016	1.026	1.274
Life saving	1.042	1.048	0.018	0.703
Mean	1.563	1.517	0.806	

	SEm±	CD(0.05)
Varieties	0.080	0.236**
Soil moisture regimes	0.056	0.167**
Duration	0.056	0.167**

DAW - Depletion of available water
DAIT - Days after imposing treatment
** Significant at 1 per cent level

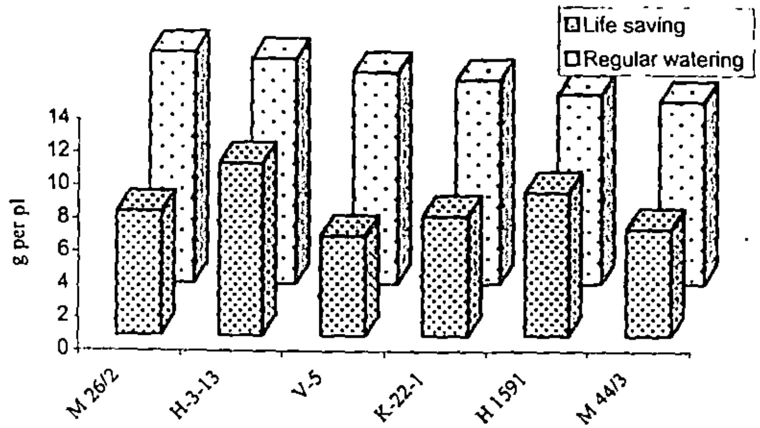

Fig19a Total dry matter production of six cashew varieties under irrigated and unirrigated condition

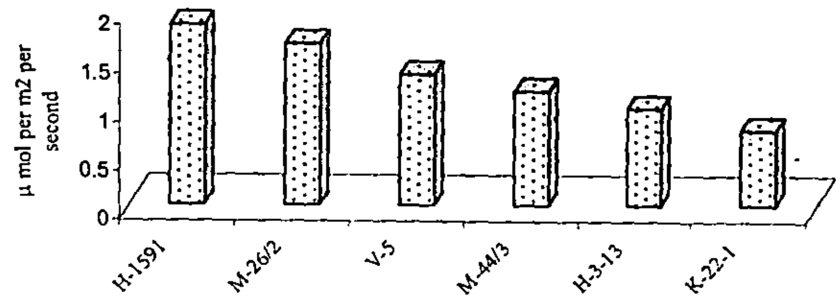

Fig. 20 Net photosynthetic rate of six cashew varieties (6 month old seedlings)

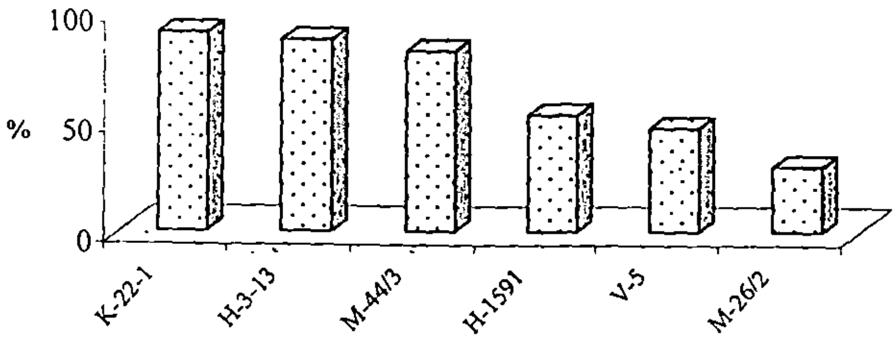

Fig 19 b Response of six cashew varieties to irrigation

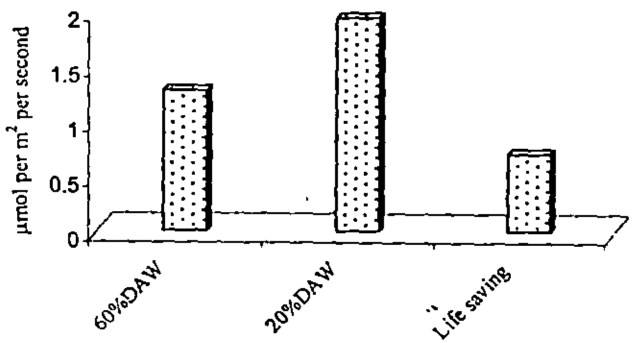

Fig21 Net photosynthetic rate at three soil moisture regimes (6 month old seedlings)

V-5 (3.029 mmol $m^{-2}s^{-1}$) followed by M-44/3 (2.844 mmol $m^{-2}s^{-1}$) and K-22-1 (2.778 mmol $m^{-2}s^{-1}$) and lowest in H-3-13 (2.232 mmol $m^{-2}s^{-1}$). The transpiration rate was highest (3.316 mmol $m^{-2}s^{-1}$) in M-26/2 followed by V-5 (2.94 mmol $m^{-2}s^{-1}$) and H-1591 (2.84 mmol $m^{-2}s^{-1}$) at 5 DAIT. Almost the same trend was noticed at 10 DAIT also.

The mean data indicated that the transpiration rate was highest (2.711 mmol $m^{-2}s^{-1}$) with the variety M-26/2 followed by H-1591 (2.519 mmol $m^{-2}s^{-1}$) and V-5 (2.387 mmol $m^{-2}s^{-1}$). The lowest transpiration rate was (Fig.22) noticed in K-22-1 (1.582 mmol $m^{-2}s^{-1}$).

Transpiration rate varied due to change in soil moisture regimes. At 2 DAIT, the highest transpiration rate was observed with plants grown under regular irrigation (2.586 mmol $m^{-2}s^{-1}$). The same trend was observed at 5 and 10 DAIT. The mean transpiration rate was highest (2.665 mmol $m^{-2}s^{-1}$) with plants under 60 per cent DAW and lowest (1.777 mmol $m^{-2}s^{-1}$) with plants under life saving irrigation (Fig. 23).

Stomatal conductance (g_s)

The g_s varied between varieties and soil moisture regimes (Table 16). At 2 DAIT, the variety V-5 had the highest g_s (83 mmol $m^{-2}s^{-1}$) followed by M-26/2 (78 mmol $m^{-2}s^{-1}$) and H-1591 (76 mmol $m^{-2}s^{-1}$). The lowest g_s was observed in seedlings of H-3-13 (65 mmol $m^{-2}s^{-1}$). More or less the same trend was noticed at 5 and 10 DAIT.

The mean data on stomatal conductance showed that g_s was highest (83 mmol $m^{-2}s^{-1}$) in H-1591 followed by M-26/2 (79 mmol $m^{-2}s^{-1}$) and V-5 (61 mmol $m^{-2}s^{-1}$). The lowest g_s (35 mmol $m^{-2}s^{-1}$) was noticed (Fig. 24) in K-22-1.

Stomatal conductance differed due to changes in soil moisture regimes. At 2 DAIT, g_s was highest with plants grown under regular irrigation (79 mmol $m^{-2}s^{-1}$) and

Table 15. Variation in transpiration rate (mmol $m^{-2}s^{-1}$) in relation to varieties (six month old seedling) and soil moisture regimes at different intervals

Treatments	2 DAIT	5 DAIT	10 DAIT	Mean
a) Variety				
V-5	3.029	2.944	1.188	2.387
M-26/2	2.749	3.316	2.064	2.711
M-44/3	2.844	2.318	1.277	2.146
H-1591	2.493	2.840	2.226	2.519
K-22-1	2.778	1.847	0.122	1.582
H-3-13	2.232	1.847	1.088	1.722
Mean	2.687	2.519	1.328	
b) Soil moisture regimes				
20% DAW	2.586	1.979	1.712	2.092
60% DAW	2.931	3.163	1.900	2.665
Life saving	2.546	2.415	0.370	1.777
Mean	2.687	2.519	1.328	

	SEm±	CD(0.05)
Varieties	0.098	0.291**
Soil moisture regimes	0.069	0.206**
Duration	0.069	0.206**

DAW - Depletion of available water
DAIT - Days after imposing treatment
** Significant at 1 per cent level

lowest in plants under life saving irrigation (63 mmol $m^{-2}s^{-1}$). The same trend was noticed at 5 and 10 DAIT. The mean data on g_s also showed similar trend (Fig. 25).

Leaf temperature

The leaf temperature was highest with the variety K-22-1 (37.66°C) followed by V-5 (37.50°C) and H-3-13 (37.45°C) at 2 DAIT (Table 17). The lowest leaf temperature was noticed in H-1591 (36.52°C). At 5 DAIT, K-22-1 had the highest leaf temperature (39.63°C) and H-1591 had the lowest (38.1°C). At 10 DAIT, the variety M-26/2 had the highest leaf temperature (38.22°C). The mean data on leaf temperature indicated that the variety M-26/2 had the highest leaf temperature (38.07°C) followed by H-1591 (37.31°C) and H-3-13 (34.26°C). The lowest leaf temperature was noticed in K-22-1 (30.25°C) (Fig. 26).

At 2 DAIT, the plants kept under regular irrigation had the lowest leaf temperature (36.25°C) and those under life saving irrigation had the highest (38.11°C). The same trend was noticed at 5 and 10 DAIT too. The mean data on leaf temperature was lowest under regular irrigation (34.24°C) and highest at 60 per cent DAW (39.07°C) (Fig. 27).

Leaf water potential (Ψ_w)

The Ψ_w varied between varieties and soil moisture regimes (Table 18). At 2 DAIT, the highest Ψ_w was noticed in seedlings of V-5 (-1.84 MPa) followed by M-44/3 (-1.9 MPa) and H-1591 (-2.29 MPa). Ψ_w was lowest with the variety H-3-13 (-3.01 MPa). Almost the same trend was noticed at 5 and 10 DAIT. The variety V-5 had highest mean Ψ_w (-2.23 MPa) followed by H-1591 (-2.49 MPa). The lowest mean Ψ_w (-3.44 MPa) was with the variety H-3-13 (Fig. 28).

Table 16. Variation in stomatal conductance (mmol $m^{-2}s^{-1}$) in relation to varieties (six month old seedling) and soil moisture regimes at different intervals

Treatments	2 DAIT	5 DAIT	10 DAIT	Mean
a) Variety				
V-5	83	68	31	61
M-26/2	78	90	68	79
M-44/3	68	48	33	50
H-1591	76	81	90	83
K-22-1	66	36	40	35
H-3-13	65	39	27	44
Mean	73	60	42	
b) Soil moisture regimes				
20% DAW	79	65	72	72
60% DAW	77	65	46	63
Life saving	63	51	8	41
Mean	73	60	42	

	SEm±	CD(0.05)
Varieties	3.70	9.90**
Soil moisture regimes	2.60	7.60**
Duration	2.60	7.60**

DAW - Depletion of available water
DAIT - Days after imposing treatment
** Significant at 1 per cent level

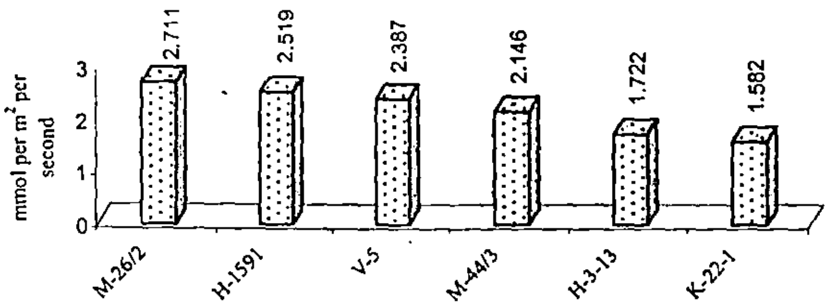

Fig. 22 Transpiration rate of six cashew varieties (six month old seedlings)

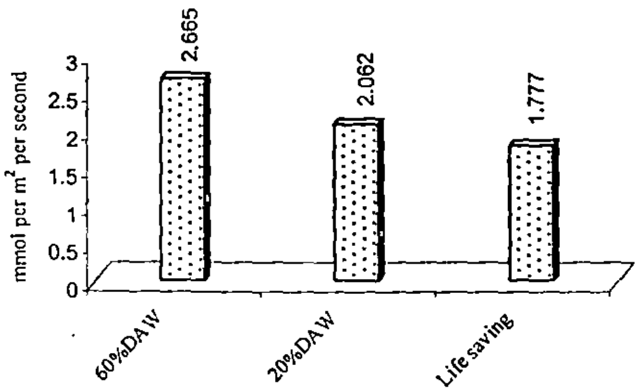

Fig23 Transpiration rate (six month old seedling) at three soil moisture regimes

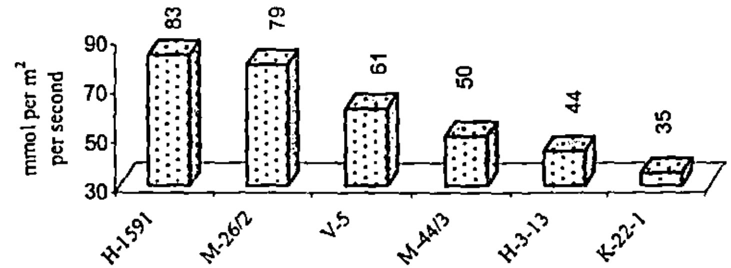

Fig24 Stomatal conductance of six cashew varieties (six month old seedling)

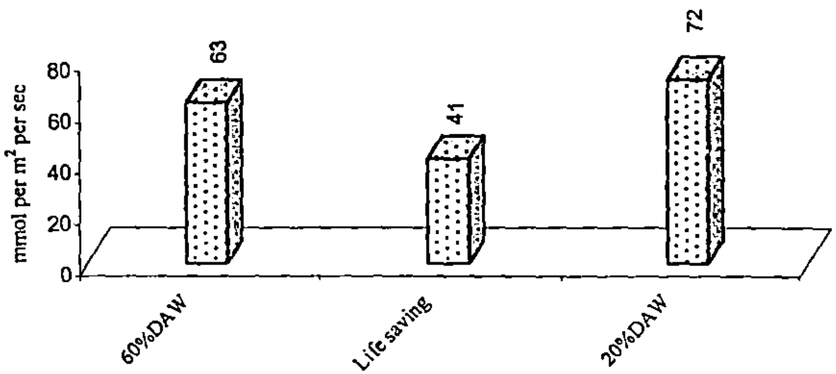

Fig25 Stomatal conductance (six month old seedlings) at three soil moisture regimes

Table 17. Variation in leaf temperature (°C) in relation to varieties (six month old seedling) and soil moisture regimes at different intervals

Treatments	2 DAIT	5 DAIT	10 DAIT	Mean
a) Variety				
V-5	37.50	39.61	25.36	34.16
M-26/2	37.20	38.79	38.22	38.07
M-44/3	37.16	39.23	25.12	33.84
H-1591	36.52	38.10	37.30	37.31
K-22-1	37.66	39.63	31.19	30.25
H-3-13	37.45	39.41	25.92	34.26
Mean	37.25	39.17	27.52	
b) Soil moisture regimes				
20% DAW	36.25	36.40	30.07	34.24
60% DAW	37.28	40.67	39.17	39.07
Life saving	38.11	40.45	31.31	36.65
Mean	37.25	39.17	33.10	

	SEm±	CD(0.05)
Varieties	0.048	0.144**
Soil moisture regimes	0.034	0.102**
Duration	0.034	0.102**

DAW - Depletion of available water
DAIT - Days after imposing treatment
** Significant at 1 per cent level

Leaf water potential differed due to changes in soil moisture regime. The Ψ_w was highest in plants under regular irrigation (20% DAW) at 2 DAIT and this was consistently seen at 5 and 10 DAIT also. Leaf water potential decreased with increase in soil moisture stress and it was lowest in plants raised under life saving irrigation (Fig. 29).

Leaf area per seedling

The leaf area per seedling varied between varieties and soil moisture regimes (Table 19). Seedlings of H-3-13 had the highest leaf area per plant (622 cm^2) and those of K-22-1 (364 cm^2) had the lowest.

The seedlings grown under regular irrigation (20% DAW) had the highest leaf area (855 cm^2) and those under life saving irrigation had the lowest (425 cm^2).

Chlorophyll 'a' content of leaves

There was considerable variation in leaf chlorophyll 'a' content between varieties and soil moisture regimes (Table 19). The chlorophyll 'a' content was highest (0.439 mg g^{-1} leaf tissue) in seedlings of M-44/3 followed by H-1591 (0.373 mg g^{-1} tissue) and V-5 (0.371 mg g^{-1} tissue). The lowest chlorophyll content was noticed in the variety M-26/2 (0.254 mg g^{-1} tissue).

The plants grown under regular irrigation (20% DAW) had the highest leaf chlorophyll 'a' (0.378 mg g^{-1} tissue) and it decreased with increase in soil moisture stress. Chlorophyll 'a' content was lowest in seedlings under life saving irrigation (0.296 mg g^{-1} tissue).

Table 18. Variation in leaf water potential (MPa) in relation to varieties (six month old seedling) and soil moisture regimes at different intervals

Treatments	2 DAIT	5 DAIT	10 DAIT	Mean
a) Variety				
V-5	-1.84	-2.04	-2.81	-2.23
M-26/2	-2.41	-2.53	-2.93	-2.62
M-44/3	-1.90	-2.66	-3.01	-2.50
H-1591	-2.29	-2.45	-2.75	-2.49
K-22-1	-2.91	-3.29	-3.69	-3.29
H-3-13	-3.01	-3.38	-3.95	-3.44
Mean	-2.39	-2.72	-3.19	
b) Soil moisture regimes				
20% DAW	-2.08	-2.35	-2.78	-2.40
60% DAW	-2.59	-3.66	-3.28	-2.91
Life saving	-3.06	-3.28	-3.56	-3.30
Mean	-2.59	-2.72	-3.19	

	SEm±	CD(0.05)
Varieties	0.018	0.054**
Soil moisture regimes	0.013	0.038**
Duration	0.013	0.038**

DAW - Depletion of available water
DAIT - Days after imposing treatment
** Significant at 1 per cent level

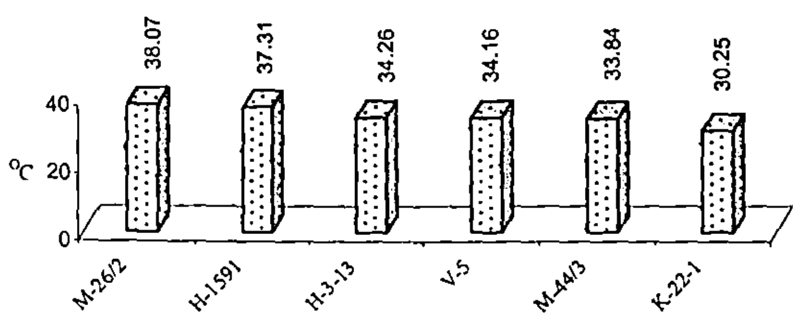

Fig26 Leaf temperature of six cashew varieties (6 month old seedling)

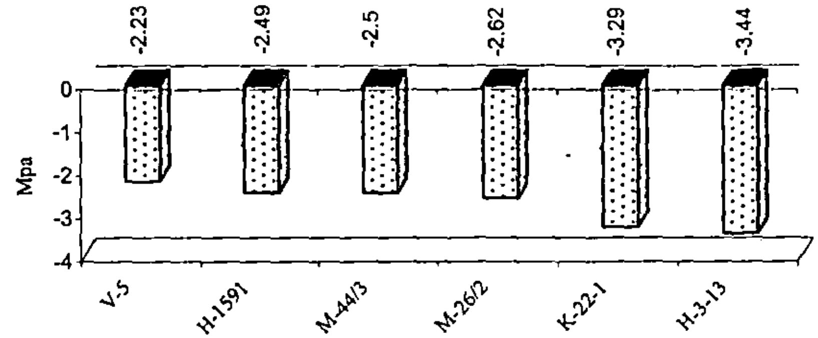

Fig28 Leaf water potential of six cashew varieties (6 month old seedlings)

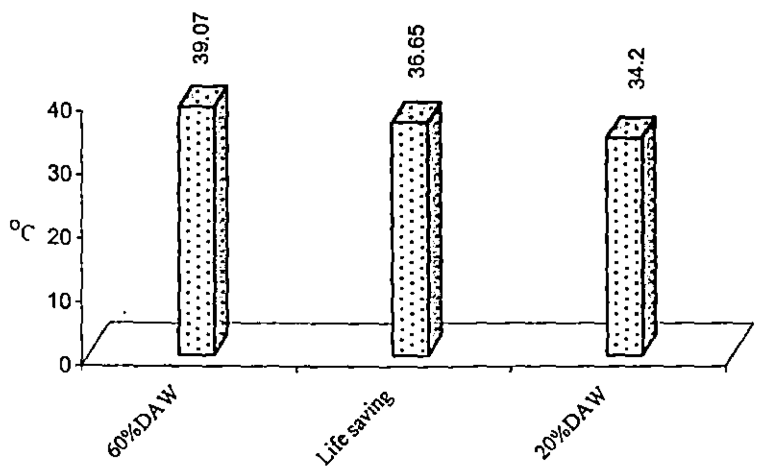

Fig27 Leaf temperature (six month old seedling) at three soil moisture regimes

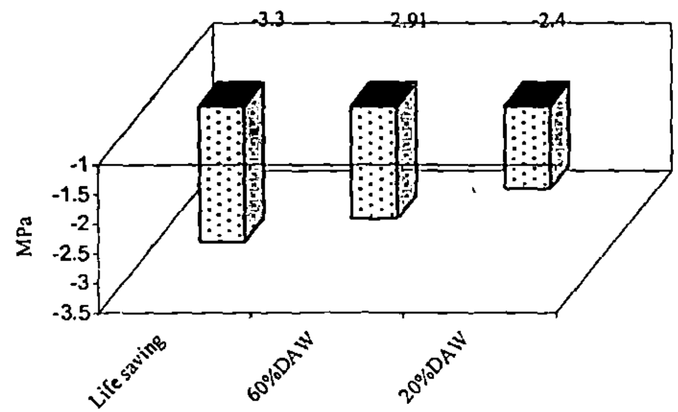

Fig29 Leaf water potential at three soil moisture regimes (6 month old seedlings)

The interaction between variety and moisture regime was significant with respect to this character (Table 20). The chlorophyll 'a' content decreased from 0.468 under regular irrigation to 0.266 mg g^{-1} leaf under life saving irrigation in V-5 whereas the corresponding change in K-22-1 was from 0.311 to 0.218 mg g^{-1} leaf.

Chlorophyll 'b' content of leaves

There was variation in chlorophyll 'b' content between varieties and due to soil moisture regimes (Table 19). The chlorophyll 'b' content was highest in seedlings of M-44/3 (0.109 mg g^{-1} tissue) followed by H-3-13 (0.082 mg g^{-1} tissue) and K-22-1 (0.068 mg g^{-1} tissue) and lowest in V-5 (0.045 mg g^{-1} tissue).

The plants received regular irrigation (20% DAW) had the highest chlorophyll 'b' (0.090 mg g^{-1} tissue) and it decreased with increase in soil moisture stress. The plants under life saving irrigation had the lowest chlorophyll 'b' (0.054 mg g^{-1} tissue).

Total chlorophyll content of leaves

The total chlorophyll content varied between varieties and soil moisture regimes (Table 19). Seedlings of M-44/3 had the highest total chlorophyll (0.548 mg g^{-1} tissue) followed by H-1591 (0.430 mg g^{-1} tissue) and V-5 (0.418 mg g^{-1} tissue) and lowest with M-26/2 (0.311 mg g^{-1} tissue) (Fig. 30).

The total chlorophyll content decreased with increase in soil moisture stress. The seedlings under regular irrigation had the highest total chlorophyll (0.465 mg g^{-1} tissue) whereas those under life saving irrigation had the lowest (0.366 mg g^{-1} tissue) (Fig. 31).

The interaction between variety and moisture regime was significant with respect to this character (Table 20). In H-3-13, the total chlorophyll content decreased from 0.727 mg g^{-1} leaf under regular irrigation to 0.387 mg g^{-1} leaf under life saving irrigation whereas the corresponding decrease in M-26/2 was from 0.580 to 0.466 mg g^{-1} leaf.

Chlorophyll stability index (CSI)

The CSI of leaves varied between varieties and soil moisture regimes (Table 19). The CSI was highest with seedlings of H-1591 (25.33%) followed by M-26/2 (24.57%) and V-5 (24.15%) and lowest in K-22-1 (19.82%) (Fig. 32).

The CSI was lowest (38.99%) in plants under regular irrigation and it increased with increase in soil moisture stress. The seedlings raised under life saving irrigation had the highest CSI (53.66%) (Fig. 33).

The interaction between variety and moisture regime was significant with respect to this character (Table 20) . In K-22-1, the CSI increased from 27.04 per cent under regular irrigation to 48.59 per cent under life saving irrigation whereas the corresponding increase in H-3-13 was from 37.79 to 43.29 per cent.

Relative injury (RI)

RI of seedlings differed considerably between varieties and soil moisture regimes (Table 19). The RI was highest in seedlings of K-22-1 (28.67%) followed by M-26/2 (7.52%) and H-3-13 (7.52%) and lowest in H-1591 (1.98%) (Fig. 34).

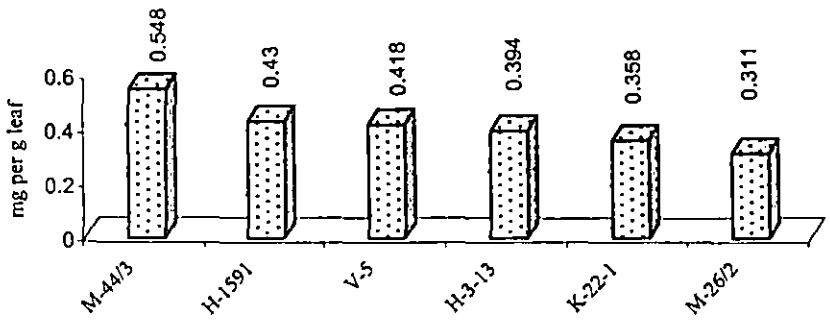

Fig30 Total chlorophyll content of six cashew varieties (six month old seedling)

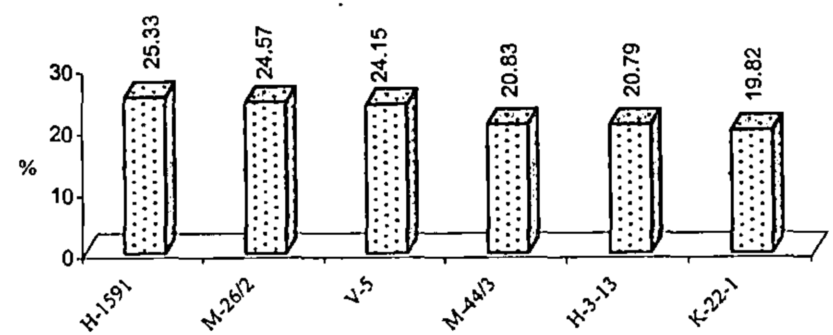

Fig. 32 Chlorophyll stability index of six cashew varieties (six month old seedling)

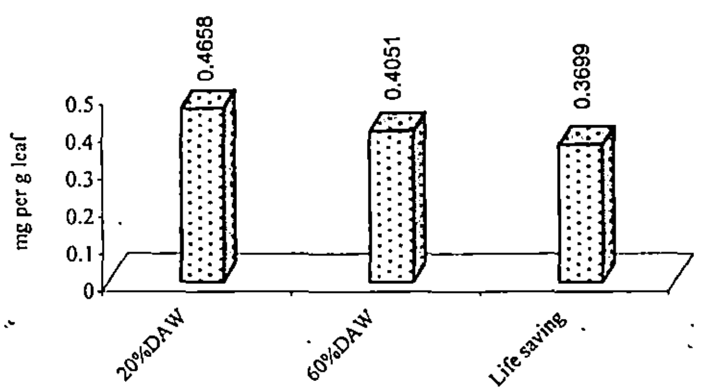

Fig31 Total chlorophyl content (six month old seedling) at three soil moisture regimes

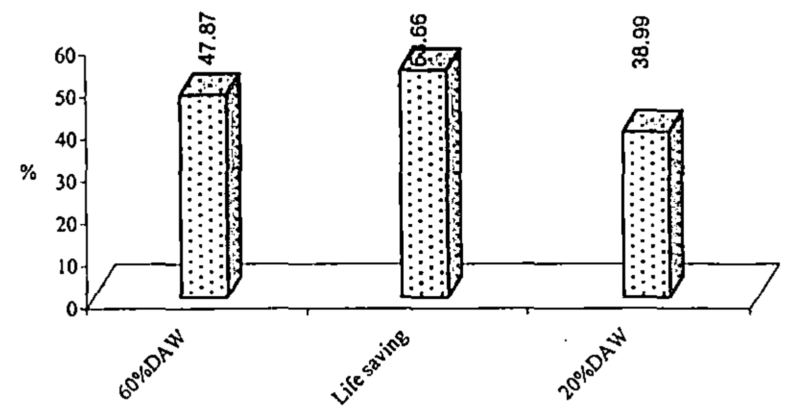

Fig33 Chlorophyl stability index (six month old seedling) at three soil moisture regimes

RI increased with increase in soil moisture stress. RI increased from 14.32 per cent in seedlings under regular irrigation to 26.72 per cent under life saving irrigation (Fig. 35).

The interaction effect between variety and moisture regime was significant with respect to this character (Table 20). In M-26/2, the RI increased from 3.24 per cent under regular irrigation to 27.78 per cent under life saving irrigation whereas the corresponding increase in K-22-1 was from 57.5 to 58.5 per cent.

Dry weight fraction (DWF)

The DWF differed considerably between varieties and soil moisture regimes (Table 19). H-1591 and M-44/3 had the highest DWF (0.229) followed by V-5 (0.223) and lowest in K-22-1 (0.183).

The DWF increased with increase in soil moisture stress and it was highest (0.249) in seedlings under life saving irrigation and lowest (0.162) in seedlings under regular irrigation.

The interaction between variety and moisture regime was significant with respect to this character (Table 20).In V-5, the DWF increased from 0.154 under regular irrigation to 0.373 under life saving irrigation whereas the corresponding increase in H-3-13 was from 0.178 to 0.250.

Relative water content (RWC)

There was considerable difference in RWC between varieties and due to soil moisture regimes (Table 19). RWC was highest in M-44/3 (47.46%) followed by M-26/2 (47.06%) and H-3-13 (43.47%) and lowest in V-5 (40.04%) (Fig. 36).

The seedlings raised under regular irrigation (20% DAW) had the highest RWC (49.33%) and those under life saving irrigation (33.21%) had the lowest (Fig. 37).

Leaf drying percentage

The leaf drying percentage differed considerably between varieties and soil moisture regimes (Table 19). The leaf drying percentage was highest in seedlings of K-22-1 (36.54%) followed by H-3-13 (35.29%) and M-26/2 (34.73%) and lowest in H-1591 (20.33%) (Fig. 38).

The leaf drying percentage increased with increase in soil moisture stress. The seedlings grown under regular irrigation had the lowest leaf drying percentage (12.09%). The leaf drying percentage was highest (41.61%) with seedlings raised under life saving irrigation (Fig. 39).

The interaction between variety and moisture regime was significant with respect to this character (Table 20). In K-22-1, the leaf drying percentage increased from 0 percent under regular irrigation to 56 per cent under life saving irrigation whereas the corresponding increase in H-1591 was from 0 to 15.8 per cent.

c) Biochemical characters

Proline

The proline content of leaves varied between varieties and due to soil moisture regimes (Table 21). The proline content was highest in the variety H-1591 (346 $\mu g\ g^{-1}$ leaf) followed by M-26/2 (311 $\mu g\ g^{-1}$ leaf) and V-5 (211 $\mu g\ g^{-1}$ leaf) and lowest in H-3-13 (112 $\mu g\ g^{-1}$ leaf) (Fig. 40).

Table 19. Variation in physiological characters in relation to varieties (six month old seedling) and soil moisture regimes

Treatments	Leaf area per plant (cm^2)	Chlorophyll 'a' mg g^{-1} tissue	Chlorophyll 'b' mg g^{-1} tissue	Total chlorophyll mg g^{-1} tissue	CSI (%)	RI (%)	DWF (%)	RWC (%)	Leaf drying percentage
a) Varieties									
V5	550.0	0.371	0.045	0.418	24.15	3.05	0.223	40.04	28.11
M-26/2	560.0	0.254	0.056	0.311	24.57	7.52	0.210	47.06	34.73
M-44/3	603.0	0.439	0.109	0.548	20.83	5.16	0.229	47.46	29.04
H-1591	588.0	0.373	0.057	0.430	25.33	1.98	0.229	40.26	20.33
K-22-1	364.0	0.289	0.068	0.358	19.82	28.67	0.183	41.99	36.54
H-3-13	622.0	0.310	0.082	0.394	20.83	7.52	0.206	43.47	35.29
SEm±	10.2	0.002	0.002	0.001	0.172	0.128	0.002	0.379	0.844
CD(0.05)	30.0**	0.006**	0.006**	0.003**	0.500**	0.345**	0.006**	1.104**	1.460**
b) Soil moisture regimes									
20% DAW	855.0	0.378	0.090	0.465	38.99	14.32	0.162	49.33	12.09
40% DAW	588.0	0.366	0.077	0.431	*	*	0.172	48.62	24.28
60% DAW	549.0	0.341	0.069	0.405	47.87	21.60	0.207	48.12	31.04
80% DAW	521.0	0.331	0.063	0.404	*	*	0.211	43.45	34.78
90% DAW	448.0	0.326	0.061	0.385	*	*	0.218	37.55	40.22
Life saving	425.0	0.296	0.054	0.366	53.66	26.72	0.249	33.21	41.61
SEm±	10.2	0.002	0.002	0.001	0.172	0.128	0.002	0.379	0.844
CD(0.05)	30.0**	0.006**	0.006**	0.003**	0.500**	0.345**	0.006**	1.104**	2.460**
Variety x soil moisture regimes	S	S	NS	S	S	S	S	NS	S

DAW - Depletion of available water; NS - Not significant; ** Significant at 1 per cent level

* CSI and RI were not estimated at these soil moisture regimes

Table 20. Variation in physiological characters of cashew varieties (six month old seedling) at different soil moisture regimes

Treatments Var./SRR		Chlorophyll 'a' $mg\ g^{-1}$ leaf	Total chlorophyll $mg\ g^{-1}$ leaf	CSI (%)	RI (%)	DWF	Leaf drying percentage
V5	20% DAW	0.468	0.599	42.24	0.99	0.154	18.21
	40% DAW	0.401	0.580	*	*	0.186	24.35
	60% DAW	0.359	0.550	50.45	4.28	0.188	26.84
	80% DAW	0.365	0.536	*	*	0.204	27.00
	90% DAW	0.368	0.521	*	*	0.234	32.16
	Life saving	0.266	0.479	59.08	13.08	0.373	40.10
M-26/2	20% DAW	0.336	0.580	44.28	3.24	0.167	0
	40% DAW	0.302	0.539	*	*	0.193	26.34
	60% DAW	0.283	0.509	52.94	14.12	0.194	37.03
	80% DAW	0.218	0.506	*	*	0.225	43.88
	90% DAW	0.195	0.485	*	*	0.228	46.09
	Life saving	0.143	0.466	54.78	27.78	0.252	55.00
M-44/3	20% DAW	0.549	0.571	43.81	5.42	0.153	1.90
	40% DAW	0.445	0.560	*	*	0.196	24.64
	60% DAW	0.428	0.500	47.30	10.97	0.243	26.20
	80% DAW	0.412	0.500	*	*	0.250	33.71
	90% DAW	0.402	0.447	*	*	0.250	40.50
	Life saving	0.400	0.390	53.80	14.61	0.281	44.21
H-1591	20% DAW	0.428	0.625	45.75	0.87	0.171	0
	40% DAW	0.408	0.625	*	*	0.180	0
	60% DAW	0.387	0.577	49.30	4.31	0.226	1.90
	80% DAW	0.363	0.521	*	*	0.229	10.10
	90% DAW	0.315	0.499	*	*	0.275	13.50
	Life saving	0.315	0.470	62.39	6.71	0.294	15.80
K-22-1	20% DAW	0.311	0.711	27.04	57.50	0.089	0
	40% DAW	0.310	0.668	*	*	0.120	29.67
	60% DAW	0.304	0.601	43.29	55.95	0.190	30.40
	80% DAW	0.264	0.561	*	*	0.226	47.14
	90% DAW	0.258	0.547	*	*	0.237	56.00
	Life saving	0.218	0.499	48.59	58.58	0.240	56.00
H-3-13	20% DAW	0.389	0.727	37.79	17.94	0.178	1.90
	40% DAW	0.316	0.637	*	*	0.178	24.64
	60% DAW	0.284	0.600	43.94	36.96	0.188	33.71
	80% DAW	0.282	0.560	*	*	0.197	40.50
	90% DAW	0.265	0.442	*	*	0.244	44.21
	Life saving	0.227	0.387	43.29	39.54	0.250	49.26
SEm±		0.018	0.011	1.007	0.962	0.017	2.441
CD (0.05)		0.054**	0.033**	3.020**	2.801**	0.051**	7.119**

DAW - Depletion of available water; * CSI and RI were not estimated at these soil moisture regimes
**Significant at 1 per cent level

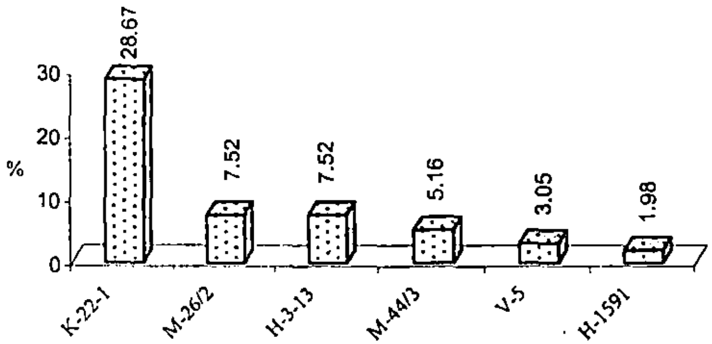

Fig. 34 Relative injury of six cashew varieties (six month old seedling)

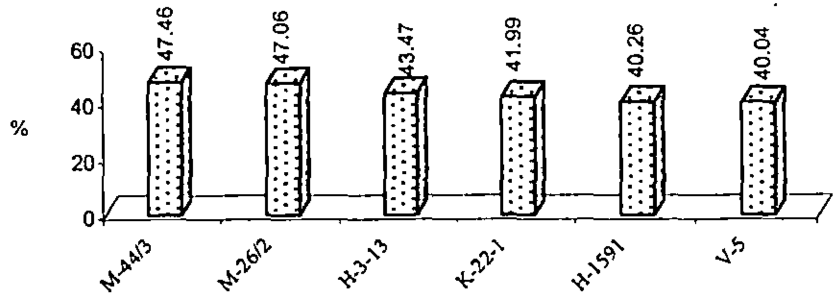

Fig. 36 Relative water content of six cashew varieties (six month old seedling)

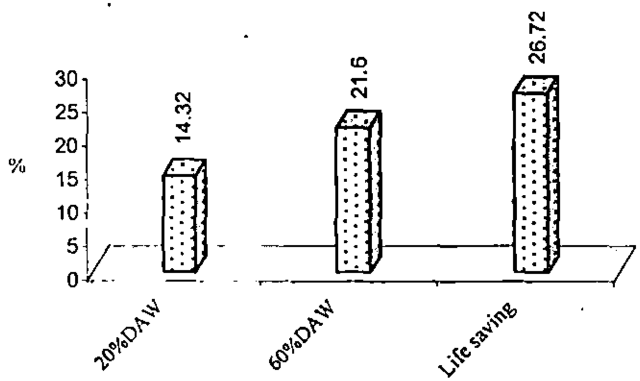

Fig35 Relative injury (six month old seedling) at three soil moisture regimes

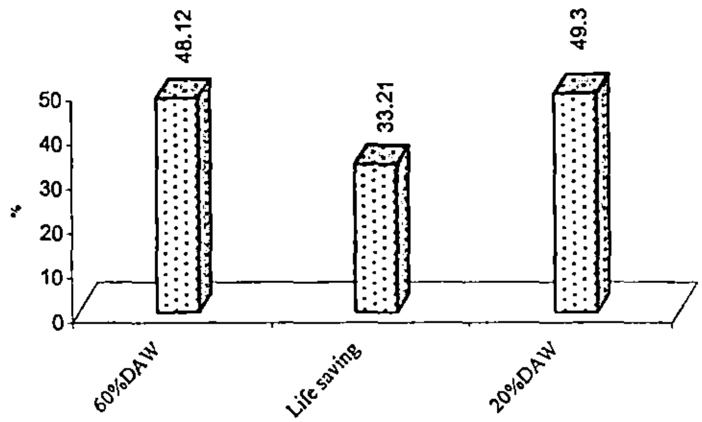

Fig37 Relative water content(six month old seedling) at three soil moisture regimes

The proline content increased with increase in soil moisture stress. The seedlings under regular irrigation had the lowest proline content (341 μg g^{-1} leaf) and it increased to 522 μg g^{-1} leaf when grown under life saving irrigation (Fig. 41).

The interaction between variety and moisture regime was significant with respect to this character (Table 22). In V-5, the proline content increased from 292 μg g^{-1} leaf under regular irrigation to 542 μg g^{-1} leaf between seedlings grown under regular irrigation and those under life saving irrigation whereas the corresponding increase in K-22-1 was from 266 to 302 μg g^{-1} leaf.

NRA of leaves

NRA of leaves differed considerably between varieties and due to soil moisture regimes (Table 21). The seedlings of H-1591 had the highest NRA in leaves (0.411 mmol NO_2 g^{-1} h^{-1}) followed by M-26/2 (0.373 mmol NO_2 g^{-1} h^{-1}) and V-5 (0.229 mmol NO_2 g^{-1} h^{-1}). The lowest NRA was noticed in K-22-1 (0.088 mmol NO_2 g^{-1} h^{-1}) (Fig. 42).

The NRA was highest in plants grown under regular watering (0.664 mmol NO_2 g^{-1} h^{-1}) and lowest in seedlings under life saving irrigation (0.308 mmol NO_2 g^{-1} h^{-1}) (Fig. 43).

The interaction between variety and moisture regime was significant with respect to this character (Table 22). In V-5, the NRA content decreased from 0.712 NO_2 g^{-1} h^{-1} under regular irrigation to 0.184 mmol NO_2 g^{-1} h^{-1} under life saving irrigation whereas the corresponding decrease in K-22-1 was from 0.232 to 0.080 mmol NO_2 g^{-1} h^{-1}.

Table 21. Variation in proline and NRA content of leaf (six month old seedling) in relation to varieties and soil moisture regimes

Treatments	Proline $\mu g\ g^{-1}$ leaf	NRA mmol $NO_2\ g^{-1}\ h^{-1}$
a) Variety		
V5	211	0.229
M-26/2	311	0.373
M-44/3	174	0.226
H-1591	346	0.411
K-22-1	143	0.088
H-3-13	112	0.157
SEm±	4.77	0.003
CD(0.05)	13.90**	0.008**
b) Soil moisture regimes *		
20% DAW	341	0.664
60% DAW	436	0.513
Life saving	522	0.308
SEm±	4.77	0.003
CD(0.05)	13.90**	0.008**

DAW - Depletion of available water

** Significant at 1 per cent level

* Proline and NRA was estimated at 3 moisture regimes

Table 22. Varietal variation in proline and NRA content of leaves (six month old seedling) at different soil moisture regimes

Treatment Variety/Soil moisture regimes		Proline $\mu g\ g^{-1}$ leaf	NRA mmol of $NO_2\ g^{-1}\ h^{-1}$
V5	20% DAW	292	0.712
	60% DAW	434	0.480
	Life saving	542	0.184
M-26/2	20% DAW	498	0.944
	60% DAW	640	0.820
	Life saving	728	0.476
M-44/3	20% DAW	282	0.712
	60% DAW	319	0.416
	Life saving	454	0.228
H-1591	20% DAW	544	0.940
	60% DAW	730	0.792
	Life saving	804	0.736
K-22-1	20% DAW	266	0.232
	60% DAW	292	0.220
	Life saving	302	0.080
H-3-13	20% DAW	164	0.448
	60% DAW	206	0.352
	Life saving	302	0.144
SEm±		3.88	0.023
CD(0.05)		11.30**	0.067**

DAW - Depletion of available water

** Significant at 1 per cent level

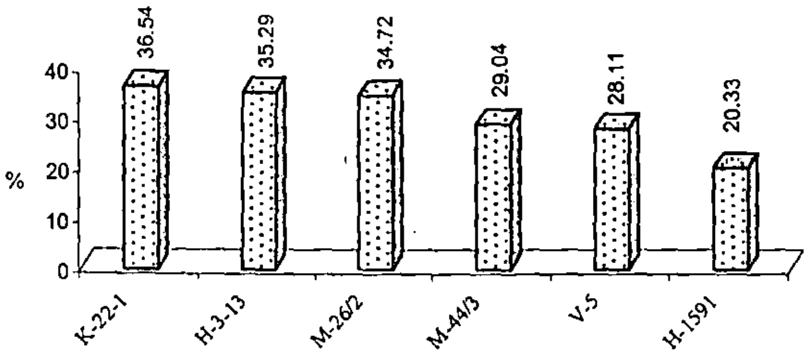

Fig. 38 Leaf drying percentage of six cashew varieties (six month old seedling)

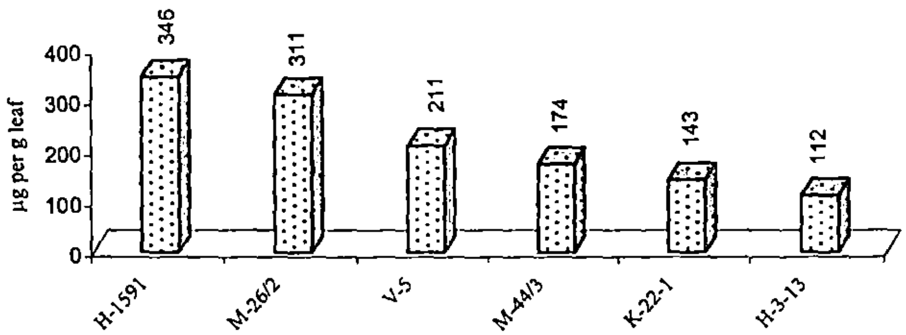

Fig. 40 Proline content of six cashew varieties (six month old seedling)

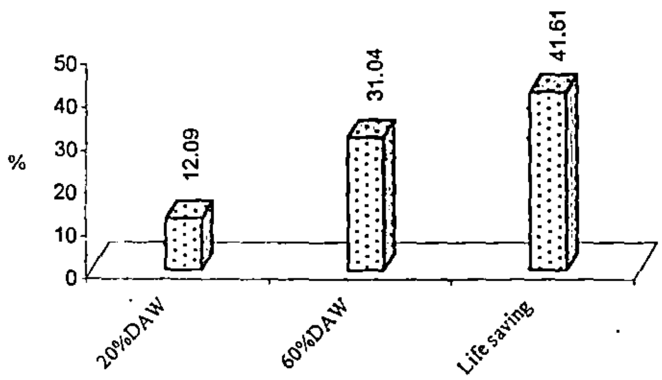

Fig39 Leaf drying percentage (six month old seedlings) at three soil moisture regimes

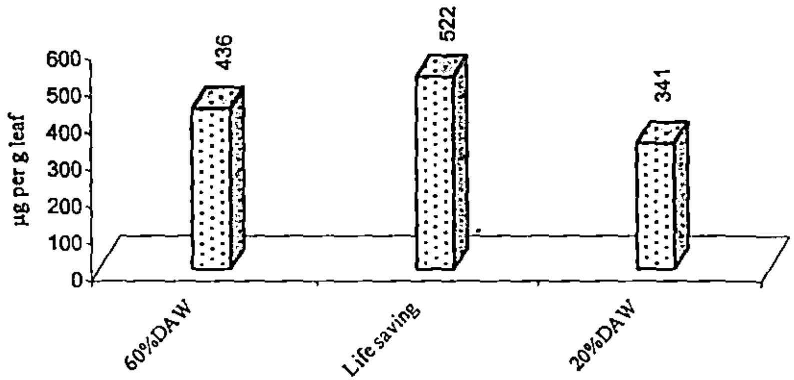

Fig41 Proline content (six month old seedling) at three soil moisture regimes

d) Anatomical characters

(a) Stomatal index

There was considerable variation in stomatal index between varieties (Fig. 44). Stomatal index was highest in K-22-1 (293.3 counts m^{-2}) followed by H-3-13 (286.6 counts m^{-2}) and lowest in V-5 (206.7 counts m^{-2}).

(b) Cuticle thickness

Cuticle thickness varied considerably between varieties (Fig. 45). The variety H-3-13 had the thinnest cuticle (3.17 μm). The cuticle thickness of K-22-1, M-26/2 and M-44/3 was more or less the same. The thickest cuticle was noticed in H-1591 (3.33 μm) followed by V-5.

(c) Leaf thickness

The leaf thickness differed considerably between varieties (Fig. 46). The variety H-1591 had the thickest leaves (1.60 mm) followed by M-26/2 (1.50 mm). The leaves of K-22-1 were the thinnest (0.80 mm).

(d) Bark thickness

There was considerable variation in bark thickness between varieties (Fig. 47). Bark thickness was highest in H-1591 (3.08 mm) followed by M-26/2 (3.07 mm) and lowest in K-22-1 (2.89 mm).

D. Field monitoring

Net photosynthesis (P_n), transpiration rate, stomatal conductance, leaf temperature and leaf water potential of the six varieties (ten year old graft raised cashew trees) were measured during March, 1998. The data on nut yield were also collected.

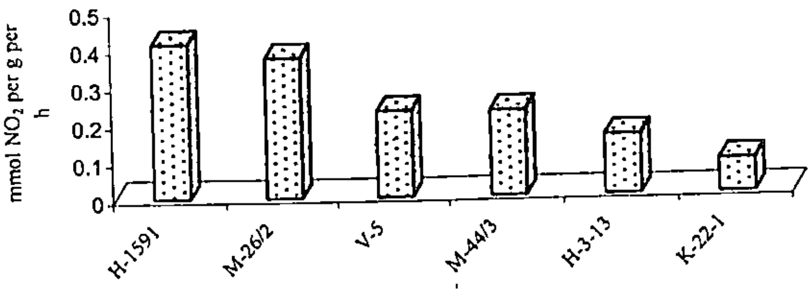

Fig. 42 Nitrate reductase activity in leaves of six cashew varieties (six month old seedling)

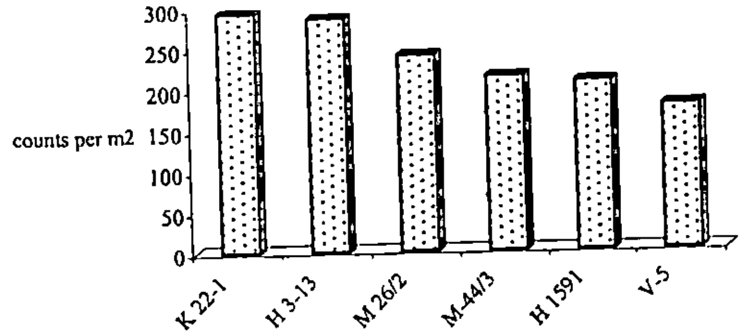

Fig44 Stomatal index of six cashew varieties (six month old seedling)

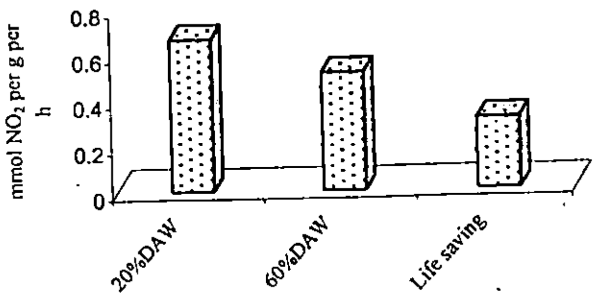

Fig43 Nitrate reductase activity in leaves (six month old seedling) at three soil moisture regimes

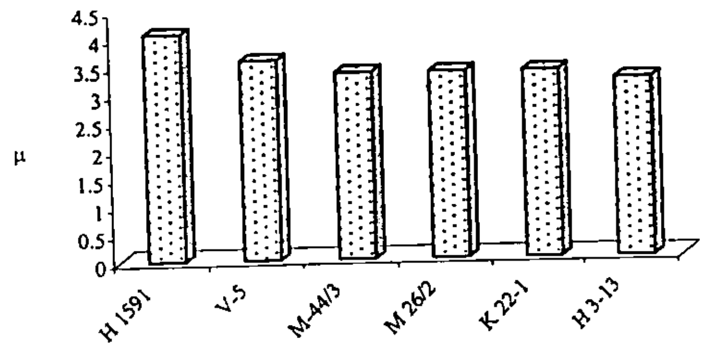

Fig45 Cuticle thickness of six cashew varieties (six month old seedling)

Net photosynthesis (P_n)

P_n differed considerably between varieties (Table 23). P_n was highest with the variety V-5 (9.496 μmol $m^{-2}s^{-1}$) followed by K-22-1 (7.101 μmol $m^{-2}s^{-1}$) and M-44/3 (5.791 μmol $m^{-2}s^{-1}$). P_n was lowest (Fig. 48) in M-26/2 (1.864 μmol $m^{-2}s^{-1}$).

Transpiration rate

There was considerable difference in transpiration rate between varieties (Table 23). It was highest in V-5 (10.099 mmol $m^{-2}s^{-1}$) followed by H-1591 (8.721 mmol $m^{-2}s^{-1}$) and K-22-1 (7.757 mmol $m^{-2}s^{-1}$) and lowest (Fig. 49) in H-3-13 (2.302 mmol $m^{-2}s^{-1}$).

Stomatal conductance

The stomatal conductance differed between varieties (Table 23). It was highest in V-5 (275.5 mmol $m^{-2}s^{-1}$) followed by H-1591 (275.06 mmol $m^{-2}s^{-1}$) and K-22-1 (271.83 mmol $m^{-2}s^{-1}$) and lowest (Fig. 50) in H-3-13 (54.03 mmol $m^{-2}s^{-1}$).

Leaf temperature

The leaf temperature differed considerably between varieties (Table 23). It was highest in H-3-13 (37.89°C) followed by V-5 (37.82°C) and H-1591 (37.68°C) and lowest in M-26/2 (34.46°C) (Fig. 51).

Leaf water potential

The leaf water potential differed considerably between varieties (Table 23). It was highest in H-1591 (-0.633 MPa) followed by M-44/3 (-0.733 MPa) and M-26/2 (-0.767 MPa) and lowest (Fig. 52) in H-3-13 (-1.067 MPa).

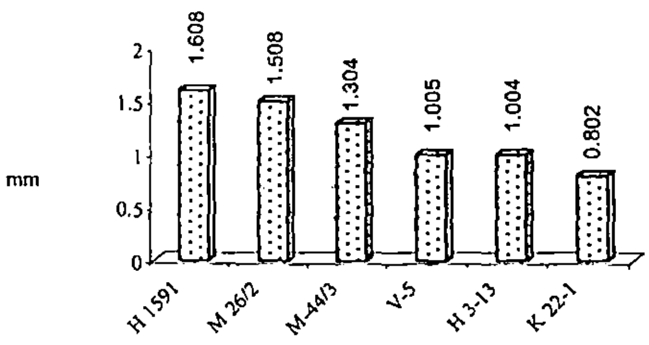

Fig46 Leaf thickness of six cashew varieties(six month old seedling)

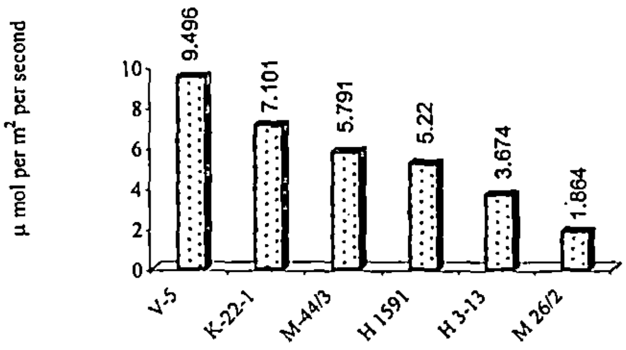

Fig48 Net Photosynthetic rate of six cashew varieties (10 year old clonal trees during peak summer)

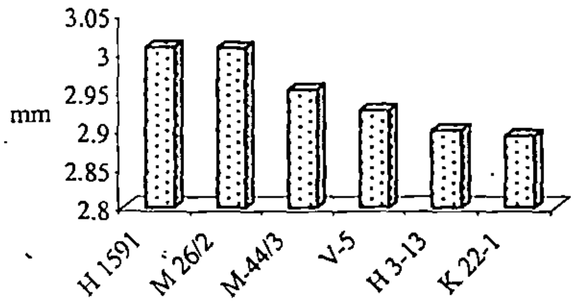

Fig47 Bark thickness of six cashew varieties (six month old seedling)

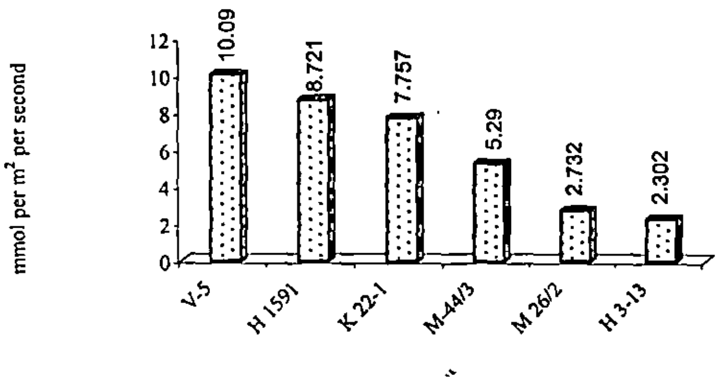

Fig 49 Transpiration rate of six cashew varieties (10 year old clonal trees during peak summer)

Nut yield

The nut yield of H-1591 was the highest (16.9 kg per tree) followed by V-5 (12.72 kg per tree) and lowest with M-44/3 (10.5 kg per tree) (Fig. 53).

Tolerance rating of varieties based on drought tolerance

The component relationship of varieties to test drought tolerance was worked out as follows.

$$y = 0.638x_1 - 0.089x_2 + 0.0866x_3 + 0.08x_4 + 0.008x_5 - 0.0075x_6 + 0.0424x_7 + 0.1745x_8 + 0.0002x_9 - 0.813x_{10} - 5.5855 \quad \text{(Eqn-I)}$$

$(R^2 = 0.9628)$

where

x_1 - Photosynthetic rate at 5 days after withholding water

x_2 - Transpiration rate at 5 days after withholding water

x_3 - Stomatal conductance at 5 days after withholding water

x_4 - Drymatter production at 1 month after withholding water

x_5 - Leaf area at 1 month after withholding water

x_6 - Relative injury at 1 month after withholding water

x_7 - Chlorophyll stability index at 1 month after withholding water

x_8 - Leaf water potential at 5 days after withholding water

x_9 - Proline at 1 month after withholding water

x_{10} - Nitrate reductase activity at 1 month after withholding water

(All observations were recorded from six month old seedling subjected to moisture stress)

The median (index) was worked out using the following formula

$$M = l + \left(\frac{N}{2} - m\right)\frac{1}{cf}$$

M - Median of the frequency distribution

l - Lowest value of median class

N - Total number of observations

m - Cumulative frequency of the class above the median class

cf - Cumulative frequency

The index was arrived as 0.48 to classify the varieties as tolerant or sensitive.

To classify the tolerant varieties as highly tolerant and moderately tolerant, another demarcating point was worked out using the following formula.

$$M = l + \left(\frac{3N}{4} - m\right)\frac{1}{cf}$$

Accordingly the index for this classification arrived as 1.55.

Similarly, to classify the sensitive varieties to moderately sensitive and highly sensitive, the demarcating point was worked out using the following formula.

$$M = l + \left(\frac{N}{4} - m\right)\frac{1}{cf}$$

Accordingly the index for this classification was arrived as -1.20.

Using Eqn-I, the varieties were rated as highly sensitive, moderately sensitive, moderately tolerant and highly tolerant (Fig. 54). It was found that H-1591, M-26/2 and V-5 are highly tolerant, M-44/3 is moderately tolerant, H-3-13 is moderately sensitive and K-22-1 is highly sensitive to moisture stress (Table 40).

Exp. II. Response of cashew to applied N at different levels of irrigation (drip)

A field experiment was conducted for two years (1996-98) in a three year old graft raised cashew plantation (variety H-3-17) to study the response of cashew to applied N at different levels of irrigation (drip). The results obtained from the study are given below.

Tree height

During 1996, the plant height increased significantly due to irrigation (Table 24). While the unirrigated trees had a height of 3.24 m, the irrigated trees (40 litres per tree per day) were 4 m tall. Increasing levels of irrigation beyond 40 litres per tree per day did not increase the plant height. But this effect of irrigation on height was not seen during the second year (1997).

N application increased tree height in both the years. But the effect of N differed with levels of irrigation. Trees applied with N @ 1500 g per tree per year along with irrigation @ 40 litres per tree per day were the tallest (4.63 m) and unirrigated trees applied with no N were the shortest (3 m).This effect was consistently seen in both the years.

Tree girth and canopy spread

The tree girth and canopy spread did not change much either due to levels of irrigation or N or due to their interactions (Table 24) in both the years.

Table 23. Net photosynthesis, transpiration rate, stomatal conductance, leaf temperature, leaf water potential and nut yield of six cashew varieties (10 year old graft raised cashew trees) under field condition (during March, 1998)

Variety	Net photosynthesis $\mu mol\ m^{-2}s^{-1}$	Transpiration rate $mmol\ m^{-2}s^{-1}$	Stomatal conductance $mmol\ m^{-2}s^{-1}$	Leaf temperature °C	Leaf water potential MPa	Yield $kg\ tree^{-1}$
H-1591	5.220	8.721	275.06	37.68	-0.633	16.90
M-26/2	1.864	2.732	90.66	34.46	-0.767	11.99
M-44/3	5.791	5.280	164.00	36.34	-0.733	10.50
V5	9.496	10.099	275.50	37.82	-0.967	12.72
H-3-13	3.674	2.302	54.03	37.89	-1.067	10.60
K-22-1	7.101	7.757	271.83	37.11	-1.067	12.27
SEm±	1.061	0.903	37.15	0.275	0.040	
CD (0.05)	3.310**	2.817**	117.02**	0.859**	0.126**	

** Significant at 1 per cent level

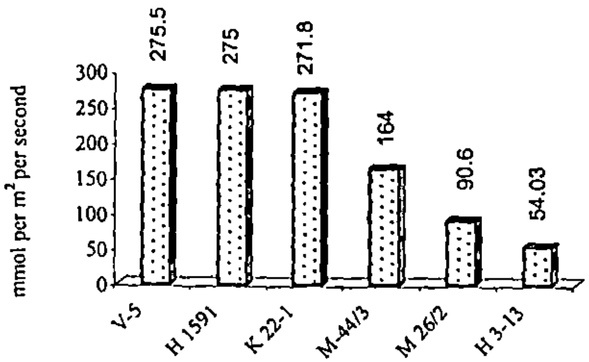

Fig50 Stomatal conductance of six cashew varieties (10 year old clonal trees during peak summer)

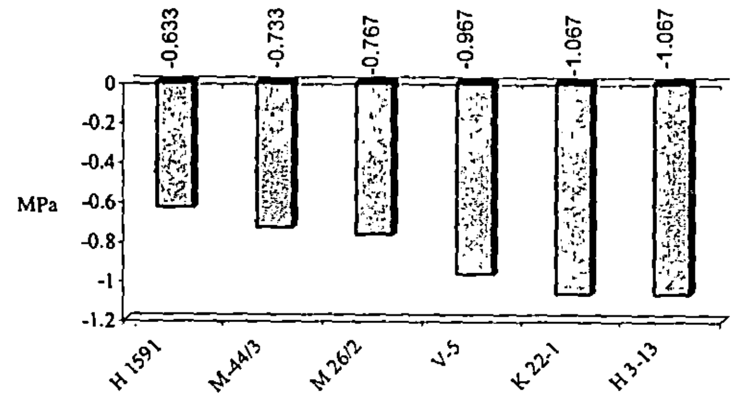

Fig52 Leaf water potential of six cashew varieties (10 year old clonal trees during peak summer)

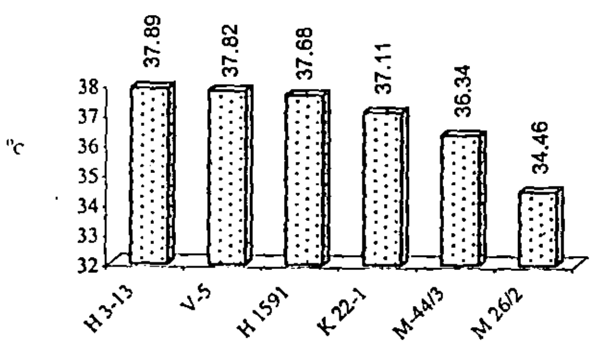

Fig51 Leaf temperature of six cashew varieties (10 year old clonal trees during peak summer)

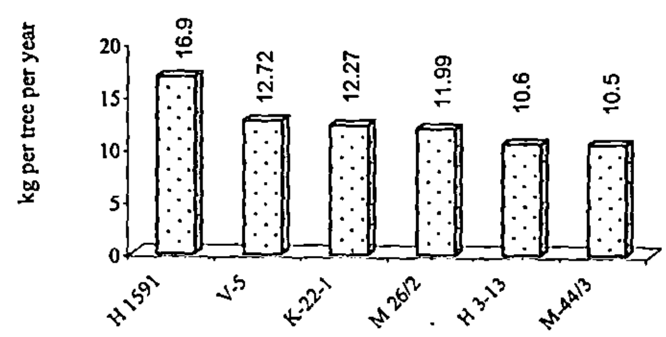

Fig53 Nut yield of six cashew varieties

Number of primary branches

The effect of irrigation was to increase the number of primary branches (Table 24) and this was not seen beyond first level of irrigation (40 litres per tree per day). This effect was seen only during 1996.

N application increased the number of primary branches up to the first level of N tried (750 g per tree per year) and this effect was seen only during first year. Interaction between N and irrigation significantly influenced this character. Trees applied with N @ 750 g per tree per year along with irrigation @ 80 litres per tree per day produced the highest number of primary branches (5.67). Neither the levels of irrigation nor the levels of N or their interactions influenced the number of primary branches during second year of study (1997).

LAI

The effects of levels of irrigation, levels of N and their interactions were significant on LAI in both the years (Table 25). LAI increased steadily due to irrigation up to the highest level tried (80 litres per tree per day). Increase in levels of N also increased LAI up to the highest level (1500 g per tree per year). Trees applied with N @ 1500 g per tree per year along with irrigation @ 80 litres per tree per day had the highest LAI in both the years.

Number of flushes per metre square

Levels of irrigation did not change the flush number during both the years (Table 25). The effect of N on number of flushes per metre square was marked during the second year (1997). N application increased the number of flushes per metre square up to the first level (750 g per tree per year).

Table 24. Effect of irrigation and nitrogen on growth of cashew trees (1992 planting) during 1996 and 1997

Treatment	Height (m)		Girth (cm)		No.of primary branches		Canopy spread (m)	
	1996	1997	1996	1997	1996	1997	1996	1997
a) Irrigation								
I_0	3.24	3.95	44.44	46.67	1.67	3.99	3.90	5.70
I_1	4.00	4.89	45.34	48.10	2.67	4.09	3.88	5.65
I_2	4.17	4.89	47.67	47.73	2.67	4.17	3.92	5.95
SEm±	0.076	0.430	2.480	2.330	0.272	0.183	0.209	0.201
CD(0.05)	0.247**	NS	NS	NS	0.884**	NS	NS	NS
b) Nitrogen								
N_0	3.56	3.68	44.79	46.33	3.22	4.02	3.88	5.48
N_1	3.79	4.78	44.22	47.30	4.33	4.10	3.85	5.72
N_2	4.08	6.00	48.44	48.83	4.33	4.14	3.98	6.11
SEm±	0.076	0.430	2.480	2.330	0.272	0.183	0.209	0.201
CD(0.05)	0.247**	1.253**	NS	NS	0.884**	NS	NS	NS
c) Irrigation x Nitrogen								
I_0N_0	3.00	3.67	39.03	41.66	1.67	3.80	4.08	5.67
I_0N_1	3.37	3.67	48.00	49.00	2.67	4.25	3.78	5.47
I_0N_2	3.37	5.00	49.00	49.20	2.67	3.91	3.85	5.97
I_1N_0	3.63	3.93	47.33	48.30	4.00	3.98	3.68	5.30
I_1N_1	3.73	5.00	45.33	46.00	4.67	3.88	3.73	5.80
I_1N_2	4.63	6.33	50.33	50.10	5.00	4.42	4.25	5.87
I_2N_0	4.07	3.93	48.00	49.10	4.00	4.26	3.87	5.47
I_2N_1	4.23	5.67	39.33	46.90	5.67	4.16	4.05	5.90
I_2N_2	4.23	6.67	46.00	47.20	5.33	4.08	3.84	6.50
SEm±	0.133	0.430	4.290	4.460	0.471	0.317	0.363	0.349
CD(0.05)	0.395**	2.253**	NS	NS	1.396**	NS	NS	NS

**Significant at 1 per cent level

Number of panicles per metre square

Number of panicles per metre square did not differ either due to levels of irrigation or N or due to their interaction during first year (Table 25). But during second year (1997), it increased with increase in level of irrigation upto 40 litres per tree per day and N up to the highest level tried in the experiment.

Yield

During first year of treatment (1996), the trees were only three years old. Due to a severe attack of tea mosquito, despite adoption of uniform plant protection measures, recordable level of yield was not obtained. There was a general set back in the cashew yield during that year due to a wide spread tea mosquito attack, in the region as a whole. But during the second year (1997), yield was recorded treatmentwise, analysed and presented (Table 25).

While unirrigated trees gave a nut yield of 0.29 kg per tree, irrigated trees (@ 40 litres of water per tree per day) gave a nut yield of 1.29 kg per tree. The nut yield increased further to 1.56 kg $tree^{-1}$ when the irrigation level was increased to 80 litres per tree per day (Fig. 55).

The nut yield increased with increase in N application upto the highest level tried (1500 g per tree per year).

But the effect of N on nut yield was modified with levels of irrigation. Yield with rainfed trees applied with no N as well as N @ 750 g per tree per year was zero (Table 25). But when N dose was increased to 1500 g per tree per year the yield increased from 0 to 0.77 kg per tree.

In irrigated trees, the response pattern was different. Irrigation @ 40 litres of water per tree per day without N application gave an yield of 1.02 kg per tree. When this level of irrigation was combined with N application @ 750 g per tree per year, nut yield was increased to 1.3 kg per tree and it further increased to 1.57 kg per tree when N dose was further increased to 1500 g per tree per year.

In trees irrigated @ 80 litres of water per tree per day, application of N @ 0, 750, 1500 g per tree per year resulted in an yield of 0.95, 1.6 and 2.13 kg per tree per year respectively. While rainfed trees produced no yield, application of water alone (@ 40 litres per tree per day) resulted in an yield of 1.02 kg per tree per year. But further increase in irrigation level did not increase the nut yield substantially.

Exp. III. Tolerance of cashew varieties to N deficient soils

Relative tolerance of ten cashew varieties to N deficient soils was studied in green house, to identify varieties suitable for N deficient environments. The results obtained are presented below.

a) Growth characters

Seedling height

There was considerable difference in seedling height between varieties (Table 26). The tallest seedlings were produced by H-1591 (39.81 cm) followed by M-26/2 (31.81 cm) and H-1598 (28.92 cm). Seedling height was lowest in K-22-1 (19.14 cm) followed by MDK-2 (19.48 cm).

The seedling height increased with increasing levels of applied N (18.5 cm with no N application to 36.9 cm with N @ 200 kg ha^{-1}). There was significant interaction between varieties and N levels with respect to this character (Table 27). In

Table 25. Effect of irrigation and nitrogen on yield attributes and yield of cashew trees (1992 planting) during 1996 and 1997

Treatment	LAI		No. of flushes m^{-2}		No. of panicles m^{-2}		Yield (kg $tree^{-1}$)	
	1996	1997	1996	1997	1996	1997	1997	1998
a) Irrigation								
I_0	1.07	1.49	6.14	3.34	2.77	3.62	-	0.29
I_1	1.92	1.96	5.74	3.82	2.66	3.70	-	1.29
I_2	2.56	2.72	5.40	3.74	2.40	3.86	-	1.56
SEm±	0.083	0.067	0.368	0.202	0.322	0.067		0.037
CD(0.05)	0.269**	0.217**	NS	NS	NS	0.198**		0.128**
b) N levels								
N_0	1.58	1.87	5.80	2.91	2.47	3.49	-	0.67
N_1	1.91	2.13	5.83	3.94	2.99	3.72	-	1.26
N_2	2.06	2.41	5.65	4.05	2.37	3.97	-	1.49
SEm±	0.083	0.067	0.368	0.202	0.322	0.067		0.037
CD(0.05)	0.269**	0.217**	NS	0.659**	NS	0.198**		0.120**
c) I x N								
I_0N_0	1.02	1.00	6.47	2.77	3.09	3.43	-	0.00
I_0N_1	1.08	1.50	6.06	3.63	2.67	3.63	-	0.00
I_0N_2	1.12	1.90	5.86	3.63	2.55	3.80	-	0.77
I_1N_0	1.43	2.03	5.58	3.20	1.99	3.37	-	1.02
I_1N_1	2.06	2.20	5.87	4.03	3.44	3.80	-	1.30
I_1N_2	2.27	2.36	5.76	4.23	2.55	3.93	-	1.57
I_2N_0	2.30	2.50	5.33	2.77	2.32	3.67	-	0.95
I_2N_1	2.60	2.70	5.54	4.17	2.88	3.73	-	1.60
I_2N_2	2.80	2.98	5.33	4.30	2.00	4.17	-	2.13
SEm±	0.145	0.116	0.638	0.350	0.558	0.224		0.065
CD(0.05)	0.428**	0.345**	NS	NS	NS	NS		0.193**

**Significant at 1 per cent

H-1591, the seedling height increased from 26.67 cm to 57.0 cm when N level was increased from 0 to 200 kg ha^{-1} whereas the corresponding increase in K-22-1 was from 10.33 to 24.0 cm.

Seedling girth

The seedling girth varied between varieties (Table 26). It was highest with H-1598 (3.98 cm) followed by MDK-1 (3.70 cm) and lowest in M-44/3 (3.03 cm).

The seedling girth increased with increase in levels of applied N (2.97 cm with no N application to 3.9 cm with N @ 200 kg ha^{-1}). The interaction effect between varieties and N levels was significant with respect to this character (Table 27). In MDK-1, the seedling girth increased from 2.67 to 4.67 cm when N level increased from 0 to 200 kg ha^{-1} whereas the corresponding increase in V-5 was from 2.83 to 3.67 cm.

Number of leaves

The leaf number differed considerably between varieties (Table 26). It was highest in seedlings of H-1591 (21.63) followed by M-44/3 (19.59) and M-26/2 (19.37).

The leaf production increased with increase in levels of N up to highest level viz. 200 kg N ha^{-1} (14.73 with no N application to 25.40 with N @ 200 kg ha^{-1}). The interaction effect between varieties and N levels was not considerable with respect to this character.

Internodal length

There was considerable variation in internodal length between varieties (Table 26). It was highest in M-26/2 and M-44/3 (2.73 cm). The lowest internodal length was observed in seedlings of H-1591 (2.35 cm). The internodal length did not change with levels of N or due to interaction between varieties and N.

Root dry matter production (RDMP)

RDMP varied between varieties (Table 26). It was highest in H-1591 (9.96 g pl^{-1}) followed by H-1608 (8.74 g pl^{-1}) and M-26/2 (8.15 g pl^{-1}) and lowest in K-22-1 (4.33 g pl^{-1}).

RDMP increased with increase in levels of N up to 175 kg N ha^{-1} (5.93 g pl^{-1} with no N application to 8.93 g l^{-1} with N @ 175 kg ha^{-1}). The interaction between varieties and N levels was significant with respect to this character (Table 27). In H-1591, RDMP increased from 5.67 to 23.33 g pl^{-1} when N level increased from 0 to 200 kg ha^{-1} whereas the corresponding increase in A-1 was from 5.67 to 7.67 g pl^{-1}.

Shoot dry matter production (SDMP)

SDMP varied between varieties (Table 26). SDMP was highest in H-1591 (40.85 g pl^{-1}) followed by H-1608 (32.82 g pl^{-1}) and M-26/2 (27.63 g pl^{-1}) and lowest in K-22-1 (16.11 g pl^{-1}).

SDMP increased with increase in level of N up to 175 kg ha^{-1} (18.3 g pl^{-1} with no N application to 33.77 g pl^{-1} with N @ 175 kg ha^{-1}). Interaction effect between varieties and N levels was significant with respect to this character (Table 27). In H-1608, the SDMP increased from 15.33 to 77.00 g pl^{-1} between seedlings supplied with N @ 0 and 200 kg ha^{-1} whereas the corresponding increase in MDK-1 was from 19.67 to 26.67 g pl^{-1}.

Root:shoot ratio (R:S ratio)

R:S ratio varied between varieties (Table 26). It was highest in H-1598 (0.339) followed by MDK-1 (0.333) and A-1 (0.325) and lowest in K-22-1 (0.268).

R:S ratio decreased with increase in levels of N (0.324 with no N application to 0.274 with N @ 200 kg ha^{-1}). Interaction effect between varieties and N levels was significant with respect to this character (Table 27). In K-22-1, the R:S ratio increased from 0.307 to 0.356 when N level increased from 0 to 200 kg ha^{-1} whereas the corresponding values in M-44/3 were from 0.333 and 0.326.

Total dry matter production (TDMP)

TDMP varied between varieties (Table 26). It was highest in H-1591 (51.07 g pl^{-1}) followed by M-26/2 (36.18 g pl^{-1}) and H-1608 (32.81 g pl^{-1}) and lowest in K-22-1 (20.44 g pl^{-1}) (Fig. 56).

TDMP increased with increase in level of N (Fig. 34) up to 175 kg ha^{-1} (24.23 g pl^{-1} with no N application to 42.70 g pl^{-1} with N @ 175 kg ha^{-1}) (Fig 57). The interaction between varieties and N levels was significant with respect to this character (Table 27). In H-1591, TDMP increased from 24.67 to 94.33 g pl^{-1} when N level increased from 0 to 200 kg ha^{-1} whereas the corresponding increase in MDK-1 was from 25.0 to 36.0 g pl^{-1}.

Response of varieties to applied N

The response of varieties to applied N is presented in Fig. 58. The highest response was observed with H-1591 (1.979 g per mg of N) followed by H-1608 (1.321 g per mg of N) and M-26/2 (1.23 g per mg of N). The response was lowest with the variety MDK-1 (0.311 g per mg of N).

Table 26. Variation in growth characters in relation to varieties (six month old seedling) and N levels

Treatments	Height (cm)	Girth (cm)	No. of leaves	Internodal length (cm)	RDMP (g pl^{-1})	SDMP (g pl^{-1})	R:S ratio	TDMP (g pl^{-1})	Leaf area per plant (cm^2)
Varieties									
H-1591 (v_1)	39.81	3.33	21.63	2.35	9.96	40.85	0.277	51.07	1589.0
M-26/2 (v_2)	31.81	3.07	19.37	2.73	8.15	27.63	0.319	36.18	1053.0
H-1598 (v_3)	28.92	3.98	19.18	2.46	6.96	21.04	0.339	28.11	1009.0
MDK-1 (v_4)	22.85	3.70	19.37	2.72	7.70	23.04	0.333	29.29	928.0
H-1608 (v_5)	28.18	3.33	16.59	2.48	8.74	32.82	0.311	32.81	892.0
M-44/3 (v_6)	23.55	3.03	19.59	2.73	7.22	22.74	0.311	26.63	785.0
V-5 (v_7)	23.29	3.17	16.11	2.52	5.52	19.41	0.285	24.85	530.0
MDK-2 (v_8)	19.48	3.09	18.78	2.48	5.82	18.82	0.304	24.67	763.0
A-1 (v_9)	24.66	3.41	16.56	2.46	6.48	21.26	0.325	27.74	829.0
K-22-1 (v_{10})	19.14	3.07	16.33	2.56	4.33	16.11	0.268	20.44	595.0
SEm±	1.155	0.089	0.782	0.101	0.348	0.831	0.016	0.891	23.07
CD (0.05)	3.201**	0.246**	1.610**	0.319**	0.965**	2.304**	0.045**	2.471**	63.90**
N levels									
0 kg N/ha (n_1)	18.50	2.97	14.73	2.38	5.93	18.30	0.324	24.23	473.0
25 kg N/ha (n_2)	20.67	3.03	15.50	2.43	5.93	18.77	0.315	24.70	664.0
50 kg N/ha (n_3)	22.73	3.04	15.70	2.45	6.23	19.87	0.313	26.10	673.0
75 kg N/ha (n_4)	23.03	3.19	16.30	2.48	6.23	20.43	0.304	26.66	733.0
100 kg N/ha (n_5)	26.46	3.27	18.57	2.52	6.67	22.87	0.292	29.54	839.0
125 kg N/ha (n_6)	27.07	3.43	19.43	2.65	7.13	23.03	0.309	30.16	893.0
150 kg N/ha (n_7)	28.03	3.45	19.67	2.65	7.43	28.47	0.261	35.90	1054.0
175 kg N/ha (n_8)	32.16	3.66	19.87	2.67	8.93	33.77	0.264	42.70	1144.0
200 kg N/ha (n_9)	36.90	3.90	25.40	2.71	9.30	33.83	0.274	43.13	1772.0
SEm±	1.096	0.084	0.741	0.103	0.330	0.789	0.015	0.846	21.89
CD (0.05)	3.035**	0.232**	2.055**	NS	0.916**	2.186**	0.042**	2.343**	60.63**

** Significant at 1 per cent level; NS - Not significant; RDMP - Root dry matter production
SDMP - Shoot dry matter production; TDMP - Total dry matter production

Table 27. Variation in growth characters of varieties (six month old seedling) at different N levels

Treatment	Height (cm)	Girth (cm)	RDMP (g pl^{-1})	SDMP (g pl^{-1})	R:S ratio	TDMP (g pl^{-1})
1	2	3	4	5	6	7
v_1n_1	26.67	2.93	5.67	19.00	0.333	24.67
v_1n_2	28.00	3.00	7.00	22.00	0.318	29.00
v_1n_3	32.33	3.00	7.00	28.67	0.297	30.67
v_1n_4	36.67	3.17	7.00	24.00	0.291	31.00
v_1n_5	39.67	3.33	7.33	24.00	0.305	31.33
v_1n_6	40.33	3.33	8.33	26.33	0.316	34.66
v_1n_7	40.67	3.67	9.33	26.33	0.354	35.66
v_1n_8	57.00	3.67	14.67	31.33	0.468	46.00
v_1n_9	57.00	3.83	23.33	71.00	0.328	94.33
v_2n_1	19.67	2.17	5.67	16.00	0.354	21.67
v_2n_2	25.00	2.67	6.00	16.00	0.375	22.00
v_2n_3	27.00	2.67	6.00	25.33	0.236	31.33
v_2n_4	28.33	2.83	6.67	25.67	0.259	32.24
v_2n_5	29.00	2.83	8.33	27.00	0.307	35.33
v_2n_6	30.67	3.00	8.67	27.67	0.313	36.24
v_2n_7	37.00	3.17	9.00	28.33	0.317	37.33
v_2n_8	37.67	2.00	9.00	31.33	0.290	40.33
v_2n_9	52.00	3.00	14.00	51.33	0.272	65.33
v_3n_1	18.00	3.33	3.67	15.00	0.244	18.67
v_3n_2	19.67	3.50	5.33	15.33	0.347	20.66
v_3n_3	19.67	3.67	5.67	17.67	0.320	23.24
v_3n_4	20.33	3.83	6.33	19.00	0.333	25.33
v_3n_5	27.67	4.00	7.00	21.67	0.323	28.67
v_3n_6	30.33	4.33	7.00	21.67	0.323	28.67
v_3n_7	39.67	4.33	8.33	22.67	0.367	31.00
v_3n_8	46.00	4.83	9.33	25.33	0.368	34.66
v_3n_9	14.33	5.00	10.00	31.00	0.322	41.00
v_4n_1	15.67	2.67	5.33	19.67	0.270	25.00
v_4n_2	21.00	3.00	7.00	21.83	0.328	28.33
v_4n_3	22.33	3.67	7.00	21.33	0.328	28.33
v_4n_4	23.67	3.67	7.67	22.00	0.348	29.67
v_4n_5	24.00	3.80	7.67	23.00	0.333	30.67
v_4n_6	25.33	3.83	8.07	23.33	0.345	31.33
v_4n_7	27.33	4.00	8.67	23.67	0.366	32.24
v_4n_8	32.00	4.00	8.67	26.33	0.329	35.00
v_4n_9	32.33	4.67	9.33	26.67	0.349	36.00
v_5n_1	15.33	2.67	7.00	15.33	0.456	22.33
v_5n_2	20.33	2.83	7.67	22.33	0.343	30.00
v_5n_3	22.33	3.00	7.67	26.00	0.295	33.67
v_5n_4	23.00	3.00	8.00	26.67	0.299	34.67
v_5n_5	31.00	3.50	8.33	28.67	0.290	35.00
v_5n_6	32.00	3.50	8.67	30.00	0.289	38.67
v_5n_7	33.33	3.67	9.67	31.33	0.308	41.00
v_5n_8	36.33	3.83	9.67	38.00	0.254	47.67

Contd.

Table 27. Continued

1	2	3	4	5	6	7
v_5n_9	40.00	4.67	12.00	77.00	0.155	69.00
v_6n_1	16.00	2.33	5.33	16.00	0.333	18.33
v_6n_2	17.00	2.67	5.33	18.00	0.296	23.33
v_6n_3	18.33	2.83	5.67	20.00	0.283	25.67
v_6n_4	22.66	3.00	6.67	20.33	0.328	27.00
v_6n_5	24.00	3.00	6.67	21.67	0.307	28.24
v_6n_6	24.67	3.17	7.00	21.67	0.323	28.67
v_6n_7	25.33	3.17	8.33	26.00	0.320	34.33
v_6n_8	29.33	3.17	9.33	28.33	0.329	37.86
v_6n_9	34.67	4.00	10.67	32.67	0.326	43.24
v_7n_1	15.00	2.83	3.33	13.00	0.254	16.33
v_7n_2	16.67	2.84	4.33	13.33	0.324	17.66
v_7n_3	17.00	3.00	4.67	17.67	0.264	22.24
v_7n_4	17.33	3.17	5.33	17.67	0.306	23.00
v_7n_5	25.00	3.17	5.67	21.33	0.265	27.00
v_7n_6	25.33	3.17	6.33	21.33	0.296	27.66
v_7n_7	26.67	3.17	6.67	22.33	0.298	29.00
v_7n_8	33.00	3.50	6.67	23.33	0.285	30.00
v_7n_9	33.67	3.67	6.67	24.67	0.270	31.24
v_8n_1	12.67	2.63	3.67	13.33	0.275	17.00
v_8n_2	15.00	2.83	5.00	15.67	0.319	20.67
v_8n_3	16.33	2.83	6.00	16.00	0.375	22.00
v_8n_4	16.67	2.83	6.00	17.00	0.352	23.00
v_8n_5	17.33	3.00	6.00	19.33	0.310	25.33
v_8n_6	18.00	3.17	6.00	19.33	0.310	25.33
v_8n_7	22.33	3.17	6.33	21.33	0.267	27.66
v_8n_8	27.33	3.67	6.33	21.33	0.267	27.66
v_8n_9	29.07	3.67	7.00	26.00	0.269	33.00
v_9n_1	18.00	3.00	5.67	14.33	0.395	20.00
v_9n_2	21.67	3.00	6.00	16.67	0.359	22.67
v_9n_3	22.33	3.00	6.00	19.00	0.315	25.00
v_9n_4	24.33	3.33	6.00	19.33	0.310	25.33
v_9n_5	24.33	3.50	6.33	19.33	0.327	25.66
v_9n_6	24.67	3.50	6.67	22.00	0.303	28.67
v_9n_7	25.67	3.67	7.00	23.00	0.304	30.00
v_9n_8	28.33	3.67	7.00	28.33	0.247	35.33
v_9n_9	32.67	4.00	7.67	29.33	0.261	36.00
$v_{10}n_1$	10.33	2.33	2.67	8.67	0.307	11.24
$v_{10}n_2$	15.67	2.67	2.67	8.67	0.307	11.24
$v_{10}n_3$	15.67	2.83	2.67	10.67	0.250	13.24
$v_{10}n_4$	18.33	2.83	2.67	11.33	0.235	14.00
$v_{10}n_5$	20.33	3.00	3.00	18.33	0.163	21.33
$v_{10}n_6$	22.00	3.00	4.67	19.00	0.245	23.67
$v_{10}n_7$	23.00	3.50	8.00	20.00	0.300	26.00
$v_{10}n_8$	23.00	3.50	9.67	24.00	0.250	30.00
$v_{10}n_9$	24.00	4.00	14.00	24.33	0.356	33.00
SEm±	3.467	0.267	0.908	2.495	0.049	2.675
CD (0.05)	9.603**	0.734**	2.515**	6.911**	0.136**	7.409**

** Significant at 1 per cent level
RDMP - Root dry matter production
TDMP - Total dry matter production
SDMP - Shoot dry matter production

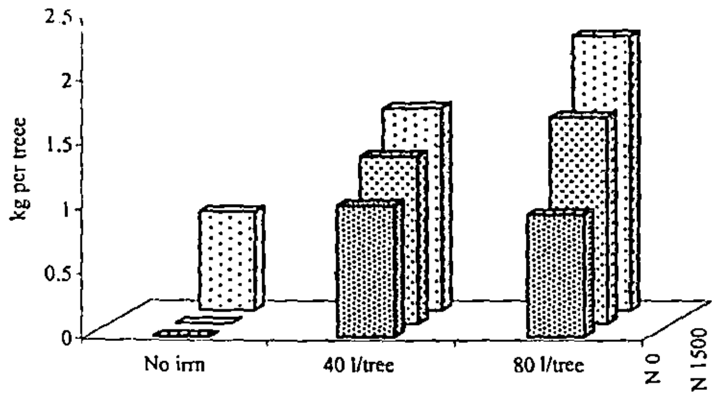

Fig55 Nut yield (kg per tree) of cashew (5year old) at different levels of N and irrigation

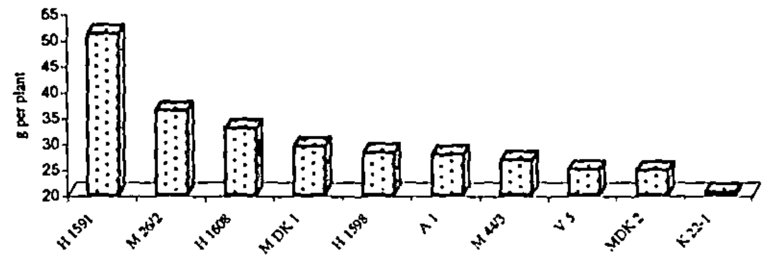

Fig56 Total dry matter production of ten cashew varieties (6 month old seedlings)

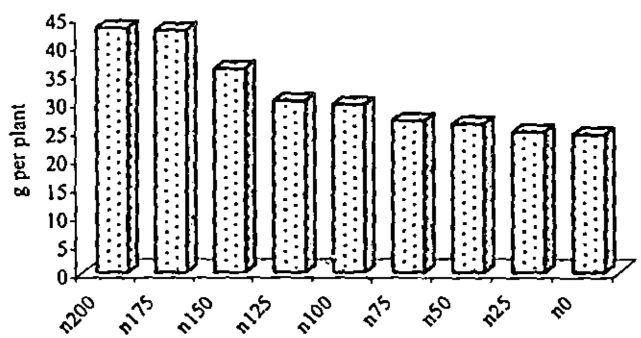

Fig57 Total dry matter production of cashew (six month old seedling) as influenced by N levels

Leaf area per plant

The leaf area per plant varied between varieties (Table 26). It was highest in H-1591 (1589 cm^2) followed by M-26/2 (1053 cm^2) and H-1598 (1009 cm^2) and lowest in V-5 (530 cm^2).

The leaf area increased with increase in level of N up to the highest level (i.e.; from 473 cm^2 with no N application to 1772 cm^2 with N @ 200 kg N ha^{-1}).

b) Content and uptake of nutrients

Leaf N

Leaf N content varied between varieties (Table 28). It was highest in H-1591 (1.764%) followed by A-1 (1.608%) and M-26/2 (1.567%) and lowest in K-22-1 (0.939%).

Leaf N content increased with increase in level of N up to 100 kg ha^{-1} (i.e.; from 0.687% with no N application to 1.394% with N @ 100 kg ha^{-1}). The interaction effect between varieties and N levels was significant with respect to this character (Table 29). In H-1591, the leaf N increased from 0.940 to 3.363 per cent when N level increased from 0 to 200 kg ha^{-1} whereas the corresponding increase in K-22-1 was from 0.677 to 1.493 per cent.

Leaf P

Leaf P content varied between varieties (Table 28). It was highest in M-44/3 (0.115%) followed by M-26/2 (0.105%) and lowest in H-1591 (0.028%). The leaf P content did not change either due to levels of N or due to its interaction with varieties.

Leaf K

The leaf K content varied between varieties (Table 28). The leaf K content was highest in H-1591 (1.531%) followed by MDK-1 (1.410%) and M-26/2 (1.240%) and lowest in A-1 (0.741%).

Leaf K content increased with increase in levels of N upto 200 kg N ha^{-1} (i.e.; from 0.63% with no N application to 1.21% with N @ 200 kg ha^{-1}). Leaf K content did not differ due to the interaction between variety and levels of N.

N uptake

The N uptake varied between varieties (Table 28). The N uptake was highest (Fig. 59) by H-1591 (395.1 mg pl^{-1}) followed by M-26/2 (292.8 mg pl^{-1}) and H-1608 (221.3 mg pl^{-1}) and lowest by K-22-1 (104.5 mg pl^{-1}).

N uptake increased with increase in levels of N up to (Fig. 60) 200 kg ha^{-1} (i.e.; from 60.1 mg pl^{-1} with no N application to 481.3 mg pl^{-1} with N @ 200 kg ha^{-1}). The N uptake did not differ due to the interaction between variety and N.

P uptake

P uptake did not differ due to varieties, levels of N or due to their interactions.

K uptake

The K uptake differed between varieties (Table 28). It was highest by M-26/2 (30.3 mg pl^{-1}) followed by H-1591 (27.1 mg pl^{-1}). The lowest K uptake was observed in seedlings of A-1 (12.29 mg pl^{-1}).

The K uptake increased with increase in levels of N up to 200 kg N ha^{-1} (i.e.; from 3.91 mg pl^{-1} with no N application to 44.9 mg pl^{-1} with N @ 200 kg ha^{-1}). Variety-N interaction effect was significant on K uptake (Table 29). The K uptake of H-1591 increased from 2.1 to 98.3 mg pl^{-1} when N level increased from 0 to 200 kg ha^{-1} whereas the corresponding increase in K-22-1 was from 1.3 to 18.1 mg pl^{-1}.

N use efficiency

N use efficiency varied between varieties and N regimes. The N use efficiency was highest (Fig. 61) with the variety H-1598 (31.84%) followed by V-5 (31.83%) and lowest with K-22-1 (15.18%).

N use efficiency decreased with increasing levels of N (Fig. 62). It decreased from 28.41 to 22.49 per cent when level increased from 25 to 150 kg ha^{-1}.

Tolerance rating of varieties to N deficient soils

The component relationship of ten varieties for testing tolerance to N deficient soils was worked out as follows.

$$y = 0.0180 x_1 - 0.089x_2 - 0.007x_3 + 1.198x_4 - 27.75x_5 - 3.433x_6 - 0.8701 \quad \text{(Eqn-II)}$$

$(R^2 = 0.9577)$

where

x_1 - Shoot dry matter production

x_2 - Total dry matter production

x_3 - Leaf area

x_4 - Leaf N

x_5 - Leaf P

x_6 - Leaf K

(The above observations were recorded from a six month old seedling at four months after imposing N deficiency).

The median was worked out using the following formula

$$M = l + \left(\frac{N}{2} - m\right)\frac{1}{cf}$$

M - Median of the frequency distribution

l - Lowest value of median class

N - Total number of observations

m - Cumulative frequency of the class above the median class

cf - Cumulative frequency

Accordingly, the index (median of the frequency distribution) was arrived as -0.479, to classify the varieties as tolerant or sensitive. To classify the tolerant varieties as highly tolerant and moderately tolerant another demarcating point was arrived using the following formula.

$$M = l + \left(\frac{3N}{4} - m\right)\frac{1}{cf}$$

Accordingly the index for this classification was arrived as 0.01. To classify the sensitive varieties to moderately sensitive and highly sensitive, the demarcating point was arrived using the following formula.

$$M = 1 + \frac{N}{4} - m \frac{1}{cf}$$

Using Eqn-II, the tolerance index of the varieties were arrived. Accordingly the varieties H-1591 and M-26/2 were rated as highly tolerant, V-5 and H-1598 as moderately tolerant and M-44/3 and H-1608 as moderately sensitive to N deficient soil (Table 40). The principal component analysis confirmed the superiority of H-1591 and M-26/2 over the others to tolerate N deficient soils.

Exp. IV. Tolerance of cashew varieties to P deficient soils

Relative tolerance of ten cashew varieties to P deficient soils was studied in green house to identify varieties suitable for P deficient environments. The results obtained are presented below.

a) Growth characters

Seedling height

The seedling height varied considerably between varieties (Table 30). It was highest with the variety H-1591 (36.18 cm) followed by H-1608 (25.66 cm) and M-26/2 (23.85 cm) and lowest with K-22-1 (19.55 cm).

Table 28. Variation in content and uptake of nutrients (N, P and K) in relation to varieties (six month old seedling) and N levels

Treatment	Leaf N (%)	Leaf P (%)	Leaf K (%)	N Uptake mg pl^{-1}	P Uptake mg pl^{-1}	K Uptake mg pl^{-1}
Varieties						
H-1591	1.764	0.028	1.531	395.1	41.3	27.10
M-26/2	1.567	0.105	1.240	292.8	2.45	30.30
H-1598	1.187	0.025	1.070	173.1	3.04	16.31
MDK-1	1.010	0.019	1.410	149.1	2.08	16.61
H-1608	1.038	0.019	1.160	221.3	2.90	24.88
M-44/3	1.068	0.115	1.130	133.5	8.20	23.41
V5	1.254	0.063	0.943	161.5	1.19	17.48
MDK-2	1.354	0.059	0.890	173.2	3.20	12.31
A-1	1.608	0.054	0.741	220.4	8.90	12.29
K-22-1	0.939	0.046	0.843	104.5	4.50	12.40
SEm±	0.031	0.003	0.030	10.1	0.327	1.800
CD (0.05)	0.087**	0.008**	0.080**	31.1**	NS	5.430**
N levels						
0 kg N ha^{-1}	0.687	0.031	0.63	60.1	0.28	3.9
25 kg N ha^{-1}	0.988	0.038	0.82	99.4	0.39	6.5
50 kg N ha^{-1}	1.192	0.043	0.98	118.3	0.52	10.6
75 kg N ha^{-1}	1.299	0.063	1.11	151.4	1.01	13.5
100 kg N ha^{-1}	1.394	0.078	1.14	171.8	1.31	17.6
125 kg N ha^{-1}	1.397	0.081	1.15	195.3	1.92	21.3
150 kg N ha^{-1}	1.467	0.093	1.17	228.5	2.83	24.5
175 kg N ha^{-1}	1.533	0.098	1.19	283.9	4.65	32.6
200 kg N ha^{-1}	1.553	0.099	1.21	481.3	9.01	44.9
SEm±	0.029	0.009	0.200	9.810	0.311	1.700
CD (0.05)	0.082**	NS	0.800**	31.88**	NS	5.800**

**Significant at 1 per cent level

Table 29. Variation in leaf N content and K uptake of varieties (six month old seedling) at different N levels

Treatment Variety/N levels	Leaf N (%)	K Uptake mg pl^{-1}
1	2	3
v_1n_1	0.940	2.1
v_1n_2	1.153	8.3
v_1n_3	1.170	9.1
v_1n_4	1.427	14.5
v_1n_5	1.600	18.7
v_1n_6	1.713	27.8
v_1n_7	2.280	28.8
v_1n_8	2.290	41.0
v_1n_9	3.363	98.3
v_2n_1	0.933	4.7
v_2n_2	1.090	7.8
v_2n_3	1.497	14.9
v_2n_4	1.617	19.2
v_2n_5	1.700	23.6
v_2n_6	1.767	33.9
v_2n_7	1.773	34.3
v_2n_8	1.847	67.8
v_2n_9	1.880	74.3
v_3n_1	0.703	2.9
v_3n_2	0.890	3.8
v_3n_3	0.910	4.1
v_3n_4	0.950	8.3
v_3n_5	0.960	18.0
v_3n_6	1.057	21.1
v_3n_7	1.193	26.7
v_3n_8	1.587	32.5
v_3n_9	2.433	33.9
v_4n_1	0.543	1.6
v_4n_2	0.877	2.5
v_4n_3	0.887	7.4
v_4n_4	0.903	15.8
v_4n_5	0.943	18.9
v_4n_6	0.980	22.5
v_4n_7	1.037	24.7
v_4n_8	1.200	28.4
v_4n_9	1.723	33.6
v_5n_1	0.630	9.3
v_5n_2	0.723	15.5
v_5n_3	0.810	18.5
v_5n_4	0.957	19.2
v_5n_5	1.040	21.2
v_5n_6	1.197	27.4
v_5n_7	1.230	29.6
v_5n_8	1.257	37.1
v_5n_9	1.497	55.9

Contd.

Table 29. Continued

1	2	3
v_6n_1	0.337	9.3
v_6n_2	0.740	16.2
v_6n_3	0.747	17.5
v_6n_4	0.743	21.6
v_6n_5	1.213	24.8
v_6n_6	1.213	26.3
v_6n_7	1.297	29.6
v_6n_8	1.370	35.7
v_6n_9	1.570	43.0
v_7n_1	0.330	7.1
v_7n_2	0.980	9.1
v_7n_3	1.120	13.4
v_7n_4	1.230	14.2
v_7n_5	1.277	18.3
v_7n_6	1.427	19.0
v_7n_7	1.583	22.3
v_7n_8	1.613	29.0
v_7n_9	1.833	32.3
v_8n_1	0.870	2.6
v_8n_2	1.010	4.4
v_8n_3	1.253	7.6
v_8n_4	1.283	9.7
v_8n_5	1.402	12.8
v_8n_6	1.543	15.1
v_8n_7	1.543	17.8
v_8n_8	1.637	19.8
v_8n_9	1.823	26.6
v_9n_1	0.910	3.5
v_9n_2	1.087	4.8
v_9n_3	1.497	5.0
v_9n_4	1.507	8.6
v_9n_5	1.513	10.7
v_9n_6	1.543	15.0
v_9n_7	1.720	17.4
v_9n_8	1.753	22.7
v_9n_9	2.643	26.7
$v_{10}n_1$	0.677	1.3
$v_{10}n_2$	0.687	2.4
$v_{10}n_3$	0.767	3.6
$v_{10}n_4$	0.837	4.8
$v_{10}n_5$	0.847	8.5
$v_{10}n_6$	0.860	11.6
$v_{10}n_7$	0.933	12.1
$v_{10}n_8$	1.347	15.7
$v_{10}n_9$	1.493	18.1
SEm±	0.094	2.7
CD (0.05)	0.262**	8.9**

**Significant at 1 per cent level

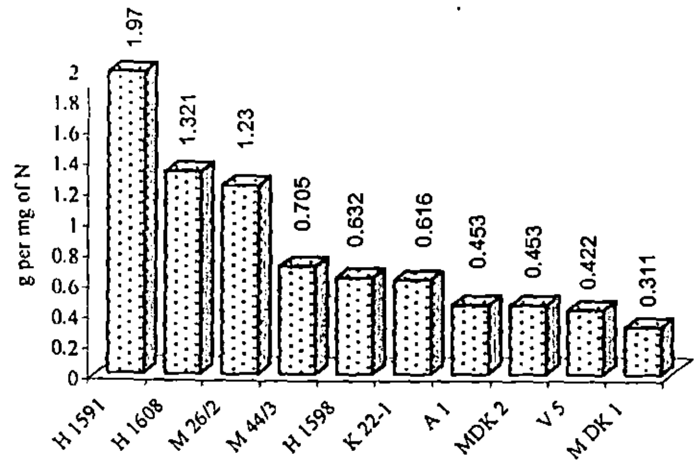

Fig58 Response of cashew varieties(six month old seedlings) to applied N

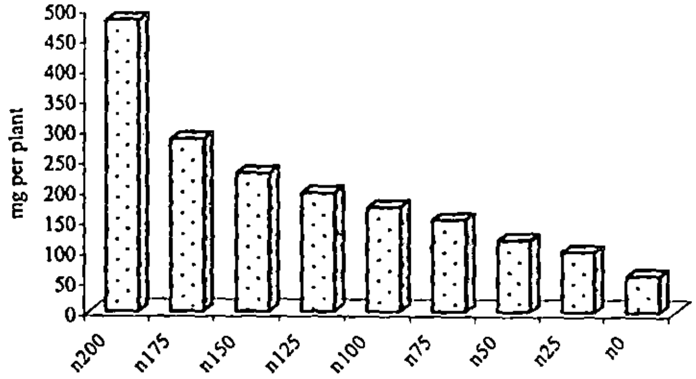

Fig60 Nitrogen uptake of cashew (six month old seedling) as influenced by N levels

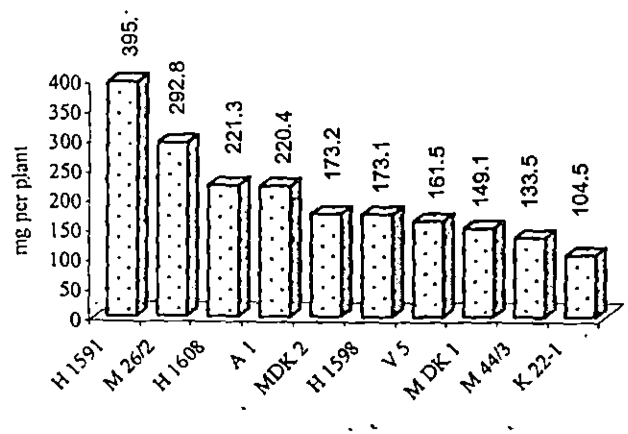

Fig59 Nitrogen uptake of cashew varieties (six month old seedling)

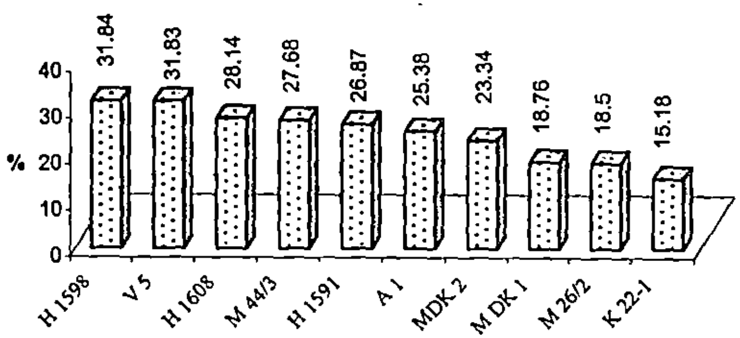

Fig61 N use efficiency of cashew varieties (six month old seedling)

The seedling height increased with increase in levels of P upto 20 kg P_2O_5 ha^{-1} (i.e.; from 16.37 cm with no P application to 23.00 cm with P @ 20 kg P_2O_5 ha^{-1}). The interaction effect between varieties and P levels was significant with respect to this character (Table 31). In H-1591, the seedling height increased from 24.67 to 48.33 cm when P level was increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in H-1598 was from 16.33 to 25.0 cm.

Seedling girth

There was considerable variation in seedling girth between varieties (Table 30). It was highest with the variety H-1591 (4.24 cm) followed by MDK-1 (3.78 cm) and MDK-2 (3.74 cm) and lowest in A-1 (3.15 cm).

The seedling girth increased with increase in level of P (i.e.; from 3.17 cm with no P application to 3.82 cm with P @ 80 kg P_2O_5 ha^{-1}). The interaction effect between varieties and P levels was significant with respect to this character (Table 31). In A-1, the seedling girth increased from 1.5 to 4.0 cm when P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in H-1591 was from 3.33 to 4.83 cm.

Number of leaves

The leaf number varied between varieties (Table 30). It was highest with H-1591 (20.56) followed by M-44/3 (16.44) and MDK-1 (16.26) and lowest with K-22-1 (13.70).

Leaf number increased with increase in levels of P upto 70 kg P_2O_5 ha^{-1} (i.e.; from 12.7 with no P application to 17.1 with P @ 70 kg P_2O_5 ha^{-1}). The interaction effect between varieties and P levels was significant with respect to this character (Table 31). In H-1591, the leaf production increased from 12.33 to 29.00 when P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in H-1598 was from 12.0 to 18.0.

Internodal length

There was variation in internodal length between varieties (Table 30). It was highest with H-1591 (3.07 cm) followed by M-44/3 (3.03 cm) and H-1598 (2.87 cm) and lowest with K-22-1 (2.44 cm).

The internodal length did not vary between levels of P. There was significant interaction between varieties and P levels with respect to this character (Table 31). In H-1598, internodal length increased from 2.00 to 3.67 cm when the P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in M-44/3 was from 2.83 to 3.33 cm.

Root dry matter production (RDMP)

RDMP varied between varieties (Table 30). It was highest with H-1591 (9.04 g pl^{-1}) followed by M-26/2 (7.0 g pl^{-1}) and M-44/3 (6.85 g pl^{-1}) and lowest with H-1608 (5.33 g pl^{-1}).

RDMP increased with increase in level of P upto the highest level (i.e.; from 5.47 g pl^{-1} with no P application to 8.97 g pl^{-1} with P @ 80 kg P_2O_5 ha^{-1}). The interaction effect between varieties and P levels was significant on RDMP (Table 31). In K-22-1, RDMP increased from 3.67 to 11.67 g pl^{-1} when P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in H-1608 was from 4.0 to 6.67 g pl^{-1}.

Shoot dry matter production (SDMP)

There was variation in SDMP between varieties (Table 30). It was highest with H-1591 (32.15 g pl^{-1}) and lowest with H-1608 (20.40 g pl^{-1}).

SDMP increased with increase in level of P upto 70 kg P_2O_5 ha^{-1} (i.e.; from 17.73 g pl^{-1} with no P application to 28.83 g pl^{-1} with P @ 70 kg P_2O_5 ha^{-1}). The interaction between varieties and P levels was significant on SDMP (Table 31). In V-5, SDMP increased from 18.67 to 43.67 g pl^{-1} when P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in H-1598 was from 20.00 to 25.33 g pl^{-1}.

Root : shoot ratio (R:S ratio)

R:S ratio varied between varieties (Table 30). It was highest with M-26/2 (0.317) followed by M-44/3 (0.309) and K-22-1 (0.305) and lowest with V-5 (0.230).

R:S ratio decreased with increase in levels of P (i.e.; from 0.318 with no P application to 0.241 with P @ 70 kg P_2O_5 ha^{-1}). The interaction effect between varieties and P levels was significant with respect to this character (Table 31). In H-1591, the R:S ratio decreased from 0.307 to 0.283 when P level increased from 0 to 70 kg P_2O_5 ha^{-1} whereas the corresponding change in H-1608 was from 0.266 to 0.274.

Total dry matter production (TDMP)

TDMP varied between varieties (Table 30). It was highest with H-1591 (41.03 g pl^{-1}) followed by V-5 (35.11 g pl^{-1}) and A-1 (30.37 g pl^{-1}) and lowest with H-1608 (26.25 g pl^{-1}) (Fig. 64).

TDMP increased with increase in level of P upto 80 kg P_2O_5 ha^{-1} (i.e.; from 22.56 g pl^{-1} with no P application to 38.07 g pl^{-1} with P @ 80 kg P_2O_5 ha^{-1}) (Fig. 65). The interaction effect between varieties and P levels was significant with respect to this character (Table 31). In M-44/3 TDMP increased from 18.0 to 49.67 g pl^{-1} when P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in H-1598 was from 25.0 to 33.0 g pl^{-1}.

Response of varieties to applied P

The response of ten varieties to applied P is presented in Fig. 66. The highest response was observed with M-44/3 (5.14 g per mg of P) followed by V-5 (5.09 g per mg of P) and H-1591 (4.51 g per mg of P). The response was lowest with the variety H-1608 (1.89 g per mg of P).

Leaf area per seedling

The leaf area per seedling varied between varieties (Table 30). It was highest with H-1591 (1167 cm^2) followed by H-1608(653 cm^2) and MDK-1 (650 cm^2) and lowest with K-22-1 (416 cm^2).

Leaf area per seedling increased with increase in level of P upto 80 kg P_2O_5 ha^{-1} (i.e.; from 419 cm^2 with no P application to 742 cm^2 with 80 kg P_2O_5 ha^{-1}).

b) Content and uptake of nutrients

Leaf N

The N content of leaf varied between varieties (Table 32). It was highest in M-26/2 (0.796%) followed by H-1598 (0.766%) and V-5 (0.619%) and lowest in H-1591 (0.391%).

Leaf N content increased with increase in level of P upto 80 kg P_2O_5 ha^{-1} (i.e.; from 0.256% with no P application to 0.812 % with 80 kg P_2O_5 ha^{-1}). The interaction effect between varieties and P levels was significant with respect to this character (Table 33). In V-5, the leaf N content increased from 0.093 to 0.960 per cent when P level increased from 0 to 80 kg P_2O_5 ha^{-1} whereas the corresponding increase in MDK-1 was from 0.247 to 0.687 per cent.

Table 30. Variation in growth characters in relation to varieties (six month old seedling) and P levels

Treatment	Height (cm)	Girth (cm)	No. of leaves	Internodal length (cm)	RDMP g pl^{-1}	SDMP g pl^{-1}	R:S ratio	TDMP g pl^{-1}	Leaf area per seedling (cm^2 pl^{-1})
Varieties									
H-1591 (v_1)	36.18	4.24	20.56	3.07	9.04	32.15	0.288	41.03	1167
M-26/2 (v_2)	23.85	3.30	14.74	2.65	7.00	21.11	0.317	27.92	605
H-1598 (v_3)	22.25	3.65	15.19	2.87	6.19	23.04	0.263	28.66	607
MDK-1 (v_4)	23.25	3.78	16.26	2.82	6.78	21.89	0.294	28.44	650
H-1608 (v_5)	25.66	3.33	16.04	2.59	5.33	20.40	0.261	26.25	653
M-44/3 (v_6)	22.51	3.46	16.44	3.03	6.85	21.48	0.309	27.82	528
V5 (v_7)	21.03	3.20	14.56	2.61	6.67	29.00	0.230	35.11	513
MDK-2 (v_8)	22.66	3.74	14.56	2.83	6.00	20.44	0.296	26.44	465
A-1 (v_9)	20.44	3.15	14.52	2.67	6.44	23.41	0.277	30.37	476
K-22-1 (v_{10})	19.55	3.30	13.70	2.44	6.11	20.44	0.305	26.55	416
SEm±	0.052	0.087	0.597	0.108	0.253	0.603	0.014	0.454	5.960
CD (0.05)	0.741**	0.241**	1.653**	0.301**	0.699**	1.672**	0.039**	1.258**	16.53**
P levels									
0 kg P_2O_5 ha^{-1} (p_1)	16.37	3.17	12.70	2.53	5.47	17.73	0.318	22.56	419
10 kg P_2O_5 ha^{-1} (p_2)	20.60	3.30	14.20	2.55	5.77	18.53	0.311	25.60	524
20 kg P_2O_5 ha^{-1} (p_3)	23.00	3.35	14.83	2.65	6.20	19.97	0.309	26.53	551
30 kg P_2O_5 ha^{-1} (p_4)	23.53	3.37	15.83	2.68	6.37	21.03	0.300	27.67	597
40 kg P_2O_5 ha^{-1} (p_5)	24.13	3.52	15.87	2.77	6.43	22.63	0.284	27.40	599
50 kg P_2O_5 ha^{-1} (p_6)	24.53	3.62	15.93	2.85	6.73	24.93	0.269	29.06	618
60 kg P_2O_5 ha^{-1} (p_7)	25.86	3.70	16.37	2.90	6.87	27.27	0.254	31.66	651
70 kg P_2O_5 ha^{-1} (p_8)	27.50	3.82	17.10	2.92	6.97	28.83	0.241	35.80	700
80 kg P_2O_5 ha^{-1} (p_9)	28.16	3.82	18.07	2.98	8.97	29.10	0.308	38.07	742
SEm±	0.703	0.082	0.566	0.096	0.239	0.572	0.013	0.431	5.66
CD (0.05)	1.947**	0.228**	1.568**	NS	0.663**	1.586**	0.037**	1.193**	15.68**

** Significant at 1 per cent level RDMP - Root dry matter production; SDMP - Shoot dry matter production
NS Not significant TDMP - Total dry matter production

Table 31. Variation in growth characters of varieties (six month old seedling) at different P levels

Treatment	Height (cm)	Girth (cm)	No. of leaves	Internodal length (cm)	RDMP g pl^{-1}	SDMP g pl^{-1}	R:S ratio	TDMP g pl^{-1}
1	2	3	4	5	6	7	8	9
v_1p_1	24.67	3.33	12.33	2.67	6.67	21.67	0.307	28.24
v_1p_2	30.67	3.67	17.33	2.83	6.67	26.00	0.256	32.67
v_1p_3	33.00	4.17	18.67	3.00	7.67	28.67	0.267	36.24
v_1p_4	33.33	4.17	19.00	3.00	8.00	28.67	0.279	36.67
v_1p_5	33.67	4.33	20.67	3.00	8.67	29.33	0.295	38.00
v_1p_6	35.33	4.50	21.33	3.00	9.00	30.33	0.296	39.33
v_1p_7	42.67	4.67	21.67	3.00	10.67	38.33	0.278	49.00
v_1p_8	44.00	4.67	25.00	3.33	12.00	42.33	0.283	54.33
v_1p_9	48.33	4.83	29.00	3.83	12.00	44.00	0.283	56.00
v_2p_1	14.67	2.83	8.67	2.33	4.67	13.33	0.350	18.00
v_2p_2	19.67	3.00	13.67	2.50	6.37	16.00	0.395	22.33
v_2p_3	22.00	3.00	14.67	2.50	6.67	18.67	0.357	25.24
v_2p_4	23.00	3.00	15.00	2.50	6.67	20.33	0.328	27.00
v_2p_5	24.33	3.17	15.33	2.50	7.00	20.67	0.338	27.67
v_2p_6	24.67	3.33	15.33	2.67	7.67	22.33	0.343	30.00
v_2p_7	25.00	3.50	15.67	2.83	7.67	24.33	0.315	32.00
v_2p_8	27.33	3.67	16.33	3.00	7.67	26.33	0.291	34.00
v_2p_9	34.00	3.83	18.00	3.00	8.67	28.00	0.309	34.67
v_3p_1	16.33	3.17	12.00	2.00	5.00	20.00	0.250	25.00
v_3p_2	19.33	3.33	13.33	2.50	5.33	21.33	0.249	26.66
v_3p_3	21.00	3.50	14.00	2.65	5.33	22.00	0.242	27.33
v_3p_4	22.00	3.50	14.67	2.67	5.67	22.67	0.250	28.24
v_3p_5	23.33	3.67	14.67	2.83	6.00	23.67	0.260	29.67
v_3p_6	24.00	3.67	15.00	3.00	6.33	24.00	0.263	30.33
v_3p_7	24.33	3.83	17.00	3.00	6.67	24.00	0.277	30.67
v_3p_8	25.00	3.83	18.00	3.50	7.67	24.33	6.315	32.00
v_3p_9	25.00	4.33	18.00	3.67	7.67	25.33	0.302	33.00
v_4p_1	18.33	3.17	12.67	2.17	5.00	13.00	0.384	18.00
v_4p_2	18.67	3.17	13.00	2.17	5.33	17.67	0.358	24.24
v_4p_3	20.00	3.50	15.00	2.33	6.67	19.67	0.339	26.24
v_4p_4	23.00	3.67	15.00	2.50	6.67	21.00	0.317	27.67
v_4p_5	24.33	3.67	16.33	2.67	7.00	21.33	0.328	28.33
v_4p_6	25.00	3.83	17.00	3.33	7.00	24.00	0.291	31.00
v_4p_7	26.33	3.87	17.33	3.33	7.67	25.67	0.298	33.24
v_4p_8	26.67	4.00	20.00	3.33	7.67	26.00	0.295	33.67
v_4p_9	27.00	4.17	20.00	3.50	8.00	28.67	0.281	36.67
v_5p_1	21.00	2.83	12.67	1.83	4.00	15.33	0.266	19.33
v_5p_2	23.67	3.00	13.33	2.33	4.33	16.33	0.265	20.66
v_5p_3	24.00	3.17	14.00	2.17	5.00	17.67	0.282	22.67
v_5p_4	24.33	3.17	15.00	2.67	5.00	19.00	0.263	24.00
v_5p_5	25.67	3.17	15.67	2.67	5.33	21.00	0.253	26.33
v_5p_6	26.00	3.33	15.67	2.67	5.33	22.67	0.235	28.00
v_5p_7	26.67	3.50	16.33	2.83	6.00	23.33	0.257	29.33
v_5p_8	29.67	3.83	19.33	3.00	6.33	24.00	0.263	30.33

Contd.

Table 31. Continued

1	2	3	4	5	6	7	8	9
v_5p_9	29.67	4.00	22.33	3.17	6.67	24.33	0.274	31.00
v_6p_1	23.33	3.00	11.67	2.83	5.00	13.00	0.384	18.00
v_6p_2	18.00	3.17	14.67	2.83	5.00	13.67	0.365	18.67
v_6p_3	21.33	3.17	14.67	2.83	5.33	15.33	0.347	20.66
v_6p_4	23.00	3.17	15.33	2.83	6.00	18.33	0.327	24.33
v_6p_5	23.33	3.17	17.00	3.17	6.67	19.00	0.351	25.67
v_6p_6	23.67	3.50	17.67	3.17	7.00	20.67	0.338	27.67
v_6p_7	25.67	3.67	19.00	3.17	7.33	22.00	0.333	29.33
v_6p_8	27.00	4.17	19.00	3.17	8.33	32.67	0.254	41.00
v_6p_9	27.33	4.17	19.00	3.33	11.00	38.67	0.284	49.67
v_7p_1	14.00	2.33	9.33	2.33	4.00	18.67	0.214	22.67
v_7p_2	18.00	2.83	11.33	2.50	4.67	19.00	0.245	23.67
v_7p_3	19.33	2.83	12.00	2.50	5.67	20.33	0.278	26.00
v_7p_4	19.67	3.17	12.67	2.67	6.00	24.33	0.246	30.33
v_7p_5	21.00	3.33	15.67	2.67	6.67	26.00	0.256	32.67
v_7p_6	22.33	3.33	16.00	2.67	6.67	31.00	0.215	37.67
v_7p_7	25.00	3.67	16.67	2.67	7.67	36.00	0.213	42.67
v_7p_8	25.00	3.67	17.33	3.00	8.33	42.00	0.198	50.33
v_7p_9	25.00	3.67	20.00	3.00	10.33	43.67	0.236	54.00
v_8p_1	17.00	3.00	10.67	2.17	3.67	12.33	0.291	16.00
v_8p_2	18.67	3.17	11.33	2.17	4.67	15.33	0.304	20.00
v_8p_3	21.33	3.17	13.33	2.33	5.00	18.00	0.277	23.00
v_8p_4	21.67	3.33	13.67	2.50	6.00	18.33	0.327	24.33
v_8p_5	22.67	4.00	15.00	2.67	6.00	20.67	0.290	26.67
v_8p_6	23.00	4.00	15.67	3.00	6.00	22.00	0.272	28.00
v_8p_7	25.33	4.17	17.00	3.33	6.33	22.67	0.279	29.00
v_8p_8	27.00	4.17	17.00	3.67	7.33	23.00	0.318	30.33
v_8p_9	27.33	4.17	17.33	3.67	9.00	24.33	0.369	33.33
v_9p_1	10.33	1.50	11.00	2.20	3.67	17.67	0.208	21.44
v_9p_2	16.00	2.17	11.33	2.50	4.67	19.33	0.241	24.00
v_9p_3	18.67	3.00	14.00	2.50	6.67	21.66	0.307	28.24
v_9p_4	20.00	3.33	14.33	2.67	6.67	22.00	0.303	28.67
v_9p_5	20.33	3.50	15.00	2.67	6.67	22.00	0.303	28.67
v_9p_6	23.00	3.50	15.67	2.83	6.67	22.00	0.303	28.67
v_9p_7	24.33	3.67	15.67	2.83	7.00	22.33	0.313	29.33
v_9p_8	25.00	3.67	16.33	2.83	7.00	23.67	0.295	30.67
v_9p_9	26.33	4.00	17.33	3.00	9.00	24.33	0.369	33.33
$v_{10}p_1$	12.33	3.17	7.00	2.00	3.67	11.67	0.314	15.24
$v_{10}p_2$	14.67	3.17	10.67	2.00	3.67	15.67	0.234	19.24
$v_{10}p_3$	17.00	3.17	12.33	2.17	4.00	17.00	0.235	21.00
$v_{10}p_4$	17.00	3.17	13.33	2.17	5.00	18.00	0.273	23.00
$v_{10}p_5$	18.00	3.17	14.00	2.33	6.00	21.00	0.285	27.00
$v_{10}p_6$	22.67	3.33	15.00	2.50	7.00	21.33	0.328	28.33
$v_{10}p_7$	24.00	3.33	17.00	2.67	7.00	23.33	0.300	30.33
$v_{10}p_8$	24.00	3.33	17.00	2.83	8.00	24.67	0.324	32.67
$v_{10}p_9$	26.33	3.83	17.00	3.33	11.67	24.67	0.432	35.24
SEm±	2.223	0.260	1.790	0.326	0.758	1.811	0.042	1.362
CD (0.05)	6.157**	0.721**	4.958**	0.903**	2.098**	5.016**	0.116**	3.722**

** Significant at 1 per cent level

RDMP - Root dry matter production

TDMP - Total dry matter production

SDMP - Shoot dry matter production

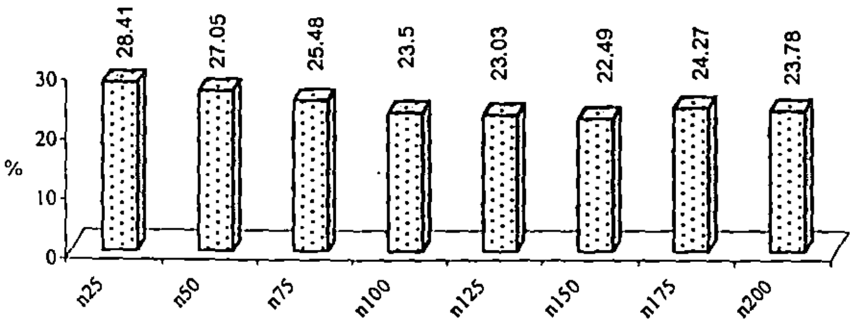

Fig62 N use efficiency of cashew (six month old seedling) as influenced by N levels

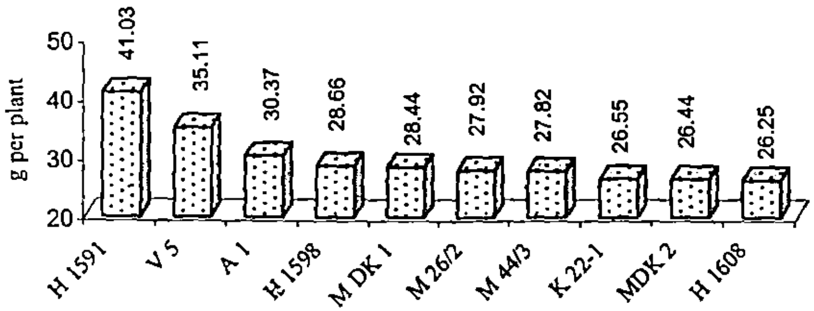

Fig64 Total dry matter production of ten cashew varieties (six month old seedling)

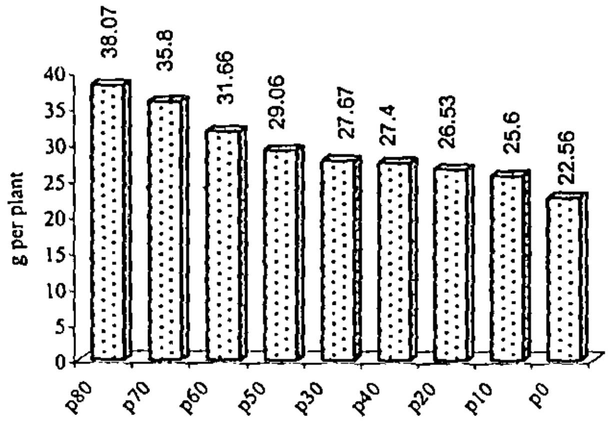

Fig65 Total dry matter production of cashew (six month old seedling) as influenced by P levels

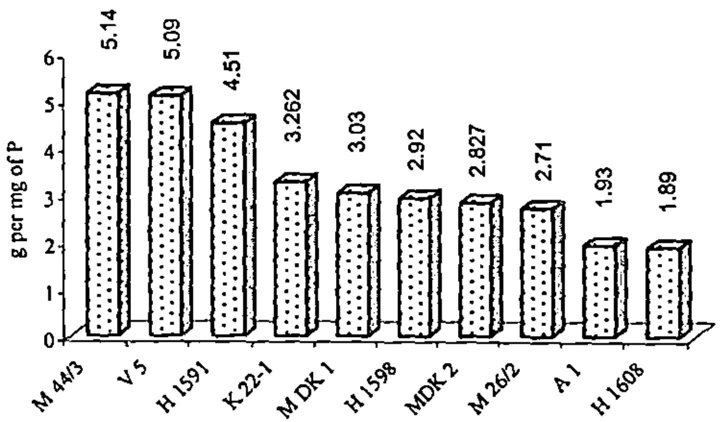

Fig66 Response of cashew varieties (six month old seedlings) to applied P

Leaf P

Leaf P content varied between varieties(Table 32). It was highest in MDK-1 (0.211%) followed by H-1608 (0.176%) and M-44/3 (0.170%) and lowest in K-22-1 (0.054%).

The leaf P content increased with increase in level of P upto 70 kg P_2O_5 ha^{-1} (i.e.; from 0.034 per cent with no P application to 0.118 per cent with 70 kg P_2O_5 ha^{-1}).

Leaf K

The leaf K content varied between varieties (Table 32). It was highest in A-1 (0.853%) followed by MDK-2 (0.778%) and H-1591 (0.689%) and lowest in M-26/2 (0.102%).

The leaf K content increased with increase in level of P upto 80 kg P_2O_5 ha^{-1} (i.e.; from 0.251 per cent with no P application to 1.443 per cent with 80 kg P_2O_5 ha^{-1}).

N uptake

The N uptake did not differ due to varieties or levels of P or due to their interaction.

P uptake

The P uptake did not differ due to varieties or levels of P or due to their interaction.

K uptake

The K uptake varied between varieties (Table 32). It was highest by H-1608 (40.4 mg pl^{-1}) followed by MDK-1 (39.5 mg pl^{-1}) and V-5 (37.8 mg pl^{-1}) and lowest by K-22-1 (14.8 mg pl^{-1}).

K uptake increased with increase in level of P upto the highest level viz. 80 kg P_2O_5 ha^{-1} (i.e.; from 7.1 mg pl^{-1} with no P application to 48.8 mg pl^{-1} with 80 kg P_2O_5 ha^{-1}).

P use efficiency

P use efficiency varied between varieties and P regimes. It was highest (Fig. 67) with the variety H-1591 (14.74%) followed by M-26/2 (13.78%) and lowest with K-22-1 (4.71%).

P use efficiency decreased with increasing levels of P (Fig. 68). It decreased from 9.45 to 8.0 per cent when P level increased from 10 to 80 kg P_2O_5 ha^{-1}.

Tolerance rating of varieties to P deficient soils

The component relationship of ten varieties for testing tolerance to P deficient soils was worked out as follows.

$$y = 0.019x_1 + 0.020x_2 + 0.089x_3 - 1.382x_4 - 3.45x_5 - 0.85x_6 - 3.735 \quad \text{(Eqn-III)}$$

$$(R^2 = 0.998)$$

where

x_1 - Shoot dry matter production

x_2 - Total dry matter production

x_3 - Leaf area

x_4 - Leaf N

x_5 - Leaf P

x_6 - Leaf K

(The above observations were recorded from a six month old seedlings at four months after imposing P deficiency).

Accordingly, the index (median of the frequency distribution) was arrived as -0.42, to classify the varieties as tolerant or sensitive. The index for classification of tolerant varieties to moderately tolerant and highly tolerant, was arrived as 1.097. For classification of sensitive varieties to moderately sensitive and highly sensitive, the index was arrived as -1.183.

Using principal component analysis, the varieties were grouped as highly tolerant, moderately tolerant, moderately sensitive, and highly sensitive. It was found that the variety H-1591 is moderately tolerant, M-26/2, V-5, MDK-1 and MDK-2 are moderately sensitive and A-1, K-22-1, H-1598, H-1608 and M-44/3 are highly sensitive to P deficiency in soils (Table 40).

Exp. V. Tolerance of cashew varieties to K deficient soils

Relative tolerance of ten cashew varieties to K deficient soils was studied in green house to identify varieties suitable for K deficient environments. The results obtained are presented below.

a) Growth characters

Seedling height

The seedling height differed considerably between varieties (Table 34). The seedlings of H-1591 were the tallest (38.74 cm) and K-22-1 the shortest (20.22 cm).

The seedling height increased with increase in level of K upto 150 kg K_2O ha^{-1} (i.e.; from 18.63 cm with no K application to 27.83 cm with 150 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character

Table 32. Variation in content and uptake of nutrients in relation to varieties (six month old seedlings) and P levels

Treatment	Leaf N (%)	Leaf P (%)	Leaf K (%)	N Uptake mg pl^{-1}	P Uptake mg pl^{-1}	K Uptake mg pl^{-1}
Varieties						
H-1591	0.391	0.121	0.689	79.6	22.50	29.1
M-26/2	0.796	0.082	0.102	92.3	65.40	31.2
H-1598	0.766	0.091	0.653	106.5	39.80	19.9
MDK-1	0.424	0.211	0.314	69.8	20.30	39.5
H-1608	0.569	0.176	0.483	73.5	61.30	40.4
M-44/3	0.438	0.170	0.021	58.3	58.60	33.9
V5	0.619	0.069	0.973	126.9	59.60	37.8
MDK-2	0.538	0.121	0.778	75.9	8.95	21.3
A-1	0.543	0.093	0.853	96.8	54.30	27.9
K-22-1	0.530	0.054	0.456	77.5	6.78	14.8
SEm±	0.014	0.250	0.031	6.70	8.20	0.004
CD (0.05)	0.041**	0.088**	0.090**	NS	NS	0.010**
P levels						
0 kg P_2O_5 ha^{-1}	0.256	0.034	0.251	26.4	2.72	7.1
10 kg P_2O_5 ha^{-1}	0.269	0.063	0.436	36.8	12.51	13.4
20 kg P_2O_5 ha^{-1}	0.347	0.074	0.645	43.5	17.56	20.9
30 kg P_2O_5 ha^{-1}	0.490	0.103	0.873	74.3	57.83	24.4
40 kg P_2O_5 ha^{-1}	0.651	0.109	1.000	89.8	62.90	31.4
50 kg P_2O_5 ha^{-1}	0.716	0.112	1.091	133.8	69.30	33.8
60 kg P_2O_5 ha^{-1}	0.766	0.114	1.223	125.3	75.30	39.9
70 kg P_2O_5 ha^{-1}	0.787	0.118	1.325	131.6	79.60	46.7
80 kg P_2O_5 ha^{-1}	0.812	0.120	1.443	142.9	83.90	48.8
SEm±	0.014	0.080	0.030	9.20	7.70	0.40
CD (0.05)	0.039**	0.232**	0.080**	NS	NS	1.10**

** Significant at 1 per cent level; NS Not significant

Table 33. Variation in leaf N content of varieties (six month old seedling) at different P levels

Treatment Variety/P levels	Leaf N %	Treatment Variety/P levels	Leaf N %
v_1p_1	0.217	v_6p_1	0.163
v_1p_2	0.227	v_6p_2	0.277
v_1p_3	0.227	v_6p_3	0.317
v_1p_4	0.320	v_3p_4	0.387
v_1p_5	0.380	v_6p_5	0.393
v_1p_6	0.390	v_6p_6	0.500
v_1p_7	0.473	v_6p_7	0.560
v_1p_8	0.570	v_6p_8	0.577
v_1p_9	0.720	v_6p_9	0.667
v_2p_1	0.570	v_7p_1	0.093
v_2p_2	0.623	v_7p_2	0.180
v_2p_3	0.767	v_7p_3	0.270
v_2p_4	0.810	v_7p_4	0.423
v_2p_5	0.810	v_7p_5	0.837
v_2p_6	0.837	v_7p_6	0.907
v_2p_7	0.927	v_7p_7	0.943
v_2p_8	0.936	v_7p_8	0.960
v_2p_9	1.080	v_7p_9	0.960
v_3p_1	0.333	v_8p_1	0.107
v_3p_2	0.443	v_8p_2	0.173
v_3p_3	0.673	v_8p_3	0.233
v_3p_4	0.900	v_8p_4	0.463
v_3p_5	0.900	v_8p_5	0.510
v_3p_6	0.900	v_8p_6	0.670
v_3p_7	0.903	v_8p_7	0.820
v_3p_8	0.913	v_8p_8	0.903
v_3p_9	0.927	v_8p_9	0.963
v_4p_1	0.247	v_9p_1	0.127
v_4p_2	0.293	v_9p_2	0.190
v_4p_3	0.310	v_9p_3	0.233
v_4p_4	0.330	v_9p_4	0.237
v_4p_5	0.353	v_9p_5	0.560
v_4p_6	0.440	v_9p_6	0.660
v_4p_7	0.627	v_9p_7	0.893
v_4p_8	0.633	v_9p_8	0.933
v_4p_9	0.687	v_9p_9	0.957
v_5p_1	0.217	$v_{10}p_1$	0.147
v_5p_2	0.267	$v_{10}p_2$	0.190
v_5p_3	0.300	$v_{10}p_3$	0.293
v_5p_4	0.337	$v_{10}p_4$	0.433
v_5p_5	0.577	$v_{10}p_5$	0.567
v_5p_6	0.823	$v_{10}p_6$	0.713
v_5p_7	0.850	$v_{10}p_7$	0.720
v_5p_8	0.857	$v_{10}p_8$	0.760
v_5p_9	0.923	$v_{10}p_9$	0.950
SEm±			0.044
CD(0.05)			0.123**

**Significant at 1 per cent level

(Table 35). In H-1591, the seedling height increased from 25.33 to 49.66 cm when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in H-1608 was from 23.67 to 30.33 cm.

Seedling girth

There was considerable variation in seedling girth between varieties (Table 34). The seedling girth was highest with the variety MDK-1 (4.79 cm) and lowest with MDK-2 (3.11 cm).

The seedling girth increased with increase in K upto 200 kg K_2O ha^{-1} (i.e.; from 3.07 cm with no K application to 3.95 cm with 200 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character (Table 35). In K-22-1, the seedling girth increased from 2.33 to 4.17 cm when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in H-1608 was from 3.00 to 4.00 cm.

Number of leaves

The leaf number varied considerably between varieties (Table 34). It was highest (21.96) with the variety H-1591 and lowest with M-44/3 (14.15).

The leaf production increased with increase in level of K upto 150 kg K_2O ha^{-1} (i.e.; from 14.33 with no K application to 17.33 with 150 kg K_2O ha^{-1}).

Internodal length

The internodal length varied considerably between varieties (Table 34). The internodal length was highest with the variety H-1591 (3.05 cm) and lowest with M-44/3 (2.17 cm).

Internodal length increased with increase in level of K up to 200 kg K_2O ha^{-1} (i.e.; from 2.33 cm with no K application to 2.60 cm with 200 kg K_2O ha^{-1}).

Root dry matter production (RDMP)

RDMP differed considerably between varieties (Table 34). The RDMP was highest in the variety H-1591 (9.66 g pl^{-1}) and lowest in V-5 (4.7 g pl^{-1}).

RDMP increased with increase in level of K upto 100 kg K_2O ha^{-1} (i.e.; from 5.96 g pl^{-1} with no K application to 6.9 g pl^{-1} with 100 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character (Table 35). In K-22-1, the RDMP increased from 2.33 to 8.00 g pl^{-1} when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in M-44/3 was from 5.0 to 7.33 g pl^{-1}.

Shoot dry matter production (SDMP)

SDMP was varied considerably between varieties (Table 34). The variety H-1591 had the highest SDMP (29.37 g pl^{-1}) and MDK-2 had the lowest (19.15 g pl^{-1}).

SDMP increased with increase in level of K up to 200 kg K_2O ha^{-1} (i.e.; from 18.17 g pl^{-1} with no K application to 26.7 g pl^{-1} with 200 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character (Table 35). In H-1591, the SDMP increased from 16.0 to 43.0 g pl^{-1} when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in M-44/3 was from 16.67 to 22.67 g pl^{-1}.

Root : shoot ratio (R:S ratio)

R:S ratio did not change between varieties as well as due to levels of K application. But the interaction between variety and K levels was significant with respect to this character (Table 35). In V-5, the R:S ratio increased from 0.157 to 0.305 when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in H-1608 was from 0.321 to 0.323.

Total dry matter production (TDMP)

TDMP differed considerably between varieties (Table 34). The TDMP was highest with the variety H-1591 (39.11 g pl^{-1}) and lowest with K-22-1 (24.59 g pl^{-1}) (Fig. 70).

TDMP increased with increase in level of K upto 200 kg K_2O ha^{-1} (i.e.; from 24.13 g pl^{-1} with no K application to 34.1 g pl^{-1} with 200 kg K_2O ha^{-1}) (Fig. 71). The interaction between variety and K level was significant with respect to this character (Table 35). In H-1591, TDMP increased from 23.33 to 56.00 g pl^{-1} when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in M-44/3 was from 21.67 to 30.33 g pl^{-1}.

Response of varieties to applied K

The response of ten varieties to applied K is presented in Fig. 72. The highest response was observed with H-1591 (1.156 g per mg of K) followed by H-1608 (0.719 g per mg of K) and MDK-1 (0.696 g per mg of K). The response was lowest with the variety M-44/3 (0.306 g per mg of K).

Table 34. Variation in growth characters in relation to varieties (six month old seedling) and K levels

Treatment	Height (cm)	Girth (cm)	No. of leaves	Internodal length (cm)	RDMP ($g\ pl^{-1}$)	SDMP ($g\ pl^{-1}$)	R:S ratio	TDMP ($g\ pl^{-1}$)	Leaf area per plant ($cm^2\ pl^{-1}$)
Varieties									
H-1591 (v_1)	38.74	4.28	21.96	3.05	9.66	29.37	0.354	39.11	1241
M-26/2 (v_2)	27.15	3.67	16.56	2.53	7.48	24.29	0.316	31.82	623
H-1598 (v_3)	27.19	3.44	16.22	2.61	7.37	22.22	0.341	29.63	536
MDK-1 (v_4)	24.70	4.79	17.41	2.41	8.00	23.77	0.338	32.66	603
H-1608 (v_5)	27.07	3.56	14.74	2.48	8.48	25.51	0.336	34.00	451
M-44/3 (v_6)	21.70	3.22	14.15	2.17	6.44	19.56	0.360	26.48	384
V5 (v_7)	20.41	3.33	17.63	2.44	4.70	20.74	0.239	25.48	651
MDK-2 (v_8)	21.33	3.11	14.56	2.52	6.11	19.15	0.330	25.07	375
A-1 (v_9)	22.33	3.33	15.74	2.68	6.00	21.37	0.284	27.11	421
K-22-1 (v_{10})	20.22	3.26	14.56	2.20	5.29	19.67	0.279	24.59	410
SEm±	0.652	0.094	0.582	0.105	0.303	0.604	0.018	0.649	11.88
CD (0.05)	1.806**	0.267**	1.612**	0.291**	0.838**	1.672**	NS	1.797**	52.10**
K levels									
0 kg $K_2O\ ha^{-1}$ (k_1)	18.63	3.07	14.33	2.33	5.96	18.17	0.329	24.13	391
25 kg $K_2O\ ha^{-1}$ (k_2)	23.06	3.42	14.43	2.43	6.63	21.50	0.308	28.20	442
50 kg $K_2O\ ha^{-1}$ (k_3)	23.46	3.43	15.33	2.45	6.80	21.67	0.314	28.47	477
75 kg $K_2O\ ha^{-1}$ (k_4)	24.46	3.43	15.96	2.47	6.90	22.00	0.313	28.93	497
100 kg $K_2O\ ha^{-1}$ (k_5)	24.76	3.43	15.96	2.47	7.06	23.10	0.297	30.43	539
125 kg $K_2O\ ha^{-1}$ (k_6)	25.50	3.48	16.80	2.48	7.20	23.43	0.307	30.70	570
150 kg $K_2O\ ha^{-1}$ (k_7)	27.83	3.62	17.33	2.57	7.30	23.70	0.317	30.76	626
175 kg $K_2O\ ha^{-1}$ (k_8)	28.23	3.63	17.96	2.60	7.33	23.70	0.309	31.10	659
200 kg $K_2O\ ha^{-1}$ (k_9)	29.80	3.95	18.47	2.60	7.40	26.70	0.277	34.10	795
SEm±	0.619	0.092	0.552	0.097	0.287	0.573	0.017	0.616	11.27
CD (0.05)	1.713**	0.253**	1.529**	0.276**	0.796**	1.586**	NS	1.705**	31.22**

** Significant at 1 per cent level   NS - Not significant

RDMP - Root dry matter production   SDMP - Shoot dry matter production

TDMP - Total dry matter production

Table 35. Variation in growth characters of varieties (six month old seedling) at different K levels

Treatment	Height (cm)	Girth (cm)	RDMP ($g\ pl^{-1}$)	SDMP ($g\ pl^{-1}$)	R:S ratio	TDMP ($g\ pl^{-1}$)
1	2	3	4	5	6	7
v_1k_1	25.33	4.00	7.33	16.00	0.395	23.33
v_1k_2	30.00	4.00	7.67	24.13	0.315	31.70
v_1k_3	36.00	4.07	8.67	27.00	0.284	34.67
v_1k_4	38.33	4.17	9.00	29.33	0.295	38.00
v_1k_5	38.66	4.17	10.33	29.67	0.303	38.67
v_1k_6	39.33	4.67	11.33	30.00	0.344	40.33
v_1k_7	45.00	4.67	12.00	31.67	0.357	43.00
v_1k_8	46.33	5.17	13.00	33.33	0.360	45.33
v_1k_9	49.66	5.20	13.10	43.00	0.302	56.00
v_2k_1	20.67	3.00	4.67	20.33	0.229	25.00
v_2k_2	21.67	3.00	5.00	21.33	0.234	26.33
v_2k_3	26.67	3.17	5.67	21.67	0.263	27.24
v_2k_4	26.66	3.33	7.33	22.33	0.328	29.26
v_2k_5	28.00	3.67	8.37	22.33	0.374	30.67
v_2k_6	28.33	4.00	8.67	26.33	0.329	35.00
v_2k_7	28.33	4.00	9.67	27.00	0.358	36.67
v_2k_8	31.67	4.16	9.67	28.33	0.314	37.33
v_2k_9	32.33	4.67	9.67	29.00	0.334	38.67
v_3k_1	13.33	3.00	4.00	13.67	0.292	17.67
v_3k_2	20.00	3.17	6.67	17.00	0.392	23.67
v_3k_3	22.00	3.17	7.00	17.67	0.396	24.67
v_3k_4	26.00	3.33	7.00	22.00	0.318	29.00
v_3k_5	27.00	3.67	7.67	24.00	0.319	31.67
v_3k_6	29.33	4.00	8.00	24.30	0.329	32.30
v_3k_7	34.67	4.17	8.33	27.00	0.308	33.33
v_3k_8	36.00	4.16	8.67	27.00	0.321	35.67
v_3k_9	36.33	4.20	9.00	27.33	0.329	36.33
v_4k_1	22.00	3.17	5.67	17.33	0.327	23.00
v_4k_2	22.00	3.33	6.00	20.67	0.290	26.67
v_4k_3	23.00	3.50	6.67	22.00	0.303	28.67
v_4k_4	24.67	3.84	8.00	22.33	0.358	30.33
v_4k_5	24.67	3.84	8.00	24.00	0.333	32.00
v_4k_6	25.00	4.00	9.00	24.33	0.369	33.33
v_4k_7	25.33	4.00	9.00	24.33	0.369	33.33
v_4k_8	27.00	4.17	9.67	26.33	0.367	36.00
v_4k_9	28.67	4.17	10.00	32.67	0.306	42.67
v_5k_1	23.67	3.00	6.00	18.67	0.321	24.67
v_5k_2	25.00	3.33	6.67	22.67	0.294	33.24
v_5k_3	25.33	3.33	7.00	23.00	0.304	30.00
v_5k_4	26.00	3.50	7.67	23.67	0.325	31.24
v_5k_5	26.00	3.50	9.00	24.00	0.369	33.00
v_5k_6	28.67	3.67	9.00	24.33	0.369	33.33
v_5k_7	29.00	3.83	10.00	28.00	0.357	38.00
v_5k_8	29.67	3.83	10.00	31.00	0.322	41.00

Contd.

Table 35. Continued

1	2	3	4	5	6	7
v_5k_9	30.33	4.00	11.00	34.00	0.323	45.00
v_6k_1	16.00	2.17	5.00	16.67	0.299	21.67
v_6k_2	19.00	2.67	6.00	17.33	0.346	20.33
v_6k_3	19.33	3.00	6.33	18.00	0.351	24.33
v_6k_4	22.67	3.00	6.33	19.33	0.327	25.66
v_6k_5	24.33	3.17	6.33	20.00	0.316	26.33
v_6k_6	24.67	3.17	6.67	20.00	0.333	26.67
v_6k_7	24.66	3.33	7.00	21.00	0.333	28.00
v_6k_8	26.33	3.67	7.00	21.00	0.333	28.00
v_6k_9	28.33	3.83	7.33	22.67	0.323	30.33
v_7k_1	11.67	2.50	2.67	17.00	0.157	19.67
v_7k_2	14.33	2.50	3.33	17.00	0.195	20.33
v_7k_3	15.00	3.17	3.67	19.00	0.193	22.67
v_7k_4	16.37	3.17	3.67	19.00	0.193	22.67
v_7k_5	19.00	3.33	4.00	21.67	0.184	25.67
v_7k_6	22.33	3.50	5.33	22.67	0.235	28.00
v_7k_7	25.67	3.67	5.67	23.00	0.246	28.67
v_7k_8	28.00	4.00	6.67	23.33	0.285	30.00
v_7k_9	31.33	4.17	7.33	24.00	0.305	31.00
v_8k_1	13.33	1.67	4.33	12.33	0.351	16.66
v_8k_2	16.67	2.67	4.67	15.33	0.304	20.00
v_8k_3	19.00	3.17	5.67	18.67	0.303	23.67
v_8k_4	19.33	3.17	5.67	19.00	0.298	24.67
v_8k_5	21.33	3.33	6.00	20.00	0.300	26.00
v_8k_6	22.67	3.50	6.67	21.00	0.317	27.67
v_8k_7	23.00	3.50	6.67	21.00	0.317	27.67
v_8k_8	23.33	3.50	7.67	22.00	0.348	29.67
v_8k_9	33.33	4.67	7.67	23.00	0.337	30.67
v_9k_1	16.00	2.83	4.00	17.67	0.226	21.67
v_9k_2	19.00	3.17	5.00	19.33	0.258	24.33
v_9k_3	20.67	3.17	5.33	21.67	0.245	27.00
v_9k_4	21.66	3.17	5.67	21.67	0.261	27.24
v_9k_5	22.66	3.33	6.00	22.00	0.272	28.00
v_9k_6	22.00	3.50	6.67	22.00	0.303	28.67
v_9k_7	26.33	3.67	6.67	22.00	0.303	28.67
v_9k_8	26.33	3.67	7.00	22.33	0.313	29.33
v_9k_9	27.00	3.83	7.67	23.67	0.324	31.34
$v_{10}k_1$	9.67	2.33	2.33	11.67	0.199	14.00
$v_{10}k_2$	15.33	2.67	3.33	15.67	0.212	19.00
$v_{10}k_3$	16.33	2.67	3.33	17.00	0.195	20.33
$v_{10}k_4$	16.33	3.00	4.67	18.00	0.259	22.67
$v_{10}k_5$	18.67	3.23	5.00	21.00	0.238	26.00
$v_{10}k_6$	22.67	3.50	6.00	21.33	0.281	27.33
$v_{10}k_7$	25.00	3.50	7.33	23.33	0.305	30.66
$v_{10}k_8$	26.00	4.17	7.67	24.33	0.315	32.00
$v_{10}k_9$	32.00	4.17	8.00	24.67	0.324	32.67
SEm±	1.956	0.289	0.908	1.811	0.054	1.947
CD (0.05)	5.418**	0.801**	2.515**	5.017**	0.151**	5.392**

** Significant at 1 per cent level

RDMP - Root dry matter production

TDMP - Total dry matter production

SDMP - Shoot dry matter production

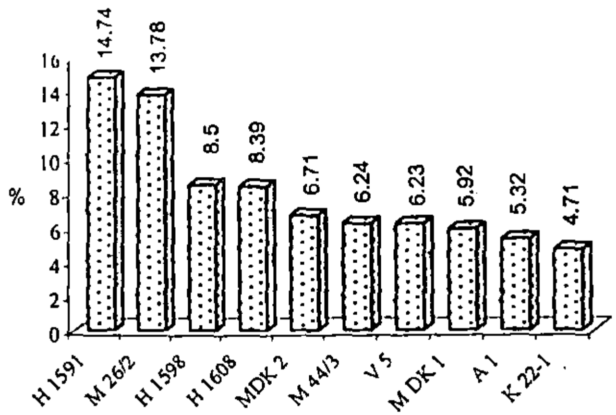

Fig67 Phosphorus use efficiency of cashew varieties(six month old seedling)

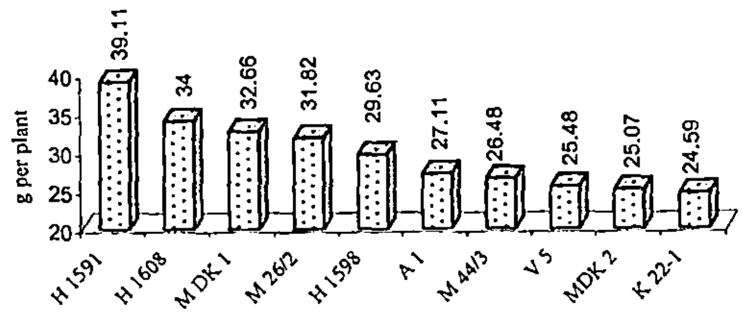

Fig70 Total dry matter production of ten cashew varieties (6 month old seedling)

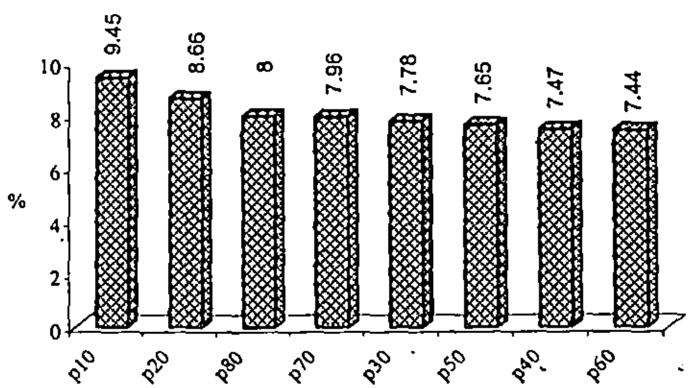

Fig68 Phosphorus use efficiency of cashew (six month old seedlings) as influenced by P levels

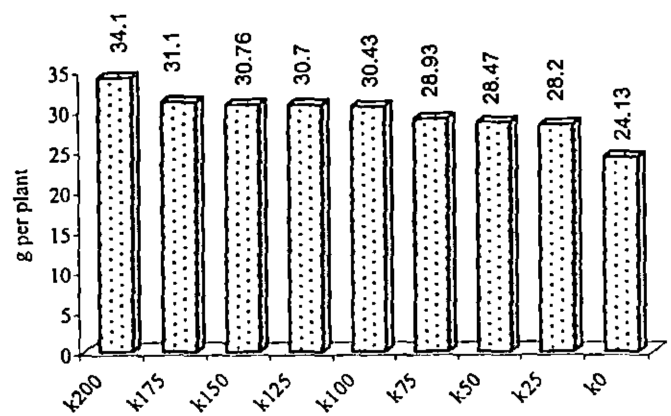

Fig71 Total dry matter production of cashew(six month old seedling) as influenced by K levels

Leaf area per seedling

There was considerable variation in leaf area per seedling between varieties (Table 34). It was highest with the variety H-1591 (1241 cm^2) and lowest with MDK-2 (375 cm^2).

The leaf area per seedling increased with increase in level of K upto 200 kg K_2O ha^{-1} (i.e.; from 391 cm^2 with no K application to 795 cm^2 with 200 kg K_2O ha^{-1}).

b)Content and uptake of nutrients

Leaf N

Leaf N varied considerably between varieties (Table 36). The leaf N content was highest with the variety H-1608 (1.050%) and lowest with MDK-2 (0.825%).

The leaf N content increased with increase in level of K upto 125 kg K_2O ha^{-1} (i.e.; from 0.694% with no K application to 1.008% with 200 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character (Table 37). In M-26/2, the leaf N content increased from 0.250 to 1.137 per cent when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in H-1591 was from 1.017 to 1.073 per cent.

Leaf P

There was considerable difference in leaf P content between varieties (Table 36). The highest leaf P content was noticed with the variety H-1591 (0.16%) and lowest with K-22-1 (0.031%).

The leaf P content increased with increase in level of K upto 200 kg K_2O ha^{-1} (i.e.; from 0.031% with no K application to 0.199% with 200 kg K_2O ha^{-1}).

Leaf K

The leaf K did not vary between varieties or due to levels of K or due to their interaction.

N uptake

The N uptake varied between varieties (Table 36). It was highest with H-1591 (274.1 mg pl^{-1}) followed by H-1608 (250.4 mg pl^{-1}) and A-1 (221.3 mg pl^{-1}).

The N uptake increased with increase in level of K upto the 200 kg K_2O ha^{-1} (i.e.; from 103.7 mg pl^{-1} with no K application to 306.7 mg pl^{-1} with 200 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character (Table 37). In H-1591, the N uptake increased from 116.1 to 529.3 mg pl^{-1} when K level increased from 0 to 200 kg K_2O ha^{-1} whereas the corresponding increase in M-44/3 was from 84.7 to 210.7 mg pl^{-1} .

P uptake

There was variation in P uptake between varieties (Table 36). It was highest with H-1591 (31.0 mg pl^{-1}) followed by M-26/2 (13.3 mg pl^{-1}) and lowest with A-1 (5.3 mg pl^{-1}).

The P uptake increased with increase in levels of K (i.e.; from 2.1 mg pl^{-1} with no K application to 26.2 mg pl^{-1} with 200 kg K_2O ha^{-1}).

K uptake

The K uptake varied between varieties (Table 36). It was highest with the variety H-1591 (201.7 mg pl^{-1}) followed by H-1598 (140.4 mg pl^{-1}) and M-26/2 (127.1 mg pl^{-1}) and lowest with V-5 (70.1 mg pl^{-1}) (Fig. 73).

The K uptake increased with increase in levels of K (Fig. 74) upto 200 kg K_2O ha^{-1} (i.e.; from 54.4 mg pl^{-1} with no K application to 156.2 mg pl^{-1} with 200 kg K_2O ha^{-1}). The interaction between variety and K level was significant with respect to this character (Table 37). In H-1598, K uptake increased from 55.4 to 214.7 mg pl^{-1} when K level increased from 0 and 200 kg K_2O ha^{-1} whereas the corresponding increase in V-5 was from 43.0 to 101.0 mg pl^{-1}.

K use efficiency

K use efficiency varied between varieties and K regimes. It was highest with the variety H-1591 (26.87%) followed by H-1608 (24.08%) and M-26/2 (22.39%) and (Fig. 75) lowest with K-22-1 (13.59%).

K use -efficiency decreased with increasing levels of K (Fig. 76). It decreased from 26.93 to 21.04 per cent when K level increased from 25 to 200 kg K_2O ha^{-1}.

Tolerance rating of varieties to K deficient soils

The component relationship of ten varieties for testing tolerance to K deficient soils was worked out as follows.

$$y = 0.018x_1 - 0.089x_2 - 0.007x_3 + 1.198x_4 - 27.75x_5 - 3.433x_6 - 0.8701$$

(Eqn-IV)

(R^2=0.9758)

where

x_1 - Shoot dry matter production

x_2 - Total dry matter production

x_3 - Leaf area

x_4 - Leaf N

x_5 - Leaf P

x_6 - Leaf K

(The above observations were recorded from a six month old seedling four months after imposing K deficiency).

Accordingly the index (median of the frequency distribution) was arrived as -0.195 to classify the varieties as tolerant or sensitive. The index for classification of tolerant varieties to moderately tolerant and highly tolerant, the index was arrived as 0.784. The index for classification of sensitive varieties to moderately sensitive and highly sensitive was arrived as -0.959. No variety fell under the group of highly tolerant. Three varieties (H-1591, M-26/2 and H-1598) were rated as moderately tolerant to K deficient soils (Table 40).

Table 36. Variation in leaf nutrient content and uptake of nutrients (N, P and K) in relation to varieties (six month old seedling) and K levels

Treatment	Leaf N (%)	Leaf P (%)	Leaf K (%)	N Uptake mg pl^{-1}	P Uptake mg pl^{-1}	K Uptake mg pl^{-1}
Varieties						
H-1591	1.049	0.160	2.442	274.1	31.0	201.7
M-26/2	0.960	0.063	2.218	200.0	13.3	127.1
H-1598	0.854	0.045	2.251	165.8	9.1	140.4
MDK-1	0.869	0.056	2.024	175.3	13.2	93.4
H-1608	1.050	0.094	2.047	250.4	11.1	111.6
M-44/3	0.857	0.142	2.143	141.1	7.2	112.0
V5	0.954	0.061	2.086	152.3	6.6	70.1
MDK-2	0.825	0.090	2.006	138.4	9.4	74.7
A-1	1.017	0.062	1.997	221.3	5.3	75.0
K-22-1	1.020	0.031	1.856	188.2	5.5	94.3
SEm±	0.013	0.011	0.011	9.00	4.00	5.00
CD (0.05)	0.035**	0.031**	NS	22.00**	11.10**	14.00**
K levels						
0 kg K_2O/ha	0.694	0.031	1.701	103.7	2.1	54.4
25 kg K_2O/ha	0.851	0.045	1.816	123.5	3.7	56.5
50 kg K_2O/ha	0.885	0.057	1.951	143.2	4.8	66.4
75 kg K_2O/ha	0.950	0.068	2.077	164.3	7.4	84.
100 kg K_2O/ha	0.980	0.072	2.138	189.0	9.2	93.8
125 kg K_2O/ha	1.008	0.079	2.492	218.2	11.3	104.7
150 kg K_2O/ha	1.040	0.124	2.609	238.2	14.2	116.8
175 kg K_2O/ha	1.045	0.165	2.849	261.2	20.3	128.2
200 kg K_2O/ha	1.057	0.199	3.097	306.7	26.2	156.2
SEm±	0.012	0.010	0.010	8.10	4.00	6.00
CD (0.05)	0.033**	0.030**	NS	24.30**	11.00**	18.00**

** Significant at 1 per cent level NS - Not significant

Table 37. Variation in leaf N content and nutrient (N and K) uptake of varieties (six month old seedling) at different K levels

Treatment Variety/K level	Leaf N (%)	N Uptake mg pl^{-1}	K Uptake mg pl^{-1}
1	2	3	4
v_1k_1	1.017	116.1	72.0
v_1k_2	1.033	180.8	85.6
v_1k_3	1.037	212.3	91.2
v_1k_4	1.040	213.6	106.2
v_1k_5	1.060	233.4	145.6
v_1k_6	1.060	275.5	181.3
v_1k_7	1.060	335.9	197.0
v_1k_8	1.063	380.1	204.3
v_1k_9	1.073	529.3	223.6
v_2k_1	0.250	97.6	66.0
v_2k_2	0.980	123.4	85.0
v_2k_3	1.027	136.6	86.3
v_2k_4	1.030	146.5	105.6
v_2k_5	1.043	211.8	120.6
v_2k_6	1.050	246.7	148.7
v_2k_7	1.057	261.1	175.0
v_2k_8	1.070	275.1	177.3
v_2k_9	1.137	307.8	189.3
v_3k_1	0.510	83.8	55.4
v_3k_2	0.577	117.6	85.4
v_3k_3	0.613	126.5	98.9
v_3k_4	0.770	165.0	134.5
v_3k_5	0.960	194.4	149.4
v_3k_6	1.060	228.6	156.1
v_3k_7	1.060	248.6	168.3
v_3k_8	1.063	275.3	201.5
v_3k_9	1.070	294.2	214.7
v_4k_1	0.590	73.7	43.8
v_4k_2	0.610	105.0	63.6
v_4k_3	0.710	121.2	70.2
v_4k_4	0.807	148.9	83.7
v_4k_5	0.960	166.0	89.9
v_4k_6	1.020	194.3	98.6
v_4k_7	1.020	207.6	106.9
v_4k_8	1.040	237.2	131.4
v_4k_9	1.063	324.7	161.7
v_5k_1	1.020	123.5	49.5
v_5k_2	1.033	175.2	73.5
v_5k_3	1.033	194.6	84.0
v_5k_4	1.037	229.6	98.0
v_5k_5	1.057	241.2	102.3
v_5k_6	1.060	257.9	108.6
v_5k_7	1.063	300.6	131.1
v_5k_8	1.063	340.7	151.2
v_5k_9	1.078	387.4	186.7

Contd.

Table 37. Continued

1	2	3	4
v_6k_1	0.533	84.7	66.9
v_6k_2	0.710	85.5	80.4
v_6k_3	0.740	114.1	89.5
v_6k_4	0.760	130.8	103.1
v_6k_5	0.837	141.9	111.9
v_6k_6	0.993	162.6	123.4
v_6k_7	1.020	168.6	140.5
v_6k_8	1.020	178.6	143.6
v_6k_9	1.037	210.7	159.5
v_7k_1	0.720	90.6	43.0
v_7k_2	0.710	100.2	55.9
v_7k_3	0.890	118.1	53.0
v_7k_4	1.007	126.7	68.7
v_7k_5	1.013	154.2	77.7
v_7k_6	1.037	178.9	81.4
v_7k_7	1.050	184.3	86.5
v_7k_8	1.063	197.4	94.2
v_7k_9	1.063	218.7	101.0
v_8k_1	0.577	61.4	38.1
v_8k_2	0.730	74.2	62.0
v_8k_3	0.737	95.3	68.1
v_8k_4	0.777	122.3	69.8
v_8k_5	0.797	133.3	73.5
v_8k_6	0.890	157.4	86.5
v_8k_7	0.914	177.8	99.0
v_8k_8	0.967	205.0	106.2
v_8k_9	1.040	223.5	149.3
v_9k_1	0.807	132.8	31.6
v_9k_2	0.977	168.1	58.5
v_9k_3	1.020	197.3	65.6
v_9k_4	1.037	209.4	75.8
v_9k_5	1.050	227.6	88.3
v_9k_6	1.060	246.5	94.9
v_9k_7	1.067	256.5	109.5
v_9k_8	1.070	267.7	121.3
v_9k_9	1.070	288.6	129.5
$v_{10}k_1$	0.803	71.8	30.5
$v_{10}k_2$	1.013	101.1	63.9
$v_{10}k_3$	1.027	127.0	85.8
$v_{10}k_4$	1.043	151.6	98.3
$v_{10}k_5$	1.050	187.4	104.1
$v_{10}k_6$	1.050	210.1	117.3
$v_{10}k_7$	1.052	235.7	124.9
$v_{10}k_8$	1.053	243.4	133.2
$v_{10}k_9$	1.080	260.1	145.4
SEm±	0.038	2.58	12.0
CD (0.05)	0.105**	7.15**	33.0**

**Significant at 1 per cent level

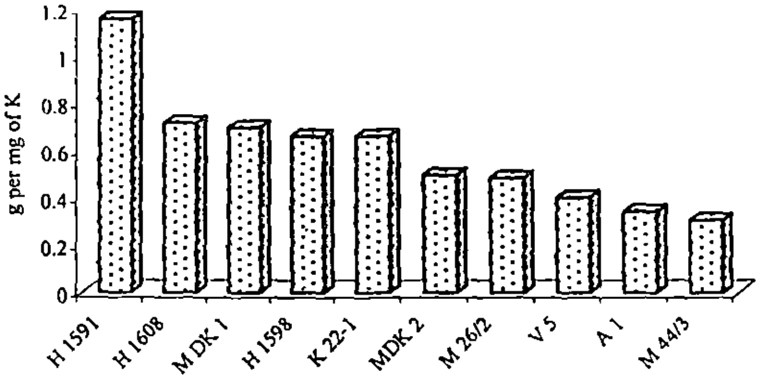

Fig72 Response of cashew varieties (six month old seedlings) to applied K

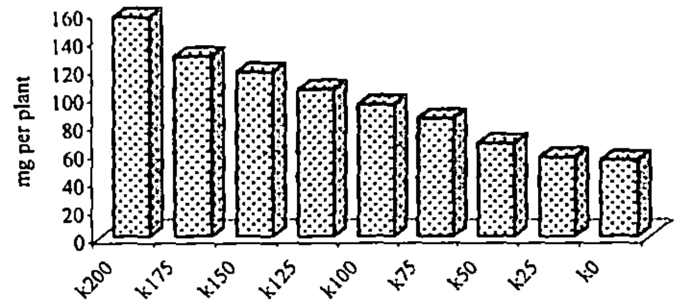

Fig74 Potassium uptake of cashew (six month old seedling) as influenced by K levels

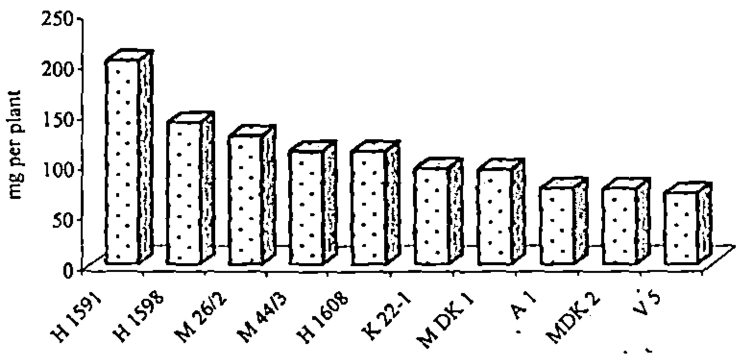

Fig73 Pottasium uptake of cashew varieties (six month old seedling)

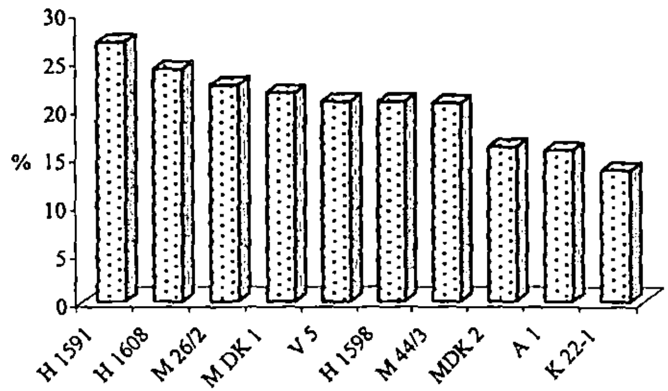

Fig75 Potassium use efficiency of cashew varieties(six month old seedling)

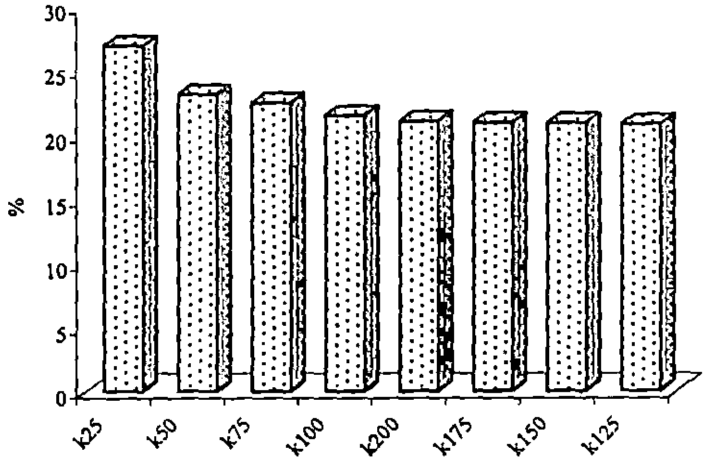

Fig76 K use efficiency of cashew (six month old seedlings) as influenced by K levels

Discussion

DISCUSSION

Exp. I. Varietal variation in drought tolerance

Cashew is well known for its ability to grow under varying levels of environmental stress. About 60 per cent of the geographical area of the country comprising 116 m ha is drought prone (Katyal *et al.*, 1997) of which a sizable portion is amenable for cashew cultivation. Considerable variation in terms of growth, morphology, physiology and anatomy of varieties indicate their differential ability to thrive under varying environments. Research efforts made in India over the past few decades led to the development of thirty four high yielding varieties. An attempt is made to identify the drought tolerant cashew varieties suitable for the drought prone areas.

Six month old seedlings of twenty one promising varieties (Table 5) were subjected to a three stage screening (preliminary, secondary and final) by imposing soil moisture stress. In the **preliminary screening** (February-September, 1996) data on DWF, RWC, percentage of dried leaves at 15 days after withholding water and number of days took for complete drying were recorded. Varieties having highest DWF and RWC during stress, lowest percentage of dried leaves and longest duration of life under drought were treated as apparently tolerant varieties.

Dry weight fraction is the ratio of dry weight to turgid weight of leaf laminae and higher DWF indicates the ability of the plant to tolerate drought (Helkvis *et al.*, 1974). Of the 21 varieties tested, H-1591, M-26/2, V-5, M-44/3, H-1608 and VTH-30/4 had high DWF (0.34-0.44) (Table 6), high RWC (80.80%) (Table 7), low leaf drying percentage (below 55%) (Fig.5) and longest duration of life under water stress (30-41 days) (Fig.6). Therefore they were treated as apparently tolerant and those varieties with opposite characters were treated as apparently sensitive. The varieties K-22-1, H-3-13, H-1600 and T-129 were having low DWF (below 0.34) (Table 6), high leaf drying percentage (above 55%) (Fig.5) and shortest duration of life (below 25 days) (Fig.6) and as such they were treated as apparently sensitive. The remaining eleven varieties (H-1610, BLA-39-4, H-2/16, H-1598, H-3-17, NDR-2-1, A-1, M-33/3, T-40, VTH-59/2 and H-1596) were treated as medium with respect to tolerance.

To verify the drought tolerance potential of the six apparently tolerant varieties (H-1591, M-26/2, V-5, M-44/3, M-30/4 and H-1608) identified during the preliminary screening, a **secondary screening** was conducted during June to December, 1996 along with four apparently sensitive varieties (K-22-1, H-3-13, T-129 and H-1600) using the same methodology adopted for the preliminary screening. Observations such as net photosynthesis, transpiration rate, stomatal conductance, leaf temperature, leaf water potential, leaf drying percentage and number of days took for complete drying were recorded.

Theoretically, a variety with high net photosynthesis, low transpiration rate, less stomatal conductance, high leaf water potential, low leaf drying percentage and longest duration of life under moisture stress can be treated as tolerant to drought. There was variation in the above characteristics between the ten varieties under test. Four varieties (H-1591, M-26/2, V-5 and M-44/3) uniformly showed low stomatal conductance (below 80 mmol $m^{-2}s^{-1}$) (Table 10), high leaf water potential (below -2.70 MPa) (Fig. 15), low leaf drying percentage at 15 days after withholding water (below 55%) (Fig. 17) and longest life (above 40 days) (Fig. 18) during stress. These four characteristics are cardinal in deciding drought tolerance and as such these varieties indicates their potential (Plate 3). On the contrary, two varieties (K-22-1 and H-3-13) uniformly showed low leaf water potential (less than -3.3 MPa) (Table 12), high leaf drying percentage (above 65%) (Fig. 17) and shortest duration of life (below 25 days) (Fig. 18) when subjected to moisture stress indicating their sensitive nature. The predawn leaf water potential is a good indicator of water availability to trees. According to Cruz and O' Toole (1954) a higher leaf water potential is an indication of drought tolerance. Thus, based on stomatal conductance, leaf water potential, leaf drying percentage and duration of life during stress, four tolerant (Plate 4) varieties (H-1591, M-26/2, V-5 and M-44/3) and two sensitive varieties (K-22-1 and H-3-13) were identified (Plate 5). These varieties were subjected to a **final screening** at different soil moisture regimes to confirm the drought tolerance as well as their response to irrigation.

Six month old seedlings of these six varieties were subjected to six soil moisture regimes (20% DAW, 40% DAW, 60% DAW, 80% DAW, 90% DAW and life saving irrigation) during August 1996 to February 1997. The growth characters such as height, girth, number of leaves, internodal length, root dry matter production, shoot dry matter production, root:shoot ratio, biomass production and total dry matter production, physiological characters such as net photosynthesis, transpiration rate, stomatal conductance, leaf temperature, leaf water potential, leaf area per plant, chlorophyll 'a', chlorophyll 'b', total chlorophyll, chlorophyll stability index, DWF, RWC, RI and leaf drying percentage , biochemical characters such as proline and NRA and anatomical characters such as stomatal index, cuticle thickness, leaf thickness and bark thickness were recorded.

Four varieties (H-1591, M-26/2, V-5 and M-44/3) showed high net photosynthesis (above 1 $\mu mol\ m^{-2}s^{-1}$) (Table 14), high leaf water potential (above -3.0 MPa) (Table 18), high leaf area (above 500 m^2) (Table 19), high total chlorophyll content (above 0.3 mg g^{-1} leaf tissue) (Fig. 30), high chlorophyll stability index (above 20.0%) (Fig. 31), high DWF (above 0.21) (Table 19), low RI (below 7.52%) (Fig. 34), low leaf drying percentage (below 35%) (Table 19), high proline content (above 175 $\mu g\ g^{-1}$ leaf tissue) (Fig. 40), high leaf NRA (above 0.2 mmol $NO_2\ g^{-1}\ h^{-1}$) (Fig. 42), low stomatal index (below 220 counts m^{-2})

Plate 3. Effect of moisture stress on 9 cashew varieties at 30 days after withholding water (Exp. IB)

Note: The varieties H-1591, M-26/2, M-44/3, H-3-17 and H-1608 survived

Plate 4. Effect of moisture stress on 5 cashew varieties at 30 days after withholding water (Exp. IB)

Note: The potential of H-1591 to tolerate drought

(Fig.44), high cuticle thickness (above 3.3 μm) (Fig. 45), high bark thickness (above 2.9 mm) (Fig. 47) and high leaf thickness (above 1.0 mm) (Fig. 46). The two varieties (K-22-1 and H-3-13) showed low net photosynthesis (below 1 μmol $m^{-2}s^{-1}$) (Table 14), low leaf water potential (below -3.2 MPa) (Table 18), low chlorophyll stability index (below 20%) (Fig. 32), low DWF (below 0.21) (Table 19), high RI (above 7.52%) (Fig. 34), high leaf drying percentage (above 35%) (Table 19), low proline content (below 175 μg g^{-1} leaf tissue) (Fig. 40), low leaf NRA (below 0.16 mmol NO_2 g^{-1} h^{-1}) (Fig. 42), high stomatal index (above 280 counts m^{-2}) (Fig.44), low cuticle thickness (below 3.2 μm) (Fig. 45), low bark thickness (below 2.9 mm) (Fig.47) and low leaf thickness (below 1.0 mm) (Fig.46).

Chlorophyll stability index is a measure of the integrity of leaf membrane under stress condition. It help to screen for drought hardiness. Relative injury indirectly measures the leaf membrane stability which is disturbed due to moisture stress (Silva *et al.*, 1974). Low RI during stress is a measure of drought tolerance. RWC is a measure of plant water status and increased RWC during moisture stress indicates the efficiency of plants to tolerate stress (Sinclair and Ludlow, 1985). Proline accumulation during water stress is an drought adaptive mechanism (Kramer, 1983).

Physiologists and breeders used indirect selection criteria such as morphological traits, metabolic proline, osmotic regulation and stomatal regulation to rate the drought tolerance in different crops (Turner and Kramer, 1980). According to Sullivan (1971), maintenance of high leaf water potential, stomatal resistance to water loss and tolerance to heat are certain important criteria to evaluate drought tolerance. Martinean (1979) suggest that relative injury is useful to screen plants for thermo-tolerance. Balasimha and Daniel (1988) identified leaf water potential as a rapid screening method for drought tolerance in coconut. Balasimha *et al.* (1987) identified moisture stress tolerant seedlings of cocoa accessions based on their high leaf water potential and high nitrate reductase stability under moisture stress. Rajagopal and Balansimha (1994) grouped drought tolerant coconut hybrids based on high leaf water potential, reduced electrolyte leakage, and high nitrate reductase activity under water stress. Kolyoreas (1958) correlated CSI with drought tolerance in pines.

From the data, it is clear that four varieties H-1591, M-26/2, V-5 and M-44/3 possess characteristics (Plate 6) desirable to tolerate moisture stress, suggesting that they are drought tolerant (Plate 7). Two varieties viz. K-22-1 and H-3-13 do not possess desirable characteristics to tolerate drought environments indicating that they are drought sensitive.

The response to irrigation measured in terms of increase in TDMP over unirrigated control was high (above 80%) with drought sensitive varieties like K-22-1 and H-3-13 and low with drought tolerant varieties like M-26/2, H-1591 and V-5. In drought sensitive varieties, the TDMP under unirrigated condition was relatively very low and it increased considerably due to irrigation. But drought tolerant varieties could maintain relatively higher amounts of TDMP even under moisture stress condition and therefore the response values were low.

Tolerance rating of varieties based on drought tolerance

In order to rate the varieties based on their relative tolerance to drought, the techni que of principal component component of used. Based on this the varieties were rated as highly sensitive, moderately sensitive, moderately tolerant and highly tolerant (Fig.54). It was found that H-1591, M-26/2 and V-5 are highly tolerant, M-44/3 is moderately tolerant, H-3-13 is moderately sensitive and K-22-1 is highly sensitive to moisture stress (Table 40).

Plate 5. Effect of moisture stress on 5 cashew varieties at 30 days after withholding water (Exp. IB)
Note: The potential of M-26/2 to tolerate drought

Plate 6. Varietal variation on growth of 6 cashew varieties at 30 days after withholding water (Exp. IC)
Note: The varieties H-1591, V-5 and M-44/3 showed better growth

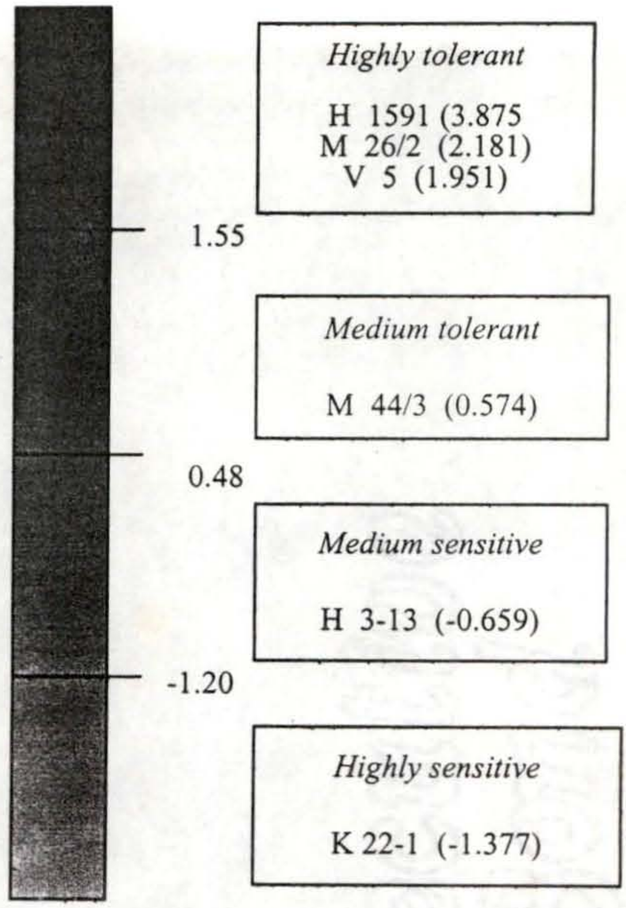

Fig 54 Tolerance rating of cashew varieties to drought
(The figures in bracket are the indices)

Plate 7. Effect of moisture stress on H-1591 and K-22-1 at 30 days after withholding water (Exp. IC)
Note: H-1591 grows well

The technique of principal component analysis indicates clearly the potential of H-1591, M-26/2, V-5 and M-44/3 to tolerate drought. The results indicate that cashew clone H-1591 tops in its ability of drought tolerance followed by M-26/2, V-5 and M-44/3. It was also clear that the varieties K-22-1 and H-3-13 are sensitive to drought.

Drought tolerating ability is seen associated with high net photosynthesis, high leaf water potential, high chlorophyll content, high chlorophyll stability index, high dry weight fraction, low relative injury, low leaf drying percentage, high proline content, high leaf NRA, low stomatal index, high cuticle thickness, high bark thickness and high leaf thickness in cashew.

Monitoring of clonal trees

The varietal variation in important physiological characters were monitored by recording the data on net photosynthesis, transpiration rate, stomatal conductance, leaf temperature and leaf water potential during peak summer in 10 year old clonal trees (H-1591, M-26/2, V-5 and M-44/3). Leaf water potential was highest in the trees of H-1591, M-26/2, V-5 and M-44/3 (Table 23). The data suggest the ability of these varieties to maintain a higher internal water status during periods of soil moisture stress. The low stomatal index (Fig. 44), high cuticle thickness (Fig. 45), high bark thickness (Fig. 47) and high leaf thickness (Fig. 46) might have helped them to maintain a high leaf water potential during summer. The leaf water potential of trees of K-22-1 and H-3-13 were low. In the green house studies also these varieties showed a lower leaf water potential during stress indicating their sensitive nature towards drought. High leaf water potential during water stress was reported in drought tolerant genotypes of cocoa (Balasimha *et al.*, 1987) and coconut (Rajagopal and Balasimha, 1994). Ability to possess high chlorophyll stability index (Fig. 32), low RI (Fig. 34), high proline content

(Fig. 40) and high leaf NRA (Fig. 42) during stress, helps the varieties H-1591, M-26/2, V-5 and M-44/3 to tolerate heat stress.

The drought tolerant species of Acacia (*A. auriculiformis)* had highest (96.6%) chlorophyll stability index (Sivasubrahmaniam, 1992 and Somen, 1998). Clarke and Mc gray (1982) used membrane stability to evaluate drought tolerance in forest species. The drought tolerant genotypes of cotton wood (Gebre and Kuhns, 1991) and coconut (Rajagopal and Balasimha, 1994) showed reduced electrolyte leakage compared to susceptible ones. A high proline accumulation under water stress was noted in tea (Rajasekhar *et al.*, 1988), durian clones (Razi *et al.*, 1994) and cocoa (Rajagopal and Balasimha, 1994). The NRA content decreased with increase in moisture stress in poplar clones (Sinha and Nicholas, 1981). It is evident from the study that the varieties H-1591, M-26/2, V-5 and M-44/3 are drought tolerant.

H-1591 is a hybrid clone released from Kerala Agricultural University in the year 1995 and it is known as Priyanka (Plate 8). It is a hybrid between BLA-139-1 and K-30-1. It has spreading canopy with extensive branching. The flowering phase is from December to March and fruiting phase extends from February to May. The apples are yellowish red. Adult trees of this variety, on an average yields 16.9 kg of nut per tree per year. The nut weighs 10.8 g and the shelling percentage is 26.54. The kernels conform to the export grade of W 180. This is the first variety released with the export grade of W180 (Mohanakumaran,1996).

M-26/2, is a high yielding variety, known as Vridhachalam-3 (Plate 9). It was released from Tamil Nadu Agricultural University in the year 1992. It has compact canopy and intensive branching. The flowering phase is from February to April and a fruiting phase from March to May. The apples are yellowish red. Adult

Plate 8. Variety H-1591 (Priyanka)
Note: A super variety tolerant to drought and N, P and K deficiency in soils

Plate 9. Variety M-26/2 (Vridhachalam-3)
Note: Tolerant to drought and N and K deficiency in soils

trees of this variety, on an average gives 14.2 kg of nut per tree per year. The nuts are medium in size weighing 7.18 g with shelling percentage of 29.1. The kernels conform to the export grade of W 210 (Selvarajan *et al.*, 1996).

V-5 (Vengurla-5) was released from Konkan Krishi Viswavidyalaya, Maharashtra in the year 1984 (Plate 10). It is a cross between Ansure Early x Mysore Kotekar. It has a compact and dense canopy. The flowering phase extends from October to December and fruiting period is from January to April. The apple colour is yellow with an average weight of 30 g. Adult trees of this variety, on an average gives 15.6 kg of nut per tree per year. The nuts are smaller in size weighing 4.54 g with a shelling percentage of 30.0. The kernels conform to the export grade of W 320 (Magde and Sawke, 1996).

M-44/3 was released from Tamil Nadu Agricultural University in the year 1985 and it is known as Vridhachalam-2 (Plate 11). It has a compact canopy with intensive branching. The flowering phase is from February to April and fruiting phase from March to May. The apples are yellow. Adult trees of this variety, on an average gives 11.92 kg of nut per tree per year. The nuts are smaller in size weighing 5.12 g with a shelling percentage of 28.5. The kernels conform to the export grade of W 320 (Selvarajan *et al.*, 1996).

The four varieties identified as drought tolerant are high yielding and recommended for large scale cultivation in the states of Kerala (H-1591), Tamil Nadu (M-26/2 and M-44/3) and Maharashtra (V-5). The variety V-5 has a disadvantage in terms of its small size. But considering its higher ability to tolerate drought, this disadvantage can very well be ignored.

The seedlings of the drought tolerant varieties at a higher planting density offer great scope for exploitation of the drought prone areas particularly Andhra

Plate 10. Variety V-5 (Vengurla-5)
Note: Drought tolerant

Plate 11. Variety M-44/3 (Vridhachalam-2)
Note: Drought tolerant

Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu so as to enhance the cashew nut production in the country. These varieties can also serve as efficient root stocks for production of cashew grafts for the dry areas. The less remunerative crops like acacia, casuarina etc. of the dry areas can be better substituted with the drought tolerant cashew varieties, at the larger interest of the nation. These varieties also offer great scope for better utilisation of marginal and waste lands and for restoration of degraded environments.

The varieties H-1591, M-26/2, V-5 and M-44/3 thus form a precious biological wealth which can go a long way to sustain cashew industry in the country. An index developed in the study to measure drought tolerance of cashew varieties will enable researchers to categorise the existing germplasm for drought tolerance.

Exp. II. Response of cashew to applied N at different levels of irrigation (drip)

During the first year of irrigation, the plant height, number of branches LAI and yield increased with increase in level of irrigation. The other characters did not differ due to irrigation (Table 25). Beneficial effect of drip irrigation on various crops are reported by different researchers. In fruits and vegetables thirty per cent saving of water and fifty per cent increase in yield due to drip irrigation was reported by Sivanappan *et al.* (1972). Raveendran (1983) reports that drip irrigation is the best water management system in terms of energy consumption in coconut. Similar observations were also recorded in sweet oranges and banana (Upadhyay, 1995) and oil palm (Vargheese, 1996). Irrigation @ 30 litres per tree once in four days resulted highest yield in cashew (NRCC, 1993). Twenty per cent increase in yield due to drip irrigation @ 43 mm per week during April to October over unirrigated control was reported by Schaper *et al.* (1996) from Australia.

The effect of N was to increase tree height, number of primary branches and LAI in the first year. During second year, LAI, number of panicles and yield per tree were increased with increase in N upto 1500 g per tree per year (Table 25). Nitrogen is the king pin of nutrients and is vital in plant nutrition. An adequate supply of nitrogen is necessary for good vegetative growth. The experimental soil was medium with respect to available nitrogen.

The trees have completed five years of age during 1996-97. Despite the adoption of uniform plant protection measures, due to a severe attack of tea mosquito, recordable level of yield was not obtained during this year. There was a general set back in the crop yield in the region as a whole due to a wide spread attack of tea mosquito and this damage was reflected on the experimental trees also.

1997-98 was also a bad year for cashew due to adverse weather conditions (high temperature and untimely rainfall). As such the yield level was low. The *El-nino* experienced during the year also caused a general set back in cashew due to high temperature. The delayed flushing and flowering observed due to shift in rainfall pattern also contributed to a decreased yield in the region. The yield level observed in the plot is to be seen in this context (Table 25).

In rainfed trees, application of N @ 1500 g per tree per year resulted in an yield of 0.77 kg per tree while trees applied with no N gave no yield (Plate 12). In irrigated trees (@ 40 litres of water per tree per day) N application @ 1500 g per tree per year resulted in an yield increase of 54 per cent compared to rainfed trees. But when the irrigation level was increased to 80 litres of water per tree per day the corresponding increase was 124 per cent (Plate 13). The data clearly suggest that a high dose of N application should go along with a higher level of irrigation

Plate 12. Rainfed cashew (4 year old) with no N application (variety H-3-17) (Exp.II)

Plate 13. Irrigated cashew (4 year old) - @ 80 litres of water per tree per day and applied with N @ 1500 g per tree per year (variety H-3-17) (Exp. II)

for getting better yields. Kumar *et al.* (1998) observed highest nut yield in trees applied with fertilizers through drip irrigation.

The results clearly suggest that under the agroclimatic conditions prevailing in the central zone of Kerala, a N dose of 1500 g per tree per year is necessary both for rainfed as well as irrigated cashew. A higher dose of N application (1500 g per tree per year) should go along with a higher dose of irrigation (80 litres of water per tree per day through drip during summer months) for obtaining best results from cashew.

Exp. III. Tolerance of cashew varieties to N deficient soils

Cashew is grown in a wide variety of soil and climatic environments. Usually, marginal lands of extremely low fertility are chosen for its cultivation. Cashew is generally grown without nutrition or care. The concept of fertilizer free agriculture is gaining momentum in the recent times. Therefore it was felt necessary to identify varieties capable of thriving well under nutrient stressed environments particularly in N, P and K deficient soils.

The response of cashew to applied N is tremendous and is observed almost universally (Salam, 1997). Cashew is a N lover and N nutrition is essential for getting larger yields. The present project was taken up to identify N efficient varieties suitable for N deficient soils.

Growth performance and nutrient uptake of ten varieties of cashew (six month old seedlings) were studied under nine N fertility regimes (0 to 200 kg per ha) during March to September, 1997. The growth characters such as seedling height, seedling girth, number of leaves, internodal length, root dry matter production, shoot dry matter production, R:S ratio, total dry matter production and leaf area per plant and the content and uptake of nutrients were recorded.

As per fertility ratings, the soils containing available N upto 250 kg per ha is rated as low, 250 to 500 kg per hectare as medium and above 500 kg per hectare as high (Cope *et al.*, 1981). The available N content of the test soil was only 8.6 kg per hectare. Even by adding the highest level of N (200 kg per ha), the N fertility rating of the test soil was only low. Theoretically, a variety that performs relatively well in a N deficient soil can be regarded as tolerant to N deficient soils.

Of the ten varieties tested, two varieties namely H-1591 and M-26/2 showed better performance (Table 26) in terms of seedling height (above 30 cm), number of leaves (above 19), RDMP (above 8 g pl^{-1}), SDMP (above 25 g pl^{-1}), TDMP (above 35 g pl^{-1}), leaf area per plant (above 1000 cm^2), N uptake (above 290 mg pl^{-1}) (Fig.57), leaf N (above 1.5%) (Table 28) and N use efficiency (above 25%) (Fig.60) irrespective of N fertility in soils (Plate 14 and 15). At the same time the performance of eight varieties (V-5, H-1598, H-1608, M-44/3, MDK-1, MDK-2, A-1 and K-22-1) was not satisfactory. The relative ability of H-1591 and M-26/2 to produce higher quantity of roots (Table 26) might have helped them to utilise the N resources more effectively. Their leaf N content and N uptake were also high (Table 28) indicating their ability to utilise N from N scarce soils.

The leaf N content of H-1591 increased from 0.786 to 1.798 per cent when N regime increased from 0 to 200 kg ha^{-1} (Fig.63). The leaf N content of M-26/2 increased from 0.615 to 1.79 per cent when N regime increased from 0 to 200 kg ha^{-1}. But the leaf N content of K-22-1 (susceptible variety) was observed to be low. It increased from 0.579 to 1.288 per cent only when N regime increased from 0 to 200 kg ha^{-1}. The results indicate the ability of H-1591 and M-26/2 to maintain a high leaf N content in N deficient soils. The varietal variation in leaf N

Plate 14.Effect of 3 levels of N on seedling growth of H-1591 (Exp. III)
Note: The variety showed satisfactory growth even in N deficient soil

Plate 15. Effect of 3 levels of N on seedling growth of M-26/2 (Exp. III)

of cashew was reported by Bhaskar (1993). According to him, the leaf N content was highest in M-26/2 (3.26%) and lowest in V-5 (2.68%).

An adequate supply of nitrogen is necessary for good vegetative growth and deficiency of N causes stunted growth, yellowing and death of leaf.

The growth and development of cashew is very much influenced by nitrogen and it responds excellently well to N application.

The response of cashew to applied N varied with varieties. It was high with varieties tolerant to N deficient soils (H-1591, M-26/2 and H-1608) and low with sensitive varieties (MDK-1, A-1 and MDK-2). The response with tolerant varieties ranged from 1.2 to 2.0 g dry matter per mg of N and with sensitive varieties ranged from 0.3 to 0.75 g dry matter per mg of N. The data on TDMP in relation to varieties explain this.

Several workers report the positive response of cashew to mineral nutrition (Nair *et al.*, 1972, Lefebvre, 1973, Pujari, 1979, Reddi *et al.*, 1982, Nambiar, 1983, Rao *et al.*, 1984, Kumar, 1985, Veeraraghavan *et al.*, 1985, Ghosh, 1988, Mathew, 1990 and Latha, 1992). Ohler (1979) reports that the response of cashew to N need be expected only in poor soils. Greater response is observed in young cashew trees than in older ones (Adi and Kurnea, 1983). Nitrogen is the element that is absorbed by cashew in largest quantity (Salam, 1997). Significant positive effects on various growth characters of cashew were reported by several workers (Nair *et al.*, 1972, Lefebvre, 1973, Pujari, 1979, Reddi *et al.*, 1982, Nambiar, 1983, Rao *et al.*, 1984, Kumar, 1985 Veeraraghavan *et al.*, 1985, Ghosh, 1988 and Mathew, 1990).

From the study the varieties H-1591 and M-26/2 are efficient N users and are suitable for N deficient soils. The principal component analysis confirmed the superiority of H-1591 and M-26/2 over the others to tolerate N deficient soils.

The importance of reduced use of chemical fertilisers and pesticides gain momentum in the context of increased awareness on environmental safety and sustainable agriculture. As such the N efficient varieties (H-1591 and M-26/2) identified will go a long way for better exploitation of N deficient soils, minimising environmental hazards, reducing the cost of cultivation and improving the income of the farmer. These varieties offer considerable scope for the exploitation of N deficient environments.

Exp. IV. Tolerance of cashew varieties to P deficient soils

Growth performance and nutrient uptake of ten promising cashew varieties (six months old seedlings) were studied in nine P regimes in soil (0 to 80 kg P_2O_5 per ha) during March to September, 1997 to identify varieties capable of performing well in P deficient soils. The growth characters such as seedling height, seedling girth, number of leaves, internodal length, root dry matter production, shoot dry matter production, R:S ratio, total dry matter production and leaf area per plant and the content and uptake of nutrients were recorded.

As per fertility ratings, the soils containing available P upto 10 kg per ha is rated as low, 10 to 25 kg per hectare as medium and above 25 kg per hectare as high (Cope *et al.*, 1981). The available P content of the test soil was only 0.896 kg per hectare. As such the P fertility status of the test soil was only low. By ammending the soil with various P doses (0 to 80 kg P_2O_5 per ha) the first two treatments formed the low P regimes, the third treatment formed the medium P regime and the others, the high P regime in soil. The tolerance of varieties to P deficiency in soil was made based on the performance of varieties in the low P regimes. Theoretically a variety that performs well in a P deficient soil can be regarded as tolerant to P deficient soils.

Of the ten varieties tested, H-1591 showed better performance (Table 30) in terms of seedling height (36 cm), seedling girth (4.2 cm), number of leaves (20.5), internodal length (3.07 cm), RDMP (9.0 g pl^{-1}), root:shoot ratio (0.28), TDMP (41.03 g pl^{-1}), leaf area per plant (1167 cm^2), leaf P content (0.121%) (Table 32), and P use efficiency (20.2%) (Fig.67) in P deficient soils (Plate 16). The performance of the other nine varieties (V-5, H-1598, H-1608, M-44/3, MDK-1, MDK-2, A-1, M-26/2 and K-22-1) were not satisfactory. The ability of H-1591 to produce higher amounts of roots (Table 30) even in P deficient soils might have helped it to utilise the native P resources more effectively. The leaf P content and P uptake were also high with H-1591 (Table 32) indicating its ability to utilise P from P scarce soils.

The leaf P content of H-1591 increased from 0.139 to 0.594 per cent when P regime increased from 0 to 80 kg P_2O_5 per ha (Fig.69). The leaf P content of M-26/2 increased from 0.100 to 0.489 percent when P regime increased from 0 to 80 kg P_2O_5 per ha. But the leaf P content of K-22-1 (sensitive variety) was low. It increased from 0.026 to 0.121 per cent only when P regime increased from 0 to 80 kg P_2O_5 per ha. The varieties H-1591 and M-26/2 could maintain high leaf P, irrespective of P regimes in soil. The varietal variation in leaf P of cashew was reported by Bhaskar (1993). According to him the leaf P content was highest in M-26/2 (0.08%) and lowest in V-5 (0.07%).

The leaf P content (0.594%) and P use efficiency (15.8%) of H-1591 were high in P rich soils as well. The results indicate that H-1591 is an efficient variety for P deficient as well as P rich soils.

The response of cashew to applied P varied with varieties. It was high with varieties tolerant to P deficient soils (H-1591, M-44/3 and V-5) and low with sensitive varieties (A-1 and H-1608). The response with tolerant varieties ranged from 4.5 to 5.5 g dry matter per mg of P and with sensitive varieties it was below 2.0 g dry matter per mg of P. The data on TDMP in relation to varieties explain this.

Phosphorus is a major nutrient element essential for root growth, development of reproductive parts, seed formation and maturity of the crop. It has a key role in energy storage and transfer in plants. Phosphorus deficiency causes stunted growth, purplish leaves, slender stem and necrosis.

Conflicting reports are observable regarding the effect of P on cashew. According to Sawke *et al.* (1985) the effect of P to increase the nut yield is limited to a dose of 25 kg P_2O_5 per hectare. Kumar (1985) and Mathew (1990) observed positive influence of P on nut yield in cashew.

Using principal component analysis, the varieties were grouped as highly tolerant, moderately tolerant, moderately sensitive, and highly sensitive. It was found that the variety H-1591 is moderately tolerant, M-26/2, V-5, MDK-1 and MDK-2 are moderately sensitive and A-1, K-22-1, H-1598, H-1608 and M-44/3 are highly sensitive to P deficiency in soils (Table 40). The principal component analysis clearly indicates the superiority of H-1591 over other varieties to tolerate P deficiency in soils.

The P efficient variety H-1591 forms a precious biological wealth for better exploitation of P deficient marginal lands, minimising environmental hazards, reducing the cost of cultivation and improving the income of the farmer.

Exp. V. Tolerance of cashew varieties to K deficient soils

Growth performance and nutrient uptake of ten promising cashew varieties (six month old seedlings) were studied in nine K regimes in soils (0 to 200 kg K_2O per ha) during March to September, 1997 to identify varieties capable of performing well in K deficient soils. The growth characters such as seedling height, seedling girth, number of leaves, internodal length, root dry matter production, shoot dry matter production, R:S ratio, total dry matter production and leaf area per plant, the content and uptake of nutrients and K use efficiency were recorded.

As per fertility ratings, the soils containing available K upto 115 kg per ha is rated as low, 115-375 kg per hectare as medium and above 375 kg per hectare as high (Cope *et al.*, 1981). The available K content of the test soil was only 5.3 kg per hectare. As such the K fertility status of the test soil was only low. By ammending the soil with various K doses (0 to 200 kg K_2O per ha), the first four treatments formed the low K regimes and the rest under the medium K regime in the soil. The tolerance of varieties to K deficiency in soil was made based on the performance of varieties in the low K regimes in soil. Theoretically a variety that perform well in a K deficient soil can be regarded as tolerant to K deficient soils.

Of the ten varieties tested, three varieties (H-1591, M-26/2 and H-1598) showed better performance (Table 34) in terms of seedling height (above 27 cm), seedling girth (above 3.3 cm), number of leaves (above 16), internodal length (above 2.5 cm), RDMP (above 7 g pl^{-1}), SDMP (above 22 g pl^{-1}), TDMP (above

29 g pl^{-1}), leaf area per plant (above 500 cm^2), K uptake (above 125 mg pl^{-1}) and leaf K content (above 2.2%) (Table 36) in K deficient soils (Plate 17 and 18). The performance of seven varieties (V-5, H-1608, M-44/3, MDK-1, MDK-2, A-1 and K-22-1) was not satisfactory. The ability of varieties H-1591, M-26/2 and H-1598 to produce higher amounts of roots (Table 34) even in K deficient soils might have helped them to utilise the K resources more effectively. The leaf K content and K uptake of these varieties (Table 36) were also high indicating their ability to utilise K from K scarce soils.

The leaf K content of H-1591 increased from 1.049 to 3.131 per cent when K regime increased from 0 to 200 kg K_2O per ha (Fig. 77). The leaf K content of M-26/2 increased from 0.931 to 1.832 per cent when K regime increased from 0 to 200 kg K_2O per ha. The leaf K content of H-1598 was also high. But the leaf K content of K-22-1 (sensitive variety) was low. Leaf K increased from 0.583 to 1.409 per cent only when K regime increased from 0 to 200 kg K_2O per ha. The varieties H-1591, M-26/2 and H-1598 could absorb K effectively irrespective of K regimes in soil. It is clear that the varieties H-1591, M-26/2 and H-1598 can perform well in K deficient soils.

The response of cashew to applied K varied with varieties. It was high with varieties tolerant to K deficient soils (H-1591, H-1608 and MDK-1) and low with sensitive varieties (M-26/2, V-5 and MDK-2). The response with tolerant varieties was above 0.6 g dry matter per mg of K and with sensitive varieties it was below 0.48 g dry matter per mg of K. The data on TDMP in relation to varieties explain this.

Potassium is a major nutrient element governing enzyme activation, osmoregulation, disease resistance, photosynthesis, translocation of assimilates, N uptake and protein synthesis in plants. Potassium deficiency causes pale green

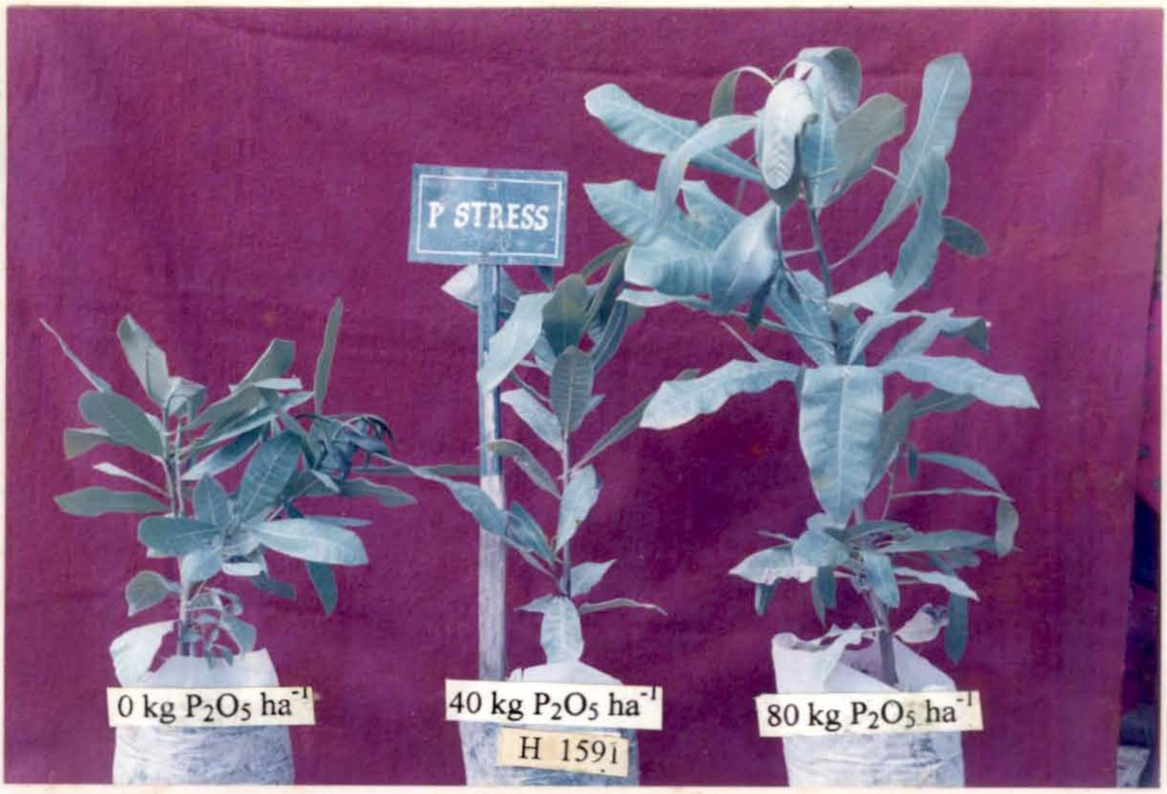

Plate 16. Effect of 3 levels of P on seedling growth of H-1591 (Exp. IV)
Note: The variety showed satisfactory growth even in P deficient soil

Plate 17. Effect of 3 levels of K on seedling growth of M-26/2 (Exp. V)
Note: The variety showed satisfactory growth even in K deficient soil

Fig 63 Leaf N content of three cashew varieties (six month old seedlings) at different levels of applied N

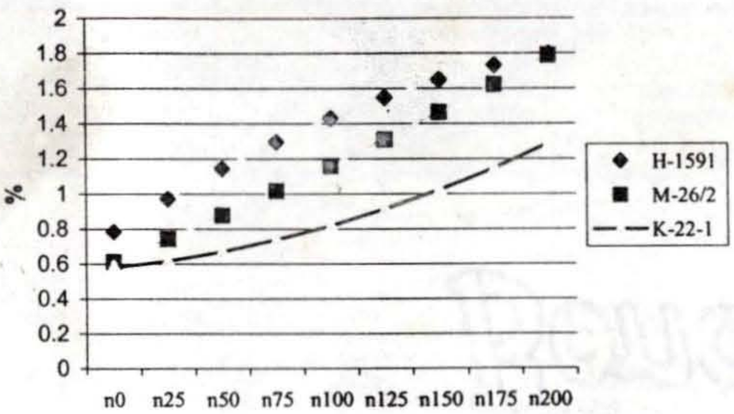

Fig69 Leaf P content of three cashew varieties (six month old seedling) at different levels of applied P

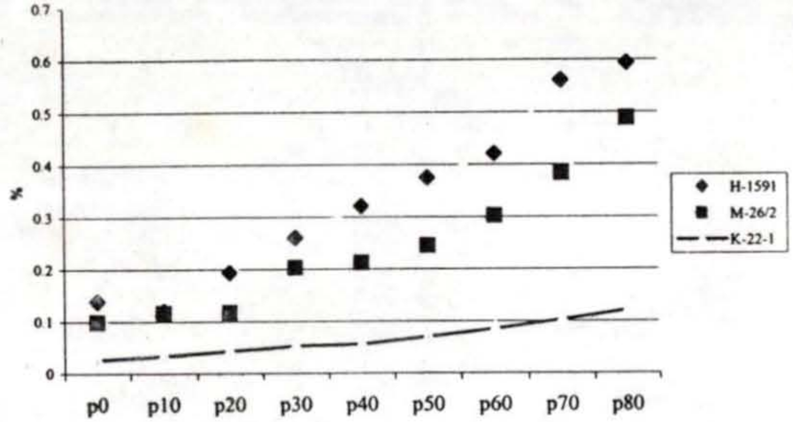

Fig 77 Leaf Kcontent of three cashew varieties (six month old seedling) at different levels of applied K

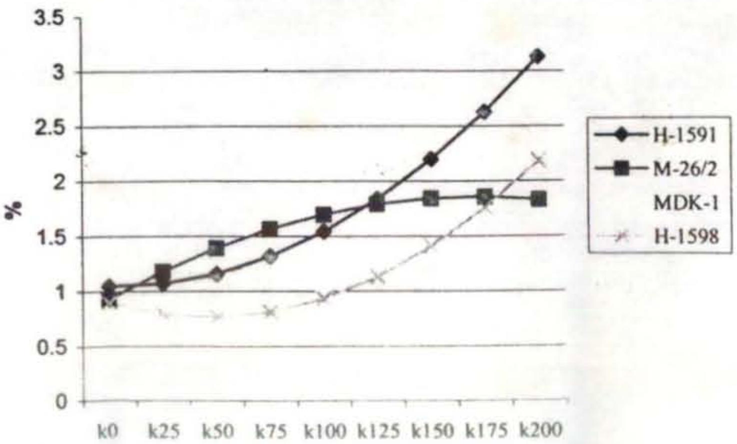

Plate 18. Effect of 3 levels of K on seedling growth of H-1598 (Exp. V)
Note: The variety showed satisfactory growth even in K deficient soil

leaves with marginal chlorosis and necrosis and plant become susceptible to diseases.

Nambiar (1983) observed positive effects of K on cashew. Application of K increased the cashew nut production (Lefebvre, 1973). Significant positive effects of K on growth and yield of cashew was reported by Ghosh (1988) and Ghosh (1990). Kumar (1985) obtained linear response to K in cashew. A review of literature indicates that next to N, K is the nutrient that is required in larger quantities for cashew (Salam, 1997).

The varieties M-44/3 and A-1 were rated as moderately sensitive and H-1608 as highly sensitive to K deficient soils. The principal component analysis indicates the superiority of H-1591, M-26/2 and H-1598 to tolerate K deficiency in soils.

The K efficient varieties (H-1591,M-26/2 and H-1598) forms precious biological wealth for better exploitation of K deficient marginal lands, minimising environmental hazards, reducing the cost of cultivation and improving the income of the farmer.

Nutrient absorption ratio

An attempt was made to assess the quantum of nutrient (N, P and K) absorption as well as the ratio of nutrient absorption by cashew (six month old seedlings). The quantum as well as the ratio of nutrient absorption depends on the type of nutrition. The seedlings applied with N removed 198.8 mg of N, 2.43 mg of P and 19.43 mg of K per plant with a nutrient absorption ratio of 82:1:8. The seedlings applied with P removed 89.37 mg of N, 51.29 mg of P and 33.35 mg of K per plant with a nutrient absorption ratio of 3:2:1 (approximately). The seedlings applied with K removed 167.7 mg of N, 11.02 mg of P and 95.66 mg of K per plant with a nutrient absorption ratio of 16:1:9 (approximately) (Table 38).

On an average N, P and K absorption of a six month old cashew seedling was in the order of 151.95 mg N, 21.58 mg P and 49.48 mg K per plant with a nutrient absorption ratio of 7:1:2 (approximately).

An attempt was also made to compare the use efficiency of N, P and K by cashew seedlings when grown under green house condition (poly bags). On an average, the N, P and K use efficiencies of cashew seedlings were 24.7, 8.02 and 12.17 per cent respectively (Table 39).

Overall performance rating of varieties

An attempt was also made to compare the overall performance of varieties in terms of tolerance to N, P and K deficient soils. The variety H-1591 showed highly tolerant to N deficient soils and moderately tolerant to P and K deficient soils. The variety M-26/2 is highly tolerant to N deficient soils and moderately tolerant to K deficient soils.

An overview of the data obtained from Exps. I, III, IV and V regarding tolerance of varieties to drought and soil nutrient deficiency (N, P and K deficient soils) indicates that the variety H-1591 is a super variety capable of tolerating not only drought but also N, P and K deficient soils. The variety M-26/2 is capable of tolerating drought as well as N and K deficiency in soils. The variety K-22-1 is drought sensitive.

The content, uptake and use efficiency of nutrients (N, P and K) were high with respect to H-1591 and M-26/2 compared to other varieties (Tables 28, 32

Table 38. Nutrient uptake and ratio of nutrient absorption by cashew (six month old seedling)

	N uptake (mg pl^{-1})	P uptake (mg pl^{-1})	K uptake (mg pl^{-1})
N levels (Exp. III)	198.98	2.43	19.43
Ratio	82	1	8
P levels (Exp.IV)	89.37	51.29	33.35
Ratio	3	2	1
K levels (Exp.V)	167.7	11.02	95.66
Ratio	16	1	9
Mean	151.95	21.58	49.48
Rato	7	1	2

Table 39. Nutrient use efficiency of cashew (six month old seedling)

	Range	Mean
N use efficiency (%)	15-32	24.70
P use efficiency (%)	7-15	8.02
K use efficiency (%)	4-27	12.17

Table 40. Tolerance rating of varieties to drought and nutrient deficiency in soils

	Highly tolerant	Moderately tolerant	Moderately sensitive	Highly sensitive
Drought	H-1591 M-26/2 V-5	M-44/3	H-3-13	K-22-1
N deficient soils	M-26/2 H-1591	V-5 H-1598	M-44/3 H-1608	
P deficient soils		H-1591	M-26/2 V-5 MDK-1 MDK-2	A-1 M-44/3 K-22-1 H-1608 H-1598
K deficient soils		M-26/2 H-1591 H-1598	M-44/3 A-1	H-1608

and 36). The ability of these varieties to absorb and accumulate higher amounts of nutrients particularly K in the tissue might have helped them to maintain a high leaf water potential even during stress. This ability of the varieties might have enable them to tolerate drought.

The varieties H-1591 and M-26/2 form precious biological wealth for the nation particularly for the adverse environments in terms of moisture stress and nutrient deficiency.

Summary

SUMMARY

Five experiments were conducted at Cashew Research Station, Kerala Agricultural University, Madakkathara during 1996-98 to identify drought tolerant varieties of cashew, to study the response of cashew to applied N at different levels of drip irrigation and to assess the tolerance of cashew varieties to N, P and K deficiency in soil. The summary of the experiments is given below.

Exp. I. Varietal variation in drought tolerance

1. Leaf drying percentage at 15 days after withholding water was less than 55 in H-1591, M-44/3, V-5, M-26/2 and H-1608 and more (over 90%) in NDR-2-1, K-22-1 and H-3-13. The lowest leaf drying percentage (20.2) was seen with H-1591 and highest (93.4%) with H-3-13.

2. Number of days took for complete drying of seedling was less than 20 days in NDR-2-1, K-22-1 and H-3-13 and over 35 days in H-1591, M-44/3, V-5 and M-26/2. The duration of life under moisture stress was longest (42 days) with H-1591 and shortest (16 days) with H-3-13.

3. The net photosynthesis at 10 days after moisture stress was high (above 1.3 $\mu mol\ m^{-2}s^{-1}$) in H-1591, M-26/2 and V-5 and lowest (0.772 $\mu mol\ m^{-2}s^{-1}$) in K-22-1.

4. The leaf water potential at 10 days after moisture stress was high (above -2.6 MPa) in H-1591, M-26/2 and V-5 and low (below -3.3 MPa) in K-22-1 and H-3-13.

5. The TDMP after 30 days of moisture stress was highest (12.82 g pl^{-1}) in H-1591 and lowest (7.12 g pl^{-1}) in K-22-1.

6. Response to irrigation measured in terms of percentage increase in TDMP over unirrigated control was high (above 95%) in K-22-1 and H-3-13 and low (below 60%) in H-1591, M-26/2 and V-5. The response was highest (90.06%) with K-22-1 and lowest (26.92%) with M-26/2.

7. The chlorophyll stability index was high (above 24%) in H-1591, M-26/2 and V-5 and lowest (19.82%) in K-22-1.

8. The relative injury was highest (28.67%) in K-22-1 and lowest (1.98%) in H-1591.

9. The proline content of leaves was high (above 210 μg g^{-1} leaf) in H-1591, M-26/2 and V-5 and lowest (112 μg g^{-1} leaf) in H-3-13.

10. The NRA content of leaves was high (above 0.229 mmol NO_2 $g^{-1}h^{-1}$) in H-1591, M-26/2 and V-5 and lowest (0.088 mmol NO_2 $g^{-1}h^{-1}$) in K-22-1.

11. The variety H-1591 had the thickest cuticle (3.33 μm), leaves (1.6 mm) and bark (3.08 mm) and K-22-1 had the thinnest leaves (0.8 mm) and bark (2.89 mm).

12. Field monitoring of the physiological characters of adult trees of H-1591, M-26/2, V-5 and M-44/3 during summer months confirmed their superiority to tolerate drought.

The varieties H-1591, M-26/2, V-5 and M-44/3 are drought tolerant and K-22-1 is drought sensitive.

Exp. II. Response of cashew to applied N at different levels of irrigation (drip)

1. Irrigation @ 80 litres of water per tree per day increased LAI and nut yield.

2. N application @ 1500 g per tree per year increased LAI and nut yield.

N application @ 1500 g per tree per year along with irrigation @ 80 litres per tree per day (through drip) is essential in the state of Kerala for obtaining best results from cashew.

Exp. III. Tolerance of cashew varieties to N deficient soils

1. RDMP was high (above 8 g pl^{-1}) in H-1591, M-26/2 and H-1608 and lowest (4.33 g pl^{-1}) in K-22-1.

2. TDMP was high (above 32 g pl^{-1}) in H-1591, M-26/2 and H-1608 and lowest (20.44 g pl^{-1}) in K-22-1.

3. The response to applied N was high (above 1.2 g dry matter per mg of applied N) in H-1591, M-26/2 and H-1608 and lowest (0.311 g dry matter per mg of applied N) in MDK-1.

4. N uptake was high (above 220 mg pl^{-1}) in H-1591, M-26/2 and H-1608 and lowest (104.5 mg pl^{-1}) in K-22-1.

5. N use efficiency was high (26.87%) in H-1591 and lowest (15.18%) in K-22-1.

6. The varieties H-1591 and M-26/2 are efficient for N deficient soils.

7. The N use efficiency of cashew seedlings grown under pot culture was 24.7 per cent.

Exp. IV. Tolerance of cashew varieties to P deficient soils

1. RDMP was highest (9.04 g pl^{-1}) in H-1591 and lowest (5.33 g pl^{-1}) in H-1608.

2. TDMP was highest (41.03 g pl^{-1}) in H-1591 and lowest (26.25 g pl^{-1}) in H-1608.

3. The response to applied P was high (4.51 g dry matter per mg of applied P) in H-1591 and lowest (1.89 g dry matter per mg of applied P) in H-1608.

4. P use efficiency was highest (14.74%) in H-1591 and lowest (4.71%) in K-22-1.

5. H-1591 is an efficient variety for P deficient soils.

6. The P use efficiency of cashew seedlings grown under pot culture was 8.02 per cent.

Exp. V. Tolerance of cashew varieties to K deficient soils

1. RDMP was high (above 7 g pl^{-1}) in H-1591, M-26/2, H-1598, MDK-1 and H-1608 and lowest (4.7 g pl^{-1}) in V-5.

2. TDMP was high (above 29.5 g pl^{-1}) in H-1591, M-26/2, H-1598, MDK-1 and H-1608 and lowest (24.49 g pl^{-1}) in K-22-1.

3. The response to applied K was high (above 0.6 g dry matter per mg of applied K) in H-1591, H-1598, MDK-1, H-1608 and K-22-1 and lowest (0.306 g dry matter per mg of applied K) in M-44/3.

4. K uptake was high (above 125 mg pl^{-1}) in H-1591, M-26/2 and H-1598 and lowest (70.1 mg pl^{-1}) in V-5.

5. K use efficiency was high (above 22%) in H-1591 and M-26/2 and lowest (13.59%) in K-22-1.

6. The varieties H-1591, M-26/2 and H-1598 are efficient for K deficient soils.

7. The K use efficiency of cashew seedlings grown under pot culture was 12.17 per cent.

8. On an average N, P and K absorption of a six month old cashew seedling was in the order of 151.95 mg N, 21.58 mg P and 49.48 mg K per plant with a nutrient absorption ratio of 7:1:2 (approximately).

9. The variety H-1591 is a super variety capable of tolerating not only drought but also N, P and K deficient soils. The variety M-26/2 is capable of tolerating drought as well as N and K deficiency in soils. The variety K-22-1 is drought sensitive.

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Appendices

Appendix-1

Weather data during the experimental period (1996-1998)

Month	Air temperature (°C)		Rainfall (mm)	Evaporation (mm)	Sunshine hours per day	Mean relative humidity (%)
	Maximum	Minimum				
1996						
January	33.1	22.4	0	208.6	9.4	53
February	34.7	23.4	0	200.9	9.9	53
March	36.4	24.3	0	219.2	9.3	60
April	34.6	25.0	152.0	157.1	8.3	73
May	32.8	25.2	95.6	135.0	7.7	77
June	30.5	23.8	400.3	103.4	4.7	85
July	28.8	23.1	588.7	88.9	2.7	90
August	29.1	23.6	310.0	100.9	3.7	87
September	29.2	23.7	391.6	94.9	4.3	84
October	30.1	22.9	219.3	92.8	6.0	82
November	31.5	23.6	23.1	119.0	7.1	72
December	30.5	21.8	60.8	133.4	6.8	68
1997						
January	32.0	22.9	0	174.8	9.6	62
February	33.9	21.8	0	158.7	9.3	61
March	35.7	24.0	0	203.0	9.6	60
April	35.2	24.5	8.2	190.2	9.4	67
May	34.4	24.5	63.0	157.1	6.7	72
June	31.2	23.0	720.5	128.2	5.9	82
July	28.6	21.8	979.2	91.7	1.9	90
August	29.0	22.8	636.8	190.4	3.4	87
September	30.6	23.4	164.0	111.6	6.8	82
October	32.2	23.6	194.7	125.3	7.3	77
November	31.6	23.2	209.7	89.6	5.3	78
December	31.7	23.8	66.7	165.3	7.5	72
1998						
January	33.3	22.8	0	174.8	9.3	64
February	34.4	23.6	0	162.8	9.6	64
March	36.2	23.6	0	203.0	9.6	67
April	36.5	25.6	0	170.8	9.9	68

Appendix-2. Abstract of ANOVA (Exp.IA)
DWF and RWC in relation to varieties and durations of stress

Source	Degree of freedom	Mean square	
		DWF	RWC
Factor A	20	0.032**	7.32**
Factor B	3	0.037**	7.25**
AB	60	0.015**	3.56**
Error	166	0.005	0.01
Total	251		

A - Varieties B - Durations of stress

Appendix-3. Abstract of ANOVA (Exp.IB)
Physiological characters in relation to varieties and durations of stress

Source	Degrees of freedom	Mean square				
		Net photosynthesis	Transpiration rate	Stomatal conductance	Leaf temperature	Leaf water potential
Factor A	9	7.591**	4.357**	0.014**	186.034**	12.46**
Factor B	2	361.938**	138.216**	0.221**	628.826**	40.45**
AB	18	5.490	2.826	0.005	245.744	0.530
Error	58	0.771	0.446	0.002	1.156	0.064
Total	89	937.670				

A - Varieties B - Durations of stress

Appendix-4. Abstract of ANOVA (Exp.IC)
Growth characters in relation to varieties and soil moisture regimes

Source	Degrees of freedom	Mean square								
		Height	Girth	Number of leaves	Internodal length	RDHP	SDHP	R:S ratio	Biomass production	TDHP
Factor A	5	1138.24**	52.45**	167.05**	6.44**	0.91	31.73**	0.07**	78.83**	60.30**
Factor B	5	52.47**	50.68	502.20**	1.61**	5.61**	28.50**	0.13**	45.29**	42.07**
AB	25	87.41	0.45	51.44**	0.96	1.60	11.04	0.06**	21.28	14.74
Error	144	63.70	0.31	54.49	0.64	1.07	13.06	0.02	19.05	13.99

A - Varieties B - Soil moisture regimes

Appendix-5. Abstract of ANOVA (Exp.IC)
Physiological characters in relation to varieties, soil moisture regimes and durations of stress

Source	Degrees of freedom	Mean square				
		Net photosynthesis	Transpiration rate	Stomatal conductance	Leaf temperature	Leaf water potential
Factor A	5	9.729**	10.933**	0.014**	970.23**	31.22**
Factor B	5	4.366**	5.443**	0.010**	211.71**	16.69**
AB	25	3.262	2.326	0.005	218.33	0.140
Factor C	2	208.33**	29.675**	0.013**	2108.62**	80.385**
AC	10	2.408	4.430	0.004	1123.98	1.368
BC	10	1.035	1.913	0.002	282.39	0.178
ABC	50	1.063	1.059	0.001	185.78	0.063
Error	214	0.173	0.263	0.000	0.065	0.018
Total	323					

A - Varieties B - Soil moisture regimes C - Durations of stress

Appendix-8. Abstract of ANOVA (Exp.ID)
Physiological characters of 6 varieties under field condition

Source	Degrees of freedom	Mean square			
		Net photosynthesis	Transpiration rate	Stomatal conductance	Leaf water potential
Factor A	5	21.14**	31.22**	30156.07**	0.016**
Error	10	3.37	2.45	4142.56	0.103

A - Varieties

Appendix-9. Abstract of ANOVA (Exp.II)
Effect of irrigation and N levels on the growth of cashew tree

Source	Degrees of freedom	Mean square							
		Height		Girth		No. of primary		Canopy spread	
		1996	1997	1996	1997	1996	1997	1996	1997
Factor A	2	4.421**	7.900	24.87	53.33	0.067**	0.074	0.003	0.336
Factor B	2	1.187**	3.387**	47.26	27.44	0.034**	0.035	0.040	0.918
AB	4	0.957**	8.61**	61.93	77.80	0.185**	0.199	0.185	0.184
Error	18	0.953	3.000	55.21	66.7	0.001	0.002	0.396	0.366
Total	26								

A - Irrigation levels   B - N levels

Appendix-10. Abstract of ANOVA (Exp.II)
Effect of irrigation and N levels on the yield attributes and yield of cashew tree

Source	Degrees of freedom	Mean square						
		No.of flushes m^{-2}		LAI		No.of panicles m^{-2}		Yield
		1996	1997	1996	1997	1996	1997	1997
Factor A	2	1.220	0.59	3.296**	22.04**	0.327	0.127**	4.28**
Factor B	2	0.079	3.58**	2.29**	3.24**	1.013	0.514**	1.59**
AB	4	0.161	0.11	0.29**	0.13**	0.712	0.036	0.14**
Error	18	1.224	0.36	0.06	0.04	0.936	0.151	0.01
Total	26							

A - Irrigation levels B - N levels

Appendix-11. Abstract of ANOVA (Exp.III)
Growth characters in relation to varieties and levels of N

Source	Degrees of freedom	Mean square								
		Height	Girth	Number of leaves	Internodal length	RDMP	SDMP	R:S ratio	TDMP	Leaf area per plant
Factor A	9	1056.32**	2.59**	91.95**	0.47**	73.72**	1507.51**	0.025**	1970.26**	3674.1**
Factor B	8	998.33**	3.04**	327.69**	0.43	47.72**	1135.13**	0.03**	1558.44**	33.38**
AB	72	80.81**	0.66**	39.81	0.87	13.81**	430.65**	0.02**	547.45**	921.38
Error	180	36.81	0.21	16.51	0.28	3.28	18.68	0.007	21.48	143.75
Total	269									

A - Varieties B - N levels

Appendix-12. Abstract of ANOVA (Exp.III)
Content and uptake of nutrients in relation to varieties and N levels

Source	Degree of freedom	Mean square					
		Leaf N	Leaf P	Leaf K	N uptake	P uptake	K uptake
Factor A	9	2.19**	0.02**	0.27**	1117.21**	21.4	9.0**
Factor B	8	2.41**	0.03	0.53**	1076.48**	17.1	17.0**
AB	72	0.37**	0.04	0.03	1378.75	17.8	3.0**
Error	180	0.03	0.002	0.005	1349.58	18.2	1.0
Total	269						

A - Varieties B - N levels

Appendix-13. Abstract of ANOVA (Exp.IV)
Growth characters in relation to varieties and P levels

Source	Degrees of freedom	Mean square								
		Height	Girth	Number of leaves	Internodal length	RDMP	SDMP	R:S ratio	TDMP	Leaf area per plant
Factor A	9	596.05**	3.08**	101.16**	1.09**	24.75**	280.53**	0.039**	538.93**	1626.0**
Factor B	8	389.45**	1.65**	75.33**	0.81	30.11**	153.51**	0.034**	671.27**	175.24**
AB	72	25.66**	0.56**	21.48**	0.45**	5.18**	40.75**	0.013**	74.47**	254.74
Error	180	14.83	0.20	9.61	0.32	1.72	9.84	0.005	5.58	110.92
Total	269									

A - Varieties B - P levels

Appendix-14. Abstract of ANOVA (Exp.IV)
Content and uptake of nutrients in relation to varieties and P levels

Source	Degree of freedom	Mean square					
		Leaf N	Leaf P	Leaf K	N uptake	P uptake	K uptake
Factor A	9	0.494**	0.003**	2.6**	260.83	2.88	0.20**
Factor B	8	1.501**	0.17**	5.0**	263.34	2.88	0.60**
AB	72	0.065**	0.002	6.3	257.27	2.90	0.80
Error	180	0.006	0.0004	0.93	257.61	2.90	0.60
Total	269						

A - Varieties B - P levels

Appendix-15. Abstract of ANOVA (Exp.V)
Growth characters in relation to varieties and K levels

Source	Degrees of freedom	Mean square								
		Height	Girth	Number of leaves	Internodal length	RDMP	SDMP	R:S ratio	TDMP	Leaf area per plant
Factor A	9	833.56**	3.17**	145.71**	1.70**	62.78**	280.52**	0.040	607.16**	2210.79**
Factor B	8	332.51**	1.65**	64.56**	0.24**	6.15**	153.51**	0.017	183.04**	620.7**
AB	72	65.54**	0.63**	29.19	0.47	7.88**	40.75**	0.021**	60.16**	147.75
Error	180	11.47	0.25	9.14	0.29	2.47	9.84	0.009	11.67	38.11
Total	269									

A - Varieties B - K levels

Appendix-16. Abstract of ANOVA (Exp.V)
Content and uptake of nutrients in relation to varieties and K levels

Source	Degree of freedom	Mean square					
		Leaf N	Leaf P	Leaf K	N uptake	P uptake	K uptake
Factor A	9	0.208**	0.01**	0.833	100**	0.6**	40**
Factor B	8	0.420**	0.01**	0.831	90**	0.8**	85**
AB	72	0.039**	0.002	0.838	8**	0.08	8**
Error	180	0.004	0.002	0.837	2	0.066	0.3
Total	269						

A - Varieties B - K levels

Appendix-17. Abstract of ANOVA (Exp.III, IV & V)

Source	Degrees of freedom	Mean		
		N use efficiency	P use efficiency	K use efficiency
Factor A	9	783.91**	291.40**	1204.09**
Factor B	7	128.62**	14.11**	131.09**
AB	63	42.11**	8.86**	17.58**
Error	158	0.003	0.004	0.003
Total	239			

A - Varieties B - Nutrient levels

ABSTRACT

Five experiments were conducted at Cashew Research Station, Kerala Agricultural University, Madakkathara during 1996-98 to identify drought tolerant varieties of cashew, to study the response of cashew to applied N at different levels of drip irrigation and to assess the tolerance of cashew varieties to N, P and K deficiency in soil. The abstract of the experiments is given below.

Exp. I. Varietal variation in drought tolerance

The varieties H-1591, M-26/2, V-5 and M-44/3 are drought tolerant and K-22-1 is drought sensitive.

Exp. II. Response of cashew to applied N at different levels of irrigation (drip)

N application @ 1500 g per tree per year along with irrigation @ 80 litres per tree per day (through drip) is essential in the state of Kerala for obtaining best results from cashew.

Exp. III. Tolerance of cashew varieties to N dificient soils

The varieties H-1591 and M-26/2 are efficient for N deficient soils. The N use efficiency of cashew seedlings grown under pot culture was 24.7 per cent.

Exp. IV. Tolerance of cashew varieties to P deficient soils

H-1591 is an efficient variety for P deficient soils. The P use efficiency of cashew seedlings grown under pot culture was 8.02 per cent.

Exp. V. Tolerance of cashew varieties to K deficient soils

The varieties H-1591, M-26/2 and H-1598 are efficient for K deficient soils. The K use efficiency of cashew seedlings grown under pot culture was 12.17 per cent.

N, P and K absorption of a six month old cashew seedling was in the order of 151.95 mg N, 21.58 mg P and 49.48 mg K per plant with a nutrient absorption ratio of 7:1:2 (approximately).

The variety H-1591 is a super variety capable of tolerating not only drought but also N, P and K deficient soils. The variety M-26/2 is capable of tolerating drought as well as N and K deficiency in soils. The variety K-22-1 is drought sensitive.