Interaction of water and nitrogen in relation to growth and yield of rabi grain sorghum.

BY

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CERTIFICATE

Mr. Sivanuri Ravi Kumar has satisfactorily prosecuted the course of research and that the thesis entitled **INTERACTION OF WATER AND NITROGEN IN RELATION TO GROWTH AND YIELD OF RABI GRAIN SORGHUM** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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CERTIFICATE

This is to certify that the thesis entitled "**Interaction of water and nitrogen in relation to growth and yield of rabi grain sorghum**" submitted in partial fulfilment of the requirements for the degree of '**Doctor of Philosophy in Agriculture**' of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr. Sivanuri Ravi Kumar** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Abstract

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Grain sorghum in post-rainy (rabi) season grows on receding soil moisture and the response to nitrogen is low because of limited water availability or non-responsive genotypes. A study was conducted under irrigated and dry conditions, to examine the influence of variable nitrogen supply on crop growth, nutrient uptake (N, K), and resource use efficiency of rabi sorghum genotypes. The concept of specific leaf nitrogen (SLN), defined as the amount of leaf nitrogen per unit leaf area proposed by Muchow (1988), was related to radiation use efficiency (RUE), and a sorghum growth model (RESCAP), proposed by Monteith et al., (1989), was validated using the sorghum cultivar M 35-1.

Nitrogen had significant influence on all growth parameters including plant height, leaf area index (LAI), leaf weight, stem, earhead and grain yield. Leaf, stem and grain nitrogen uptake

was highest in the 120 kg N ha^{-1} treatment and most of the increased nitrogen accumulated in the grain. Higher LAI resulted in increased cumulative light interception which finally resulted in higher total biomass than ICSH 86646 and SPV 783, while partitioning towards earhead (HI, harvest index), was lowest in M 35-1 (HI=0.30), it was highest in ICSH 86646 (HI=0.52) and intermediary in SPV 783 (HI=0.44). The improved genotypes ICSH 86646 and SPV 783 had higher grain nitrogen uptake when compared to M 35-1 which had higher nitrogen in the stem. In terms of quality M 35-1 had higher leaf, stem and grain nitrogen content than ICSH 86646 and SPV 783. Water use was similar in ICSH 86646 and M 35-1, while cumulative light interception and RUE were higher in M 35-1 which ultimately resulted in higher total above-ground biomass.

In irrigated plots most of the ammonical nitrogen was converted to nitrate nitrogen, but in dry plots a higher amount of NH_4-N remained in the soil profile. Dry plots had higher NO_3-N than irrigated plots at anthesis and harvest stages indicating lower plant uptake and / or lower nitrogen loss from the soil profile. The increase in N uptake due to irrigation was 10, 32, 34 and 75 kg ha^{-1}, for the 0, 20, to and 120 kg N ha^{-1} N application rates. Nitrogen increased water use efficiency by 19 kg mm^{-1} of water in irrigated plots, while in dry plots it increased by 9 kg mm^{-1}.

A linear relationship was established between SLN and RUE in M 35-1, while in ICSH 86646 and SPV 783 there was much scatter of the observations. RESCAP model over estimated total biomass production (g m^{-2}), in the early stages of crop growth in both irrigated and dry conditions. Total biomass and grain yield (t ha^{-2}), were over estimated by the model in both irrigated and dry plots, while the harvest index was correctly predicted.

CONTENTS

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SIVANURI RAVI KUMAR

DECLARATION

I declare that this thesis entitled **"INTERACTION OF WATER AND NITROGEN IN RELATION TO GROWTH RABI GRAIN SORGHUM"** is a bonafide record of work done by me during the period of research at ICRISAT, Patancheru. This thesis has not formed in whole or in part, the basis for the award of any degree or diploma.

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Date: 15 May 1995

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Introduction

1.0 INTRODUCTION

After rice and wheat, sorghum is the most important cereal grown in India. Tandon and Kanwar (1984) reported that the estimated 16.5 m ha area under sorghum in India has changed little in the last 30 years. During the post rainy season (rabi), sorghum dominates production in semi-arid tropical India where it occupies approximately 6.5 m ha.

In recent years, rainy season sorghum grain and fodder production per unit area has steadily increased while post rainy sorghum yields have remained stagnant (Tandon and Kanwar, 1984). Post rainy sorghum is an important component in traditional cropping systems, where it is used for grain and fodder. Major production districts of post rainy season sorghum are Solapur, Ahmednagar and Pune in Maharashtra, Bijapur, Gulbarga, Raichur, Belgaum and Dharwad in Karnataka, and Adilabad, Khammam, Warangal, Medak, Kurnool, Ananthapur and Prakasm in Andhra Pradesh (Murthy, 1989).

During post rainy season, sorghum is grown on Vertisols. These soils swell in the wet season and shrink in the dry season (Dudal and Eswaran, 1988). Maharashtra (29.9 m ha.), Madhya Pradesh (16.7 m ha.), Gujarat (8.2 m ha.), Andhra Pradesh (7.2 m ha.) and Karnataka (6.9 m ha.) are the states in India having Vertisols and associated soils (Murthy, 1981).

Sorghum grown under post rainy season conditions survives and produces grain and fodder in an entirely receding moisture situation. Presently reported response to nitrogen is to an extent of 40 kg N per hectare. This low response could be possibly due to two reasons : 1) non-availability of nitrogen during major part of the crop period as the receding moisture front leaves the applied nitrogen in the top layers of the soil profile, and renders the nitrogen unavailable though it may be present there or 2) non-responsive post rainy season sorghum genotypes.

The few high yielding hybrids and varieties which have been released for post rainy season cultivation during the last 10 years, have had little adoption. The cultivar M 35-1 (a selection from land race Maldandi) continues to be the most popular variety and is widely recognised for its drought resistance and good grain quality (Seetharama, 1986). Characterisation of the newly developed and local genotypes is necessary to better understand their potential and pinpoint features for further improvement.

Work by Rego et al. (1982) showed that nitrates could accumulate to the extent of 30-40 mg kg^{-1} in the upper 1 metre of a Vertisol profile but would decrease to 6-9 mg kg^{-1} under monsoon cropping. Nitrogen supply effects plant growth and productivity by altering leaf area and photosynthetic capacity (Novoa and Loomis, 1981). Muchow (1989) reported that leaf nitrogen available per unit leaf area (specific leaf nitrogen) does influence the photosynthetic activity. The relationship between specific leaf nitrogen and radiation use efficiency has to be established to signify its influence on biomass production or whether nitrogen merely increases leaf area of the plant.

A new resource capture model, RESCAP, (Monteith, in press), places equal emphasis on the role of leaves in relation to the interception of light and to the role of roots in relation to the uptake of water. A central feature of the model is the comparison each day between the accumulated extractable water and the net decrease of soil water content since the start of growth. If the demand in the plant system is met from the available soil water then dry matter production is a function of intercepted light (light-limited), but if the demand exceeds supply, the rate of transpiration reverts to total potential extraction by the root system (water-limited). Post rainy season provides excellent conditions to validate a crop model and this study entitled "Interaction of water and nitrogen in relation to growth and yield of rabi grain sorghum" was framed to achieve the following objectives:

1. To characterize in terms of growth, yield and nutrient (N and K) uptake, a sorghum genetic base representing improved and traditional cultivars during post rainy season.

2. To study the response of rabi sorghum genotypes to applied nitrogen and the availability of soil nitrogen under irrigated and dry conditions.

3. To relate specific leaf nitrogen to radiation use efficiency and to validate a sorghum growth model (RESCAP) under receding soil moisture contitions.

Review of Literature

2.0 Literature review

2.1 Sorghum :

Globally, sorghum (Sorghum bicolor (L.) Moench), ranks fifth in importance among cereals, and sixth among important dietary sources of energy for the worlds population (Cock, 1985). Of the world area of 47.56 m ha under sorghum, 34.5 % is located in India. In terms of production India contributes around 17.0 % of total world production, second to the U.S. (27.0 %), however yields on a land unit basis are less than half the world avearage of 1433 kg ha^{-1} (FAO, 1983).

Bapat (1986), reported that core rainy season sorghum areas in India extend from 9^0N (Madurai) to 25^0N (Hamirpur), while that of post rainy season sorghum are restricted to a narrow belt of 14^0N (Nellore) to 21^0N (Dhule). Average temperatures in the zone varies from 22^0c to 29^0c in the postrainy season. However, maximum temperature increases from 30^0c at the end of October to 35^0c by March. Sorghum during postrainy season is grown in Vertisols and the associated group of soils. Vertisols constitute one of the most widely occuring soils of the world in general and the Indian subcontinent in particular. Dudal ~~et al.~~ (1965) reported the global distribution of black soils or dark clay soils as 257 million hectares, confined between 45^0N and 45^0S latitudes. The extensive areas of occurence are in Australia, the blue Nile valley of Sudan, in Ghana, Cuba, Puerto Rico, Uruguay and Taiwan and in the Deccan plateau in India (~~Hagen-Zicker, 1964)~~. These soils are low in nitrogen (N), and the availability of soil N is a serious constraint to crop productivity (Tandon and Kanwar, 1984; William et al. 1985).

Crop productivity depends on the development of leaf area (L) to intercept the radiant energy, and the rate of net photosynthesis (P) to convert it into drymatter. With the exception of forage crops, only a proportion of the above-ground drymatter contributes to economic yield (Y). The distribution of assimilates (H) within the plant determines the proportion of the total that is harvested as economic yield. Genetic improvement of crops and the development of improved agronomic practices to make more effective use of water and nitrogen, are important steps in developing better farming systems. Hence

$$Y = f(L, P, H)$$

(Turner and Beg, 1981). Of the various soil factors which influence sorghum productivity, soil nitrogen, soil water and their interaction are of primary importance in the postrainy scenario. Variable responses to application of N fertilizer have been observed in the semi-arid tropics under rainfed conditions, with the largest responses generally being observed in the seasons of above average rainfall (Myers, 1978).

2.2 Soil nitrogen :

Nitrogen is a key element in improving crop productivity throughout the world. It has attracted considerable research attention both as a plant nutrient and as an environmental pollutant and several reviews have appeared (Bartholomew and Clark, 1965, Nielsen and MacDonald, 1978). Most of the soil N is in the organic form and has to undergo mineralization before it is taken up by the plant roots. Vlek et al. (1981) emphasize the uncertainity about rates of mineralization and immobilization of nitrogen in soils because they are closely linked to the turnover of organic matter which usually contains more than 95 percent of the soils nitrogen.

2.2.1 Mineralization :

Most soil nitrogen (N), is in organic forms, but plants can only use soil nitrogen if it is converted to inorganic forms (NH_4 and NO_3). Change in total soil nitrogen is expressed as a simple first order rate equation :

$$\frac{dN}{dt}=-kN+A$$

where k is the decomposition constant, N is the nitrogen content of a given mass of soil at time t, and A is an accretion constant giving the amount of nitrogen added to the given mass of soil per unit time (Greenland, 1971). A more refined equation developed by Russell (1975), allows for year-to-year variation of the rate constant and include a factor to account for addition of manure :

$$\frac{dN}{dt}=-k1(t)N+k2+k3(t)Y(t)$$

where N is soil organic nitrogen, k (t) is a time dependent decomposition coefficient, k2 represents a constant addition of N not associated with cropping, y (t) is plant biomass at time t and k3(t)y(t) is the addition of N from plant residues which depends on the nature of the sequential crop.

Attempts have been made to follow the short term nitrogen dynamics in soil by simulation of the various transformation in mechanistic models. these models are based on the assumption that microbially mediated processes are kinetically first order in nature :

$$\frac{d[orgN]}{dt}i = K1[orgN]i + k2[NH4+] + k3[No2-] + k4[No3-]$$

(Tanji and Gupta, 1978).

Various models incorporate environmental factors to allow for seasonal variations in the rate constant (k1, k2, k3, k4) of the transformations (Beek and Frissel, 1973; Hagin and Amberger, 1974; Watts, 1975).

Temperature and soil moisture variation in the environment has a great impact on the dynamics of nitrogen transformation in soil. For instance, during dry periods carbon decomposition exceeds nitrogen mineralization (Birch, 1960), resulting in a decreased C:N ratio which will favour net mineralization during the subsequent wet season. If the temperatures are favourable, the onset of the rainy season will be accompanied by a flush of mineral nitrogen in the soil (Hardy, 1946; Birch, 1960).

In a winter rainfall climate, the early rains coincide with low soil temperatures, the mineral nitrogen flush may be delayed until early spring. Recent work in the Indian Deccan has shown that, under monsoon fallow system with post-monsoon cropping, 36 to 40 ppm nitrate nitrogen could accumulate in the upper 1 m. of the soil profile by the end of the rainy season. However, under monsoon cropping, the nitrate nitrogen content decreased to 6 to 9 ppm (Rego et al. 1982). A better understanding of the kinetics of mineralization in dryland agriculture would help to predict the availability of mineral N and allow for timely correction of nitrogen deficiencies through application of fertilizers.

2.2.2 Ammonification :

Ammonification of organic N in soil is affected by a number of factors, many of which are related to biological activity (Vlek et al. 1981). Myers (1975), studying the temperature effect on ammonification in a tropical soil, found it to fit an Arhenius type equation with a maximum at about 50^{0}C. The lower temperature limit for ammonification is generally around freezing (Stanford et al. 1973). The optimum soil potential for ammonification ranges from 10 to 50 K Pa (0.1 to 0.5 bar) (Miller and Johnson, 1964; Stanford and Epstein, 1974), while the rate of ammonification declines linearly with decreasing water content (Stanford and Epstein, 1974).

Cameroon and Kowelenko (1976), demonstrated the importance of a temperature : water content interaction term in quantifying microbially mediated ammonification . The effect of soil factors such as pH, salinity and texture on ammonification has been studied, but good fundamental relationships have not been established (Laura, 1973; Nyborg and Hoyt, 1978).

2.2.3 Nitrification :

Ammonical N mineralized from organic matter can be either assimilated by microorganisms and plants or oxidized to NO_3^- in the process termed nitrification. Nitrosolobus and Nitrosopira were the dominant NH_4^+ oxidizers in a range of soils examined by Soriano and Walker (1973). Where inorganic N is derived chiefly from the ammonification of organic N, nitrification will rarely limit the rate of production of NO_3^-. Only at low and high pH (Morill and Dawson, 1967), at high water potentials and temperatures (Focht and Verstraete, 1977), or at water potentials below 1.5 M Pa (Justine and Smith, 1962), might NH_4^+ or NO_2^- accumulate following ammonification.

The use of ammonia or ammonia forming fertilizer such as urea in arid zone soils may lead to high concentrations of mineral N and, in the case of urea, to a temporary increase in soil pH (Hauck and Stephenson, 1965). Thus NO_2^- might accumulate where high NH_4^+ and associated pH inhibit Nitrobacter activity (Alexander, 1965).

2.2.4 Nitrogen losses :

Negatively charged nitrate ions can be lost by denitrification (Stefanson, 1972) or leaching (Shaw, 1962). Positively charged ammonium ions, however, are rarely leached because they are attached to negatively charged sites on the soil exchange complex (Broadbent et al. 1958; Gasser, 1964). Nitrogen can be lost to the atmosphere as ammonia from surface applied Urea (Hargrove and Kissel, 1979), and from ammonium compounds on calcareous soils (Fenn and Kissel, 1976). Ammonical nitrogen can be immobilised by microbial biomass (Shen et al. 1984; Wickramasinghe et al. 1985).

Gillman and Bristow (1990), examined the effect of two sources of N (urea and ammonium sulfate) on the leaching of exchangeable cations in an inceptisol over a 6 week period. They found that all applied urea was hydrolysed within 3 days of application. All applied nitrogen from both sources was retained in the top 20 cm following the first irrigation, about 70-80 % after the second irrigation and about 50 % following the third and final irrigation. Increasing losses of nitrogen at each watering period were associated with increased nitrate production. They suggest that loss of nitrogen from the ammonium sulfate treatment was associated with a reduction in basic exchangeable cations, indicating that nitrogen was leached as nitrates. In the urea plots, the constancy of exchangeable cation data suggests that denitrification could have contributed to nitrogen loss, or more likely that nitrogen was leached as ammonium nitrate.

2.2.5 Nitrogen availability index :

Extensive research conducted by FAO (1973), in the Mediterranean climate of central Chile confirmed the usefulness of the mineral N soil test (0 to 15 cm) as predictive tool for fertilizer response in dryland agriculture. Whenever soil contained more than 40 ppm mineral N before planting, the response to fertilizer N was less than 10 percent. In the absence of supplemental irrigation the reliability of such prediction is less (Vlek, 1981).

However Taylor et al. (1974) used soil nitrate levels in the top 30 cm of soil as an index of available soil N for studying possible N response levels in dryland wheat production in Southern New South Wales. They concluded that nitrate levels would restrict yields on most farms whenever nitrate concentrations fell below 20 ppm. Profitable response to N (34 kg N ha^{-1}) was generally obtained if soil nitrate was less than 8 ppm, provided seasonal conditions were better than average (Taylor et al. 1978).

2.3 Soil water :

The concept of the soil as a reservoir for water is appealing and useful. Since only a small amount of water can be stored in crop plants relative to the rate of transpiration through them, it is the storage of water with in the soil pores that permits transpiration to continue for several days without recharge by rainfall or irrigation (Ritchie, 1981).

Vertisols have a relatively high water storage capacity in the root zone because of their usually high content of clay dominantly a 2:1 type (Virmani et al. 1982). The available water range of vertisols has been reported as 110 mm in Australia (Stace et al. 1968), 125 mm in the Sudan (Jewitt et al. 1979), and 230 mm in India (ICRISAT, 1978), for the upper metre depth of the soil profile. Soil water storage capacity is particularly important in semi arid regions with uncertain rainfall distribution. Krantz et al. (1978), concluded that the growing season on a deep vertisol at ICRISAT centre was 21 to 33 weeks, where as it was only 14 to 21 weeks on an alfisol.

Dry matter in the grain (Y), is a function of the water passing through the crop in transpiration (T), and water use efficiency (W), and the proportion of total dry matter which is partitioned to the grain (H), (Passioura, 1977; Fischer and Turner, 1978).

$$Y = f(T, W, H)$$

Thus to improve the grain yield of crops in a dryland area one must either increase transpiration, increase the water use efficiency and/or increase the proportion of total dry matter partitioned to the grain (Turner and Begg, 1981).

2.4 Interaction of water and nitrogen :

In the field, soil moisture content may become so low that water uptake and hence nutrient transport are restricted. Garwood and Williams (1967), observed that during a dry period, depressions in the growth rate of a grass sward which could be remedied, not by irrigation, but by an injection of nitrogenous fertilizer in the deeper soil layers. Nitrogen in the upper soil layers was rendered unavailable by the soil dryness but the plants were able to draw water from deeper layers where no nitrogen was present. Some times increased vegetative growth results in greater evaporative demand, and a more rapid diminution of soil water reserves so that the crop may be left with insufficient water to complete its growth (Russell, 1967). This type of situation indicates the need for caution in the use of N fertilizer.

The effects of nitrogen and water shortage and their interactions were illustrated in a series of elegant pot experiments with a system in which nitrogen and water could be applied independently in three compartments (Rehatta et al. 1979). Moisture shortage with equal availability of nitrogen led to reduced nitrogen uptake. Uptake must then be governed by the reduced rate of dry matter production, because the concentration of the element in the tissue is at its maximum level (Van Kuelen, 1981). Moisture shortage may have both a direct and an indirect effect on nitrogen uptake. In one case it controls the physical transport processes in the soil, the other by metabolic processes in the plant.

A significant positive interaction between fertilizer and moisture was reflected in sorghum yields (Kanwar, 1978; Nagre and Bathkal, 1978; Venkateswarlu and Rao, 1978), and this interaction is stronger in an alfisol than in a vertisol (Kanwar, 1978).

2.5 Influence of soil nitrogen and water on crop growth :

2.5.1 Leaf growth :

Leaf area is the main factor in biomass formation (Watson, 1947), and it varies in amount with plant population and nutrient supply. Leaf area is normally increased by nitrogen (Langer and Liew, 1973; Pearson, et al. 1977; Spiertz and Ellen, 1978). Leaf area duration is also extended by nitrogen (Langer and Liew, 1973; Thomas et al. 1978). Thorne's (1974), analysis of Rothamsted experiments before 1965 and experiments in Holland, Australia and Canada, led her to conclude that most of the variations in wheat grain yields due to nitrogen could be related to variation in leaf area duration.

Nitrogen has a significant effect on leaf area expansion and senescence, but only a small effect on leaf number (Muchow, 1988a). Muchow (1988a), determined a minimum specific leaf nitrogen (1.0 g N m^{-2}), for leaf growth to proceed at the potential rate determined by temperature. If nitrogen uptake and partitioning to leaf are not sufficient to reach this minimum level, leaf growth is reduced. Leaf senescence is affected by the balance between N uptake and the mobilization of leaf nitrogen to meet grain demand.

The effect of water shortage on leaf area development has been quantified by relating relative leaf growth to the fraction of available soil water (Rosenthal et al. 1987; Hammer and Muchow, 1991). Rosenthal et al. (1987), reduce leaf growth once the fraction of available soil water drops below 0.5, while Hammer and Muchow (1991), discount leaf growth at the fraction of available soil water below 0.3. Both studies show considerable scatter in the relationship, nevertheless in both instances, leaf growth is more severely affected by water deficit than is the rate of transpiration. Quantification of the effect of water limitation on senescence has been neglected so far in models.

2.5.2 Biomass accumulation :

Biomass accumulation has been considered by Ludlow and Muchow (1992), as the product of incident radiation, the fraction of that intercepted by the crop and the efficiency with which the intercepted radiation is converted to biomass (RUE). The fraction of daily incident radiation intercepted by a crop is an exponential function of its leaf area index. The radiation extinction coefficient for this function (k), together with RUE are conservative parameters under good growing conditions with reported values of 0.4 and 1.25 g MJ^{-1} respectively (Muchow and Coates, 1986; Muchow and Davis, 1988; Muchow, 1989a).

The effect of water shortage on biomass accumulation has been quantified using the relationship between relative transpiration and the fraction of available soil water, in a similar manner to the effect on relative leaf growth, (Rosenthal et al. 1987; Hammer and Muchow, 1991).

Nitrogen has a significant effect on biomass accumulation (Muchow and Davis, 1988; Lafitte and Loomis, 1988). Muchow and Davis (1988), reported that the reduction in biomass accumulation under nitrogen shortage was due to a relatively greater reduction in RUE than in the amount of radiation intercepted. They reported a linear relationship between RUE and specific leaf nitrogen. Burstrom (1943), observed an enhancement in apparent CO_2 assimilation with a rise in the nitrate content of wheat leaf laminae. Osman and Milthorpe (1971) found that the increase in the gross photosynthesis in wheat species was linear with nitrogen content. Thomas et al. (1978) did not find any effect of nitrogen on photosynthesis or photorespiration of wheat, but they suggested that there was an effect on dark respiration.

2.5.3 Grain growth :

Grain yield accumulation can be quantified as the product of biomass accumulation and harvest index. For sorghum, Muchow (1990a), found that harvest index increased linearly at a rate of 0.0185 per day from the first day after anthesis and this rate of increase was relatively stable for a number of sowings in tropical Australia. Towards the end of grain filling, harvest index reaches its maximum value (Muchow, 1990b). This maximum value is reduced by water and nitrogen deficit (Muchow, 1988b; 1989b), but the rate of increase in harvest index is a conservative parameter under varying environmental conditions. The determination of the timing of the harvest index asymtote and of physiological maturity is a major limitaiton in using this approach in simulation modelling (Hammer and Muchow, 1991).

The accumulation of nitrogen in the grain has important implications both for grain quality and yield physiology. Muchow (1990b), observed that soil nitrogen uptake during grain filling was unresponsive to fertilizer nitrogen applied at the time of sowing, and that it was small relative to total N uptake during the crop cycle. Consequently, mobilisation of leaf nitrogen to the grain was more significant than nitrogen uptake during grain filling, thus variability in biomass at maturity accounted for 95 % of variance in grain yield. Howell (1990), obtained comparable results.

Similarly, variability in total N uptake accounted for 92 % of the variance in grain nitrogen accumulation.

Numerous studies have described the effect of nitrogen deficiency and nitrogen application on grain sorghum (Cowie, 1973). The effect of inadequate nitrogen supply on final crop yield has been linked to reduced leaf area index (LAI), and consequent reduction in light interception and photosynthate supply, which in turn reduces grain yield per hectare (Heslehurst, 1976).

The importance of grain number as the main determinant of yield has been pointed out by Thorne et al. (1968) and many others (Evans and Wardlaw, 1976; Speirtz and Ellen, 1978 and Yoshida, 1972). A synthesis of 12 reports covering 24 experiments on sorghum shows that the dominant factor contributing to higher grain yields is an increase in the number of grains per panicle as a result of fertilizer application and average increase in grains per panicle was 61 % (Tandon and Kanwar, 1984). Grain weight generally shows much less variation than grain number. Grain weight may be greater with higher nitrogen (Halse et al. 1969; Spiertz and Ellen, 1978) or unchanged (Pushman and Bingham, 1976).

2.5.4 Nitrogen uptake :

The demand for nitrogen by crops vary widely with location, cropping system and year-year weather conditions. Large fluctuatuions in drymatter production of the natural vegetations of the northern Negev resulted in total N uptake varying from nil to 100 kg N ha^{-1} (Van Keulen, 1977) with estimated average of 50 kg N ha^{-1} (Noy-Meir and Harpaz, 1977). Data from control plots (0 N) of several experiments indicate that 25-83 kg ha^{-1} N can be removed by sorghum from different sites (Roy and Wright, 1974; Venkateswarlu et al. 1978).

Variable responses to application of nitrogen fertilizer have been observed in the semi-arid tropics under rainfed conditions, with the largest responses generally being observed in seasons of above average rainfall (Myers, 1978; Patil et al. 1981; Umrani and Bhoi, 1981). Depending on soil depth and moisture storage capacity, the optimum level of nitrogen for sorghum varied from 25 to 85 kg N ha^{-1} (Patil et al. 1981). A non-irrigated crop of CSH 1 at Parbhani, fertilized at 125-75-0 kg of N-P-K per hectare produced 4.16 t ha^{-1} grain and removed 170 kg N ha^{-1} (Tatwawadi and Hadole, 1972).

2.5.5 Nitrogen use efficiency :

Fernandez and Laird (1959) showed that under optimum soil moisture, wheat yielded 24 kg grain kg^{-1} applied nitrogen but only 11 kg kg^{-1} N when water was limiting. Bruetsch and Estes (1976) studied the variation in nutrient efficiency for above-ground dry matter production by 12 corn genotypes. The efficiency of nitrogen use ranged from 59 to 82 kg biomass kg^{-1} N absorbed showing the importance of genetic component.

Optimum rates of nitrogen for high yielding cultivars of sorghum in the rainy season are seen to vary from 60 to 120 kg N ha^{-1} and at these levels, an overall response rate (grain yield increase over 0 N) of 18.3 kg grain kg^{-1} N applied is obtained (Tandon and Kanwar, 1984).

Crop recovery of added N varied rather narrowly from 46.3 to 51.1% as nitrogen levels increased from 40 to 160 kg N ha^{-1}. At the highest level tested, soil + crop could account for 78-90 % of added N, as compared with 93.2 % at 40 kg N ha^{-1} (Tandon and Kanwar, 1984).

2.6 Crop modelling :

Models can integrate a large body of research knowledge that has been derived over many years. They provide a means to link this research effort with decision makers via simulation studies to evaluate likely outcomes of decision options (Hammer and Muchow, 1992). A number of sorghum models exist and their evolution is a continuing process. Considerable effort has been made in building and validating these models in the U.S.A. (Arkin et al. 1976; Vanderlip and Arkin, 1977; Rosenthal et al. 1989; Ritchie and Algarswamy, 1989; McCree and Fernandez, 1989), Australia (Hammer et al. 1989; Birch et al. 1990; Hammer and Muchow, 1991), and India (Huda, 1987; Monteith et al. 1989).

2.6.1 Model applications :

Models provide a vehicle to integrate research and highlight knowledge gaps. Models provide a framework for design and analysis of experiments. McCree and Fernandez (1989) found simulation models to be useful tools for integrating ideas about physiological responses to soil water deficit at the whole plant level. Robertson (1991) used a radiation interception model to show that the percentage contributions of reduced leaf expansion, reduced extinction coefficient (due to leaf rolling) and leaf death to the overall reduction in radiation interception of sorghum under drought were 64, 28 and 7 %, respectively. Using models developed elsewhere, Carberry and Abrecht (1991) found yield advantages for sowings early in the wet season. However, they noted that these models did not cater adequately for establishment problems related to high soil temperature and the effect of water deficit on seedlings.

Models enable creation and assessment of hypothetical genotypes (Shorter et al. 1991). Muchow et al. (1991) and Muchow and Carberry (1992) evaluated the impact of varying phenology, RUE, transpiration efficiency and extent of soil water extraction of sorghum in tropical and sub-tropical Australia. These studies highlight the potential of models in assessing the value of traits.

Models can be employed, with long-term climatic records, simulate likely outcomes of the range of decision options. Muchow et al. (1993) used the sorghum model of Hammer and Muchow (1993) to simulate the effects of planting date, soil water stored at planting and cultivar maturity on production predicted for a range of locations in north-east Australia. Hammer et al. (1991) simulated the predicted yield of sorghum, with non-limiting N supply, for a particular planting condition at Dalby using a long term climatic record (100 years).

A sorghum simulation model is also the appropriate tool to consider the impact of climate change associated with the greenhouse effect on sorghum production. Analysis of this nature, as conducted for agricultural production in Queensland by McKeon et al. (1988), provide a basis for government planning. Simulation modelling thus has immense value in decision making for a broad range of decisions in the fields of research, management and policy spheres (Hammer and Muchow, 1992).

2.6.2 Resource capture model (RESCAP) :

Monteith et al. (1989) describing his generic model states that two processes dominate crop growth: resource capture and the distribution of metabolites to organs with different functions. The resource capture model places equal emphasis on the role of leaves in relation to light interception, and to the role of roots in relation to the uptake of water. The central feature of the model is that the amount of dry matter produced per unit of radiation intercepted by foliage is effectively constant during vegetative growth when water is not limited. When the rate of water uptake by the root system is assumed to be limited by the daily estimation of available soil moisture, then the rate of transpiration and growth are both treated as water-limited. Dry matter produced per unit of water transpired is calculated as an inverse function of mean saturation deficit constant whether water is limiting or not.

Materials and Methods

3.0 MATERIALS AND METHODS

3.1 Experimental Site :

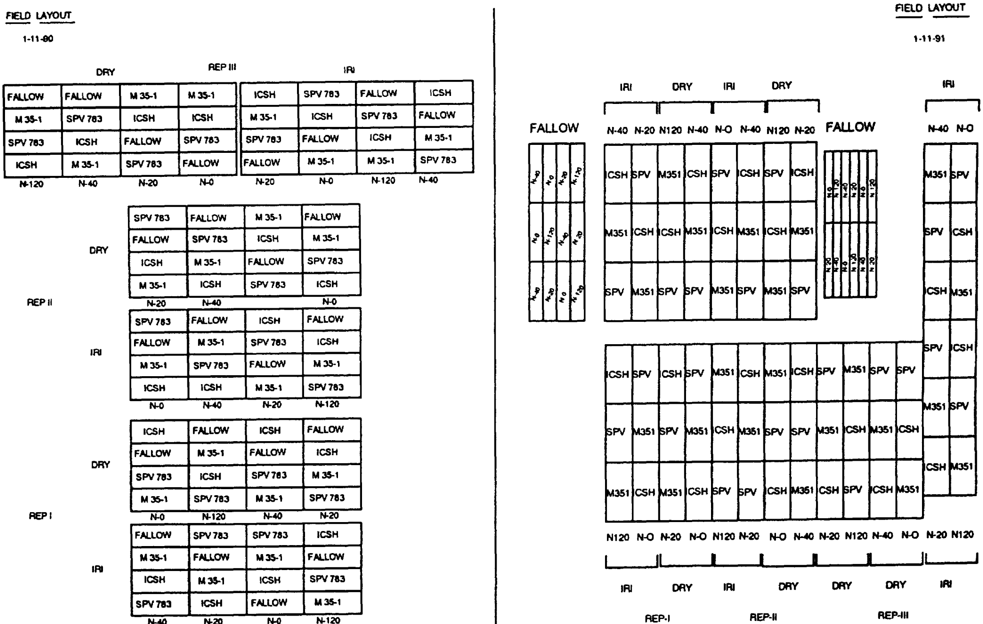
The experiment was conducted, at field No. BW 4 and BW 4A of the International Crops Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, during the post rainy seasons of 1990-91 and 1991-92. Patancheru is located on latitude 18^0 N and longitude of 78^0 E at an altitude of 545 m. above mean sea level.

3.2. Field Layout and operations :

The experiment consisted of two main, four sub and three sub-sub plots laid out in a split-split plot design and replicated thrice. The treatments were allotted at random in different plots of each replication as shown in Fig: A 4.74. The field was ploughed with a tractor drawn disc plough and worked with a cultivator. Seeding was done using a tractor mounted planter with nine rows spaced at 45 cm.

Irrigation was uniformly applied to all plots using sprinkler system so as to enable germination of planted seed. Irrigated plots received water at 32, 58, 80 and 93 days after emergence. One weeding was provided at 20-25 DAE., during both the years. Composite soil samples collected at random from the field prior to sowing upto 2.1 m. depth were analysed for the chemical properties listed in Appendix Table : 26 & 27.

Fig : A 4.74 Field layout in 1990-91 and 1991-92.



Appendix table : 26 Initial chemical characteristics of soil in 1990-91.

Year	Soil depth (cm)	NH_4 - N (ppm)	NO_3 - N (ppm)	Total N (ppm)	P (ppm)	K (ppm)	Organic carbon (%)	P^H	E.C. (m mhos cm^{-1})
1990-91	0-15	7.10	3.50	485	1.33	145	0.76	8.20	0.14
	15-30	10.0	2.97	440	0.75	115	1.06	8.19	0.18
	30-45	9.63	3.47	397	0.50	110	0.84	8.19	0.20
	45-60	9.47	1.63	380	0.58	127	0.69	8.30	0.22
	60-90	7.30	1.70	355	0.67	115	0.79	8.41	0.22
	90-120	6.13	2.50	319	0.50	141	0.55	8.42	0.33
	120-150	6.90	3.60	255	1.08	166	0.63	8.86	0.29
	150-180	7.63	2.37	256	0.67	156	0.90	6.14	0.40
	180-210	6.57	3.97	240	1.08	175	0.62	8.85	0.44

Appendix table : 27 Initial chemical characteristics of soil in 1991-92.

Year	Soil depth (cm)	NH_4 - N (ppm)	NO_3 - N (ppm)	Total N (ppm)	P (ppm)	K (ppm)	Organic carbon (%)	P^H	E.C. (m mhos cm^{-1})
1991-92	0-15	6.43	3.20	442	4.00	170	0.50	8.45	0.17
	15-30	7.50	2.53	419	4.17	154	0.37	8.66	0.22
	30-45	4.57	1.03	346	2.75	163	0.41	8.89	0.34
	45-60	4.60	2.07	361	0.92	169	0.32	8.96	0.40
	60-90	5.57	1.03	312	0.67	154	0.29	8.98	0.49
	90-120	3.90	1.27	253	0.58	193	0.25	8.89	0.60
	120-150	4.37	2.10	250	3.83	203	0.30	8.88	0.72
	150-180	2.43	1.30	233	1.08	185	0.25	8.90	0.83
	180-210	2.90	1.17	237	0.83	192	0.22	8.96	0.74

Appendix Table: 28. Weather data recorded at meteorological observatory, ICRISAT, Patancheru, A.P.

a. 1990-91.

MONTH	RAIN (mm)	EVAP (mm)	TMAX (C)	TMIN (C)	RH07 (%)	RH14 (%)	WIND (km/hr)	SUN (hr)	RAD (MJ/sq.m/D)
APR	2	323	38.5	22.7	56.0	19.0	9.1	10	23.2
MAY	140	222	33.8	23.3	81.4	46.0	11.9	7	19.5
JUN	84	169	30.8	22.7	90.3	61.4	14.7	4	17.2
JUL	83	182	30.5	22.3	89.4	59.6	16.8	4	16.1
AUG	269	130	28.9	22.2	92.1	68.9	14.5	4	14.1
SEP	96	137	30.0	22.0	93.3	63.1	8.3	6	17.3
OCT	129	125	28.8	19.7	93.8	62.6	6.9	6	16.5
NOV	11	126	28.6	17.9	92.8	51.0	6.6	8	16.0
DEC	0	126	27.4	14.8	93.1	42.2	6.7	9	16.0
JAN	16	141	28.7	15.8	91.7	42.0	7.9	9	16.5
FEB	3	194	32.3	16.5	78.2	24.4	7.9	10	20.1
MAR	1	277	35.9	21.3	73.7	23.1	8.9	10	21.5

b. 1991-92.

MONTH	RAIN (mm)	EVAP (mm)	TMAX (C)	TMIN (C)	RH07 (%)	RH14 (%)	WIND (km/hr)	SUN (hr)	RAD (MJ/sq.m/D)
APR	67	267	37.0	23.4	69.7	27.8	8.7	9	21.2
MAY	37	332	39.6	25.6	55.5	25.2	9.8	9	22.4
JUN	238	194	32.4	23.6	86.2	57.1	15.2	5	17.2
JUL	145	147	29.3	22.4	90.2	68.4	17.7	2	14.5
AUG	172	147	29.6	22.0	91.0	63.2	13.9	3	16.5
SEP	106	151	31.2	22.2	89.2	52.3	7.8	6	18.6
OCT	55	162	30.9	19.7	89.7	43.6	6.4	7	18.5
NOV	3	130	27.9	16.5	90.9	47.9	8.0	7	15.1
DEC	0	140	27.8	13.0	92.2	35.3	7.1	8	16.3
JAN	0	165	28.5	11.7	91.5	27.4	7.2	9	17.9
FEB	0	182	31.3	14.9	71.7	25.9	6.4	9	19.9
MAR	0	274	36.7	18.2	59.5	15.3	7.1	9	22.1

3.3 Experimental details :

The treatment comparisons were as follows :

1. Water	-	a. Irrigated	b. Dry
2. Nitrogen	-	a. 0 kg $N.ha^{-1}$	b. 20 kg $N.ha^{-1}$
		c. 40 kg $N.ha^{-1}$	d. 120 kg $N.ha^{-1}$
3. Genotypes-		a. ICSH 86646 (ICSA 70 x ICSR 161)	
		b. SPV 783 (R 91 x E 36-1)	
		c. M 35-1 (Selection from land race Maldandi)	

Nitrogen levels of 20 and 40 were included, since the lower part of the response curve was not well defined in the earlier experiment conducted at ICRISAT. Twenty four treatments were laid out in a split-split plot design with irrigated and non-irrigated treatments as the main plots, nitrogen as the sub plot, and genotype as the sub-sub plot. A fallow plot without any crop was included in each replication for observing soil water and nitrogen changes.

The experiments were located at field BW 4 (1990-91) and BW 4A (1991-92), ICRISAT centre, Patancheru. The plot sizes were 7.2m x 9.0m (1990-91) and 6.0m x 9.0m (1991-92) sown on 25th November during the two years.

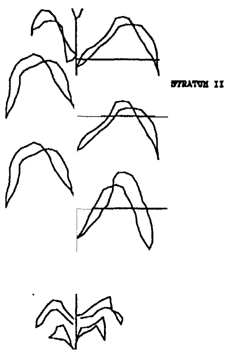
3.4 DATA RECORDED

3.4.1 Growth parameters:

<u>3.4.1.1</u> <u>Plant height:</u>

After seedling emergence 5 plants were tagged in all treatments and plant height was measured at weekly intervals.

<u>3.4.1.2</u> <u>Leaf area and dry weights :</u>



Ten plants from each treatment were harvested at weekly intervals for leaf area and dry matter estimations. At earhead emergence the plant leaves were first segregated into 5 different strata from the top with leaf area and dry weights recorded individually for each strata. Stem, earhead and grain weights dried at 80°C were recorded.

3.4.2 Yield and yield components:

3.4.2.1 Earhead number:

Before harvest, earhead number in each net plot was recorded to calculate earhead number per square metre.

3.4.2.2 Grains per earhead:

Five earheads from each harvest plot, were used for a grain number count. Grains in individual rachis were counted beginning at the base and reaching to the tip of the earhead. Total grain number and secondary rachis per earhead were then computed.

3.4.2.3 Secondary rachis weight:

The weight of individual secondary rachis with grains in each earhead was recorded.

3.4.2.4 Grain and straw yield:

Harvested grain from net plots (1.2m x 7.0m) was oven dried and the weight recorded. Fresh stalk weights from net plots were recorded in the field. A sub-sample weighing approximately 2 kg was weighed and later oven dried. Fresh and dry weights of sub-samples were used to transform the net plot fresh straw yields to dry straw yield.

3.4.3 Plant Chemical Analysis:

3.4.3.1 Plant N and K content:

Nitrogen content was determined in individual plant parts (leaf strata, stem and grain) at six different plant growth stages of crop using a Technicon Auto analyser (Technicon Industrial system, 1976).

The same digested sample was diluted to a 1:50 ratio with distilled water and fed in an atomic absorption spectrophotometer to measure the light absorbance.

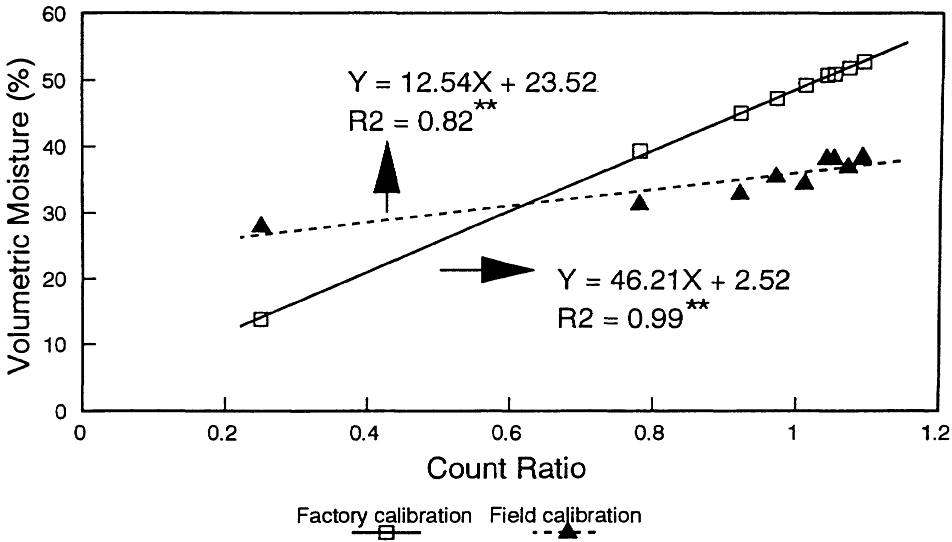
3.4.3.1 Specific leaf nitrogen:

Specific leaf weight was computed as the leaf weight per unit leaf area and specific leaf nitrogen, defined as the amount of leaf nitrogen per unit leaf area, was calculated as the ratio of leaf N content : specific leaf weight.

3.4.4 Soil moisture:

Soil moisture from 0-15 and 15-30 cm depth samples was measured by gravimetric method and from 30 to 150 cm at 15 cm intervals using neutron moisture probe (Troxler 4300). These measurements were restricted to the irrigated and dry main plots, all nitrogen levels and only two genotypes (ICSH 86646 and M 35-1) plus a fallow treatment from the irrigated and dry main plot treatments. [i.e., water=2 x nitrogen=4 x genotypes=2] = 16+2 fallow = 18 plots. The bulk density was calculated using the core volume and the dry weight of the

Fig : A 4.73. Troxler neutron probe calibration.



soil sample for each depth. These bulk density values were used to convert the gravimetric moisture content to volumetric content. The neutron probe was calibrated by regressing the count-ratio on to the volumetric moisture content, and was used to calculate the moisture content for different sampling dates.

3.4.5 Soil mineral nitrogen:

A screw type auger was used to collect the soil samples at the following soil depths (0-15, 15-30, 30-45, 45-60, 60-90, 90-120 cms) in all treatments. Soil samples were collected at four stages during the crop period. The first before sowing, the second immediately after the first irrigation, the third at 50 % anthesis and the fourth at harvest. Samples were analysed for soil mineral (NH_4 and NO_3) nitrogen (Keeney and Nelson, 1982). During the 1990-91 rabi season wet samples were used for extraction, however in 1991-92, air dried and pounded samples were used for analysis. The reason for change from wet to dry was that, in wet samples due to high clay content especially at lower depths, the sub-sample taken was not truly representative of the main sample due to formation of bigger clods and hence it was necessary to dry the samples and pound them to get a true representative sub-sample.

3.4.6 Light interception:

An instrument termed a " mouse " consisting of a length of square-section aluminium tube, with holes drilled at 2 cm intervals along its length was used to measure horizontal light distribution. The mouse was placed at right angles to the sorghum rows and the length of the mouse covered two rows. A sensor was pulled manually through the tube, while a portable data logger scanned the sensor output at a high frequency and selected the highest reading under each hole. This represents the irradiance at that point (Mathews et al. 1987). Light intercetion measurements were made at weekly intervals during mid-day.

3.4.7 Statistical Analysis:

Data for different variables was analysed using SAS split-split plot design for the 1990-91 and 1991-92 studies. The interaction effects with days after emergence and soil depth were analysed by considering them as a fourth factor.

Results

4.0 RESULTS

4.1.1 Plant height :

4.1.1:1 Measured at weekly interval :

The interaction effect of water * DAE, was significant (P<0.05), during 1990-91 and highly significant (P<0.01), during 1991-92 (Appendix table 1). In 1990-91, there were significant differences between irrigated and dry plots after 55 DAE (Figure 1.1). In 1990-91 plants had a mean maximum height of 2.00 metres. In 1991-92, height differences become significant from 45 DAE onwards, with irrigated plots having significantly higher plant height than dry plots.

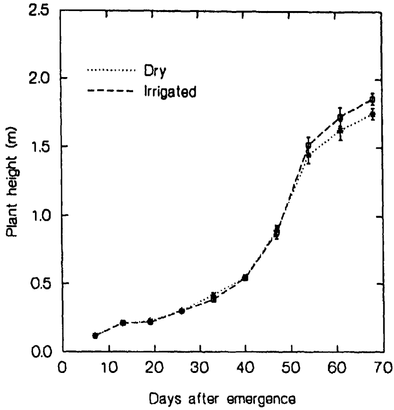
The interaction effect of nitrogen * DAE, was highly significant (P<0.01), in both years. Across nitrogen treatments (Figure A 1.2), the 120 kg N ha^{-1} treatment had the highest plant height in both years. The 40 and 120 kg N ha^{-1} treatments and the 0 and 20 kg N ha^{-1} were similar in 1990-91. In 1991-92, from 45 DAE onwards the 20, 40 and 120 kg N ha^{-1} treatments had significantly higher plant height than the control. The local genotype M 35-1 had significantly higher plant height than improved genotypes in 1990-91 (Figure A 1.3).

4.1.1.2 Measured at harvest :

The main effect of water was significant (P < 0.05) only in 1991-92 (Table 1). Plant height at harvest was significantly higher in irrigated plots in 1991-92. The main effect of nitrogen was significant (P<0.05), in 1990-91 and highly signficant in 1991-92 (P<0.01). Among nitrogen treatments the 40 and 120 kg N ha^{-1}

Fig : 1.1. **Plant height of sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)

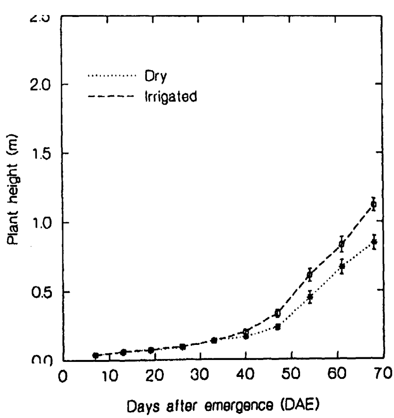


Table : 1. Mean plant height of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Plant height (cm)		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	186.03 A	111.87 A	148.95 A
Dry	174.99 A	84.58 B	129.78 B
LSD (0.05)	39.04	18.53	10.26
Nitrogen (N) :			
0 kg N ha^{-1}	167.24 B	71.00 C	153.56 C
20 kg N ha^{-1}	178.51 BA	96.33 B	147.37 B
40 kg N ha^{-1}	186.33 A	108.42 BA	137.42 A
120 kg N ha^{-1}	189.96 A	117.17 A	119.12 A
LSD (0.05)	18.40	18.85	9.55
Genotypes (G) :			
ICSH 86646	167.77 C	102.19 A	134.98 B
SPV 783	173.69 B	87.56 B	130.63 C
M 35-1	200.07 A	104.94 A	152.50 A
LSD (0.05)	5.88	7.00	3.73
Interactions : SE			
YEAR (Y)	-	-	0.23 **
W * Y	-	-	0.33 *
N * Y	-	-	0.47
G * Y	-	-	0.40 *
W * N * Y	13.96	21.36	0.66
W * G * Y	12.09	18.58 *	0.33
N * G * Y	17.18	26.16 *	0.82
W * N * G * Y	24.19	37.00	1.15
CV %	4.34	9.51	11.11

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

treatments were significantly higher than the control in 1990-91. In 1991-92 the 40 and 120 kg N ha^{-1} treatments were similar and had a significantly higher plant height than the control.

The main effect of genotye was very highly significant (P<0.001), in 1990-91 and highly significant (P<0.01), in 1991-92. At harvest, M 35-1 had a significantly higher plant height (2.00 m) than the improved genotypes ICSH 86646 (1.68 m) and SPV 783 (1.73 m) in 1990-91. In 1991-92 both M 35-1 (1.05 m) and ICSH 86646 (1.02 m) had significantly higher plant height than SPV 783 (0.87 m).

The interaction of water * genotype significant (P<0.05), in 1991-92 (Table 1), indicates that, in irrigated plots, ICSH 86646 had higher plant height, but in dry plots M 35-1 was highest (Figure A 1.4). The interaction of nitrogen * genotype significant (P<0.05), in 1991-92 indicates that at 0, 20 and 40 kg N ha^{-1} genotypes did not differ significantly in plant height, but for the 120 kg N ha^{-1} treatment the improved hybrid ICSH 86646 and the local M 35-1 were significantly higher than SPV 783 (Figure A 1.5 and A 1.6).

4.1.2 Leaf area index :

4.1.2.1 Measured at weekly interval :

A maximum leaf area index of 3 in 1990-91 and 2 in 1991-92 were recorded

The interaction of water * DAE was highly significant (P<0.01), in both years (Appendix table 2). Differences in leaf area index between irrigated and dry treatments were significant after 42 DAE in 1990-91 and after 35 DAE in 1991-92

Fig : 1.7. **Leaf area index of sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)

b) 1991-92 (Mean of nitrogen and genotype treatments)

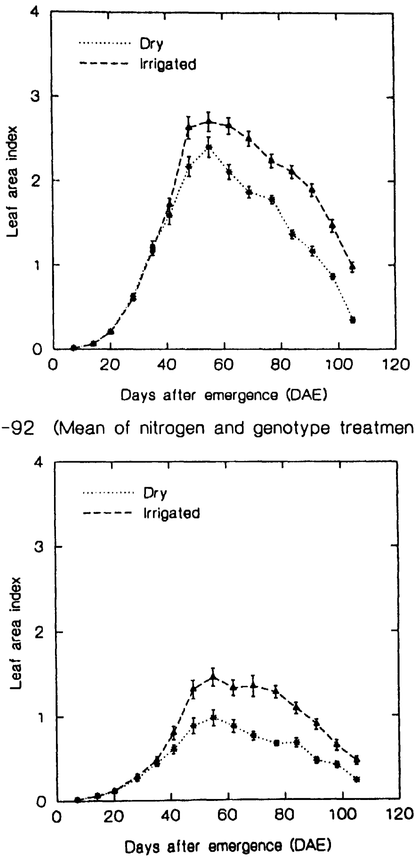
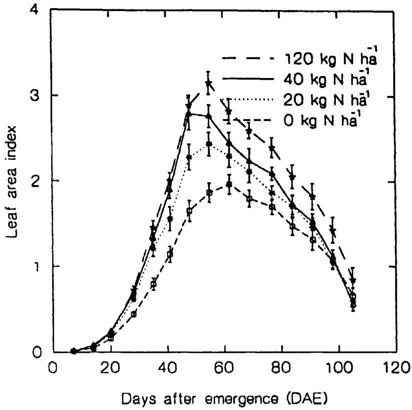
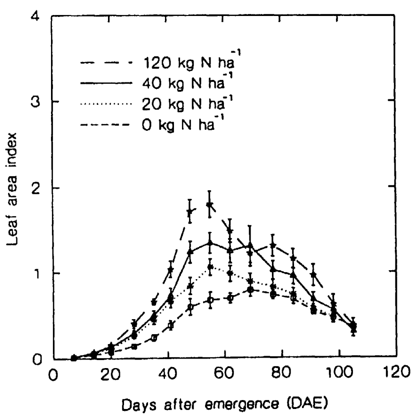


Fig : 1.8. **Leaf area index of sorghum as a function of time for the interaction effect of nitrogen * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)



(Figure 1.7). Maximum leaf area index was attained at 56 DAE in both years. Leaf area index after 56 DAE declined more markedly in dry plots while in irrigated plots the maximum leaf area index was retained for an additional 3 to 4 weeks.

The interaction of nitrogen * DAE highly significant ($P<0.01$), in both years had strong influence on leaf area index during the early stages of crop growth (Figure 1.8). Maximum leaf area index was obtained with the 120 kg N ha^{-1} treatment in both years. Differences between the 0 kg and 120 kg N ha^{-1} treatments were significant in both years, but the 20 and 40 kg N ha^{-1} treatments had a similar leaf area index in 1990-91. In 1991-92 the 0 and 20 kg N ha^{-1} treatments were similar while the 40 and 120 kg N ha^{-1} treatments were alike.

The interaction of genotype * DAE significant ($P<0.05$), in 1990-91 and highly significant ($P<0.01$) in 1991-92. Leaf area index pooled over irrigation and nitrogen treatments was similar for all three genotypes (Figure A 1.9). Differences were significant only at a few growth stages in 1991-92. The local genotype M 35-1 and the hybrid ICSH 86646 had higher leaf area index than SPV 783.

The interaction of water * nitrogen * DAE significant ($P<0.05$), in both years indicates (Figure A 1.10), that in dry plots in 1990-91, maximum leaf area index was attained a week later than irrigated plots and the decline was more pronounced in dry plots. In irrigated plots, the three nitrogen treatments (20, 40 and 120 kg N ha^{-1}), had higher leaf area index than the control at the early and late crop growth stages, with leaf area index for the 120 kg N ha^{-1} treatment remaining higher than the other fertilizer treatments to the end of the season. In

Fig : 1.11. **Leaf area index of sorghum as a function of time for the interaction effect of water * nitrogen * time, in a) Irrigated and b) Dry plots during rabi 1991-92.**

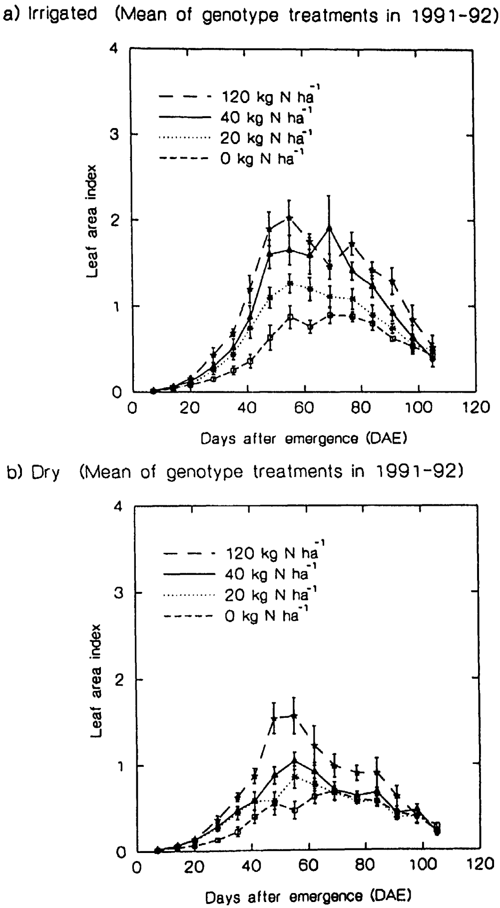
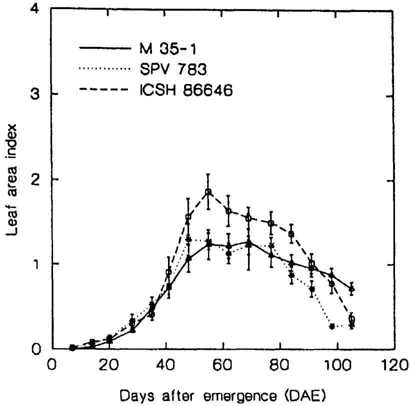
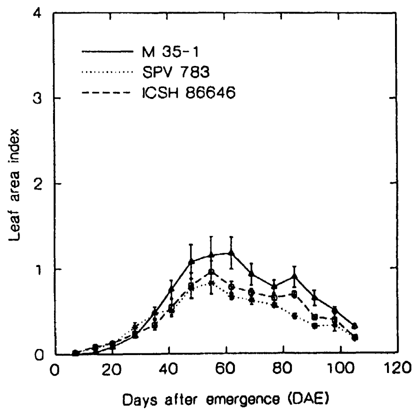


Fig : 1.12. **Leaf area index of sorghum as a function of time for the interaction effect of water * genotype * time, in a) Irrigated and b) Dry plots during rabi 1991-92.**

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)



dry plots, the 0, 20 and 40 kg N ha^{-1} treatments were similar for the entire crop growth period, however the 120 kg N ha^{-1} treatment had a significantly higher leaf area index between 50 and 80 DAE. In 1991-92 (Figure A 1.11), differences between the control and all nitrogen treatments were significant in irrigated plots but in dry plots only the 120 kg N ha^{-1} treatment maintained a higher leaf area index through most of the growing season.

There was highly significant ($P<0.01$), water * genotype * DAE interaction in 1991-92. In irrigated plots, ICSH 86646 had a higher leaf area index than M 35-1 or SPV 783, while in dry plots, M 35-1 had a higher leaf area index (Figure A 1.12).

The water * nitrogen * genotype * DAE interaction (Figures A 1.13, 1.14, 1.15 and 1.16), indicate that, in irrigated plots, ICSH 86646 had a higher leaf area index in all nitrogen treatments. However in dry plots, the local genotype M 35-1 had a significantly higher leaf area index from 56 DAE onwards in the 120 kg N ha^{-1} treatment.

<u>4.1.2.2</u> <u>Measured at harvest :</u>

The main effect of water was significant ($P<0.05$), in both years (Table 3). Irrigated plots had a significantly higher leaf area index than dry plots at harvest for both the years. The effect of nitrogen was significant ($P<0.05$), only in 1990-91 and the 0 and 120 kg N ha^{-1} treatments retained higher leaf area index than the 20 and 40 kg N ha^{-1} at harvest. In 1991-92 there were no significant differences

Table : 2. Mean leaf area index of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

	Leaf area index		
Treatment	**1990-91**	**1991-92**	**Pooled**
Water (W) :			
Irrigated	0.98 A	0.45 A	0.72 A
Dry	0.35 B	0.43 B	0.28 B
LSD (0.05)	0.17	0.18	0.17
Nitrogen (N) :			
0 kg N ha^{-1}	0.65 AB	0.35 A	0.50 AB
20 kg N ha^{-1}	0.59 B	0.34 A	0.47 AB
40 kg N ha^{-1}	0.55 B	0.30 A	0.42 B
120 kg N ha^{-1}	0.84 A	0.37 A	0.60 A
LSD (0.05)	0.20	0.15	0.16
Genotypes (G) :			
ICSH 86646	0.79 A	0.27 B	0.48 B
SPV 783	0.51 B	0.23 B	0.37 C
M 35-1	0.68 A	0.51 A	0.65 A
LSD (0.05)	0.14	0.08	0.08
Interactions : SE			
YEAR (Y)	-	-	0.12 **
W * Y	-	-	0.08 **
N * Y	-	-	0.11
G * Y	-	-	0.09
W * N * Y	0.13 *	0.26	0.16 *
W * G * Y	0.11	0.22 *	0.14 *
N * G * Y	0.16	0.32	0.20
W * N * G * Y	0.22	0.45	0.28
CV %	36.24	43.42	39.16

: Significant at p = <0.05 and 0.01 % level, respectively.

between nitrogen treatments at harvest. Among genotypes, ICSH 86646 and M 35-1 maintained a highly significant ($P<0.01$), leaf area index than SPV 783 at harvest in 1990-91. In 1991-92, M 35-1 had very significantly higher ($P<0.001$), leaf area index than the improved genotypes.

The interaction of water * nitrogen significant ($P<0.05$), in 1990-91 indicated that, in dry plots, there were no differences among nitrogen treatments, but in irrigated plots the 120 kg N ha^{-1} treatment had a higher leaf area index at harvest (Figure A 1.17). The interaction effect of water * genotype significant ($P<0.05$), in 1991-92 indicate that in irrigated and dry plots (Figure A 1.18), M 35-1 maintained a significantly higher leaf area index at harvest.

4.1.3 Total above-ground dry biomass :

4.1.3.1 Measured at weekly intervals :

The total above ground biomass accumulation in 1990-91 was higher than in 1991-92 (Figure A 1.19). The interaction of effect of water * DAE was highly significant ($P<0.01$), in both years (Appendix table 3). Irrigated plots had more total above ground biomass than dry plots in both years and this difference was significant from 64 DAE in 1990-91 and from 42 DAE in 1991-92.

The interaction of nitrogen * DAE highly significant ($P<0.01$), indicates that all three nitrogen treatments (20, 40 and 120 kg N ha^{-1}) had higher total above ground biomass than the control for both years (Figure A 1.20). Differences between nitrogen levels of 20, 40 and 120 kg N ha^{-1}, were not significant in 1990-

Fig : 1.19. **Total above ground biomass of sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91 and 1991-92.**

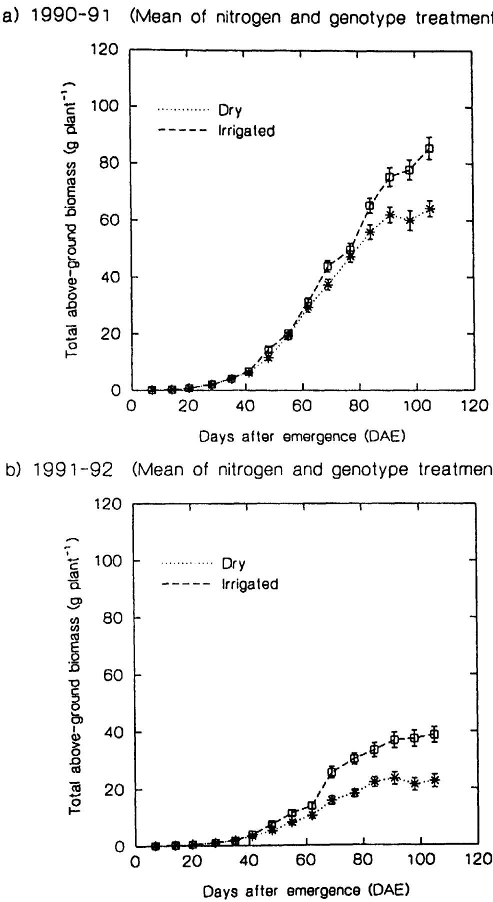
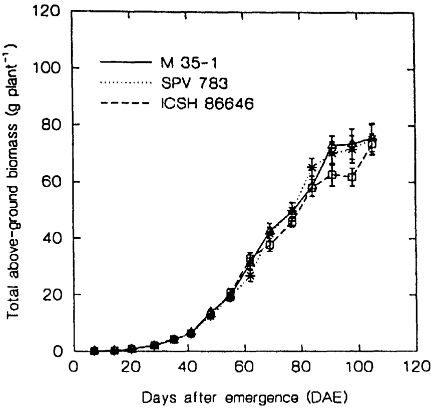
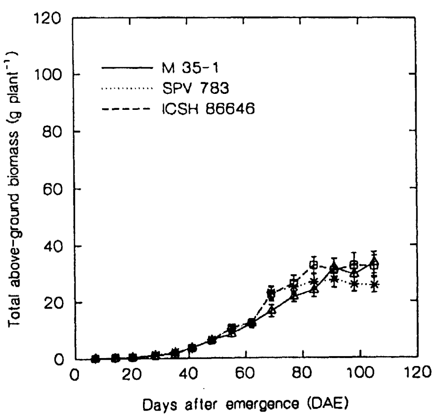


Fig : 1.21. **Total above ground biomass of sorghum as a function of time for the interaction effect of genotype * time during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)



91, while in 1991-92 the 120 kg N ha^{-1} treatment had significantly higher above ground biomass than 40 and 120 kg N ha^{-1} from 50 DAE onwards.

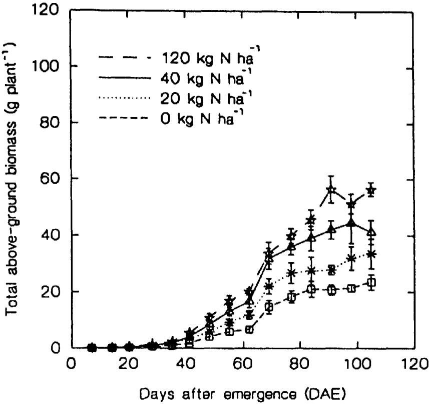
Genotypes did not differ in their biomass accumulation pattern until 56 DAE in both years (Figure A 1.21). In 1990-91, biomass accumulation in all genotypes continued up to harvest, while in 1991-92 there was little increase in biomass after 90 DAE. Mean maximum total above ground biomass was 78 g plant^{-1} and 38 g plant^{-1} for the respective years.

The interaction of water * nitrogen * DAE was highly significant ($P<0.01$), in 1991-92. Nitrogen had a marked influence on total biomass production in irrigated plots (Figure A 1.22). Among nitrogen treatments in irrigated plots, the 40 and 120 kg N ha^{-1} treatments were similar until 70 DAE, but there after 120 kg N ha^{-1} had significantly higher biomass than other nitrogen treatments. In dry plots, N treatment differences were significant from 42 DAE to harvest. While 20 kg N ha^{-1} treatment was similar to the control, the 40 kg N ha^{-1} treatment had an intermediary level of biomass production and the 120 kg N ha^{-1} had significantly higher biomass than all other nitrogen treatments from 42 DAE to harvest.

The interaction of water * genotype * DAE highly significant ($P<0.01$), in 1991-92 indicates that, among genotypes ICSH 86646 and SPV 783 were more responsive in their above ground biomass production to irrigation, these differences were significant after 49 DAE. In dry plots M 35-1 had significantly higher above ground biomass after 84 DAE (Figure A 1.23).

Fig : 1.22. **Total above ground biomass of sorghum as a function of time for the interaction effect of water * nitrogen * time, in a) Irrigated and b) Dry plots during rabi 1991-92.**

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

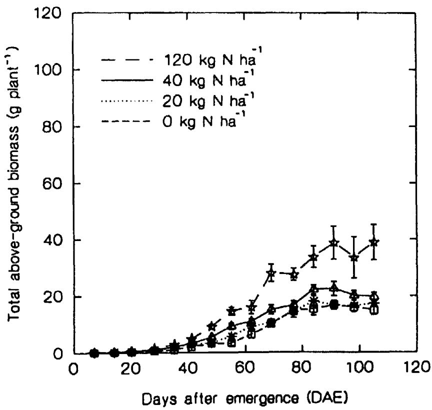
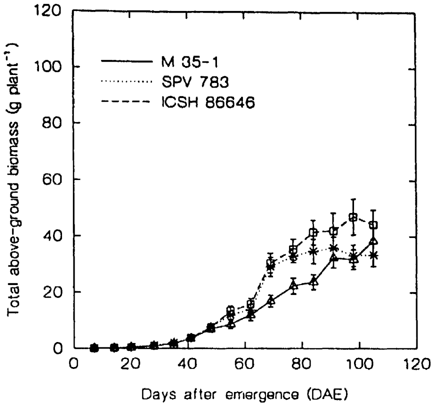
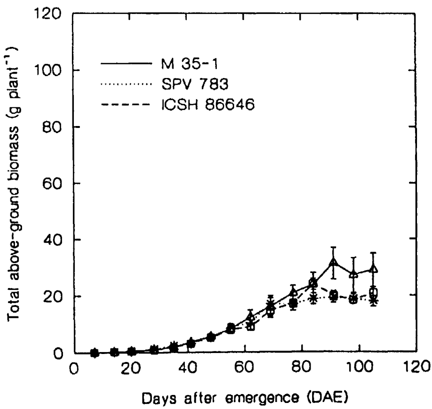


Fig : 1.23. **Total above ground biomass of sorghum as a function of time for the interaction effect of water * genotype * time, in a) Irrigated and b) Dry plots during rabi 1991-92.**

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)



The interaction of nitrogen * genotype * DAE significant ($P<0.05$), in 1991-92 indicates that, ICSH 86646 at all nitrogen treatments (20, 40 and 120 kg N ha^{-1}), SPV 783 at 40 and 120 kg N ha^{-1} treatments and M 35-1 at 120 kg N ha^{-1} had a significantly higher biomass production (Figures A 1.24 and A 1.25).

The interaction of water * nitrogen * genotype * DAE highly significant ($P<0.01$) in 1991-92 , indicates that, in irrigated plots, ICSH 86646 and M 35-1 had significantly higher biomass in all three nitrogen treatments (20, 40 and 120 kg N ha^{-1}), when compared to the control, but for SPV 783 only the 40 and 120 kg N ha^{-1} had significantly higher biomass than the 0 and 20 kg N ha^{-1} treatments after 42 DAE. Under dry conditions, both ICSH 86646 and M 35-1 had significantly higher biomass accumulation in 120 kg N ha^{-1} treatment after 42 DAE, while for SPV 783 the differences were not significant (Figures A 1.26, 1.27, 1.28 and 1.29).

4.1.3.2 Measured at harvest :

A two year combined analysis of total above ground biomass (Table 3), indicated that the years were highly significant. Total above ground biomass production in 1990-91 was higher than in 1991-92.

The main effect of water was highly significant ($P<0.01$), in 1990-91 and significant ($P<0.05$), in 1991-92. The mean increase in biomass production as a result of 120 mm water being applied as irrigation was 2.5 t ha^{-1} in 1990-91 and 2.0 t ha^{-1} in 1991-92. The influence of nitrogen was very highly significant ($P<0.001$), in both years. The respective increases in total above ground biomass

Table : 3. Mean total above ground biomass of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total above ground dry biomass (t ha^{-1})		
	1990-91	**1991-92**	**Pooled**
Water (W) :			
Irrigated	7.53 A	4.54 A	6.04 A
Dry	5.02 B	2.56 B	3.79 B
LSD (0.05)	0.56	0.99	0.73
Nitrogen (N) :			
0 kg N ha^{-1}	4.68 C	2.24 D	3.46 D
20 kg N ha^{-1}	5.67 C	3.03 C	4.35 C
40 kg N ha^{-1}	6.83 B	3.60 B	5.21 B
120 kg N ha^{-1}	7.95 A	5.33 A	6.64 A
LSD (0.05)	1.04	0.52	0.62
Genotypes (G) :			
ICSH 86646	5.75 B	3.43 A	4.59 C
SPV 783	6.17 B	3.61 A	5.26 A
M 35-1	6.91 A	3.62 A	4.90 B
LSD (0.05)	0.43	0.31	0.28
Interactions : SE			
YEAR (Y)	-	-	0.19 **
W * Y	-	-	0.27
N * Y	-	-	0.38
G * Y	-	-	0.33 *
W * N * Y	0.33 *	0.69 *	0.54
W * G * Y	0.28	0.60 *	0.47
N * G * Y	0.40	0.85 *	0.66
W * N * G * Y	0.57	1.20	0.93
CV %	11.64	14.81	18.57

* = Significant at p = <0.05 and 0.01 % level, respectively.

for the 20, 40 and 120 kg N ha^{-1} treatments over the control were 1.0, 2.0 and 3.0 t ha^{-1} in 1990-91 and 0.8, 1.4 and 3.0 t ha^{-1} in 1991-92. While there were no significant differences among genotypes in 1991-92, the genotype M 35-1 had significantly higher total biomass (6.91 t ha^{-1}), when compared to the improved cultivars ICSH 86646 (5.75 t ha^{-1}) and SPV 783 (6.17 t ha^{-1}) in 1990-91 (Table 3).

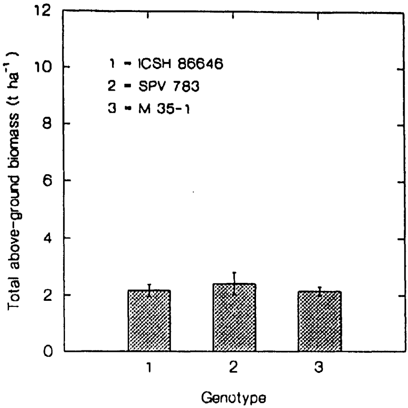
There were significant ($P<0.05$), water * nitrogen interactions at harvest for both years. In irrigated plots, all nitrogen treatments (20, 40 and 120 kg N ha^{-1}), had significantly higher total above ground biomass than the control. In dry plots, this increase was lower with the 20 and 40 kg N ha^{-1} treatments and the increase was 2.0 t ha^{-1} over the control with the 120 kg N ha^{-1} treatment. Increase due to irrigation were 1.0, 2.0, 4.0 and 4.0 t ha^{-1} over dry plots for the respective nitrogen treatments in 1990-91, while in 1991-92 the respective increases were 0.5, 2.0, 2.5 and 2.5 t ha^{-1} (Figure A 1.30 and A 1.31). The influence of nitrogen in irrigated and dry plots was similar in both the years.

The interaction of water * genotype significant ($P<0.05$), in 1991-92, shows that the improved genotypes (ICSH 86646 and SPV 783), produced a higher biomass in irrigated plots, while the local genotype M 35-1 had higher biomass values in dry plots (Figure A 1.32).

The interaction of nitrogen * genotype was significant ($P<0.05$), in 1991-92. At the higher nitrogen levels (40 and 120 kg N ha^{-1}) the varieties (SPV 783 and M 35-1) produced higher total biomass than the hybrid (ICSH 86646). While at 0 and

Fig : 1.33. **Total above ground biomass of sorghum for the interaction effect of nitrogen * genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest in 1991-92.**

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

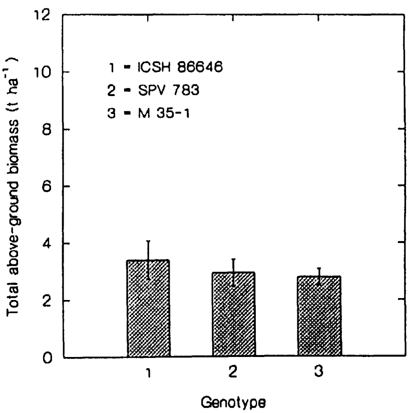
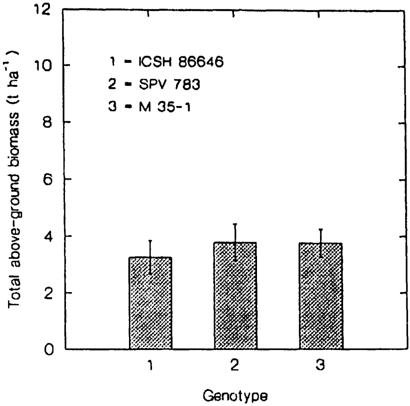
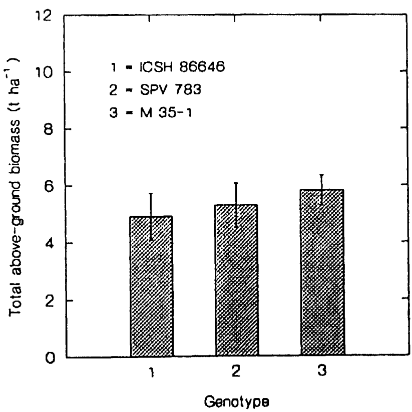


Fig : 1.34. **Total above ground biomass of sorghum for the interaction effect of nitrogen * genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest in 1991-92.**

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)



40 kg N ha^{-1} ICSH 86646 and SPV 783 produced higher total biomass than M 35-1 (Figure A 1.33 and A 1.34).

4.1.4 Leaf dry weight :

4.1.4.1 Measured at weekly interval :

The interaction of water * DAE was highly significant (P < 0.01) for both the years (Appendix table 4). Differences in leaf dry weight between irrigated and dry plots were significant after 42 DAE in both years (Figure A 1.35). These differences persisted up to harvest.

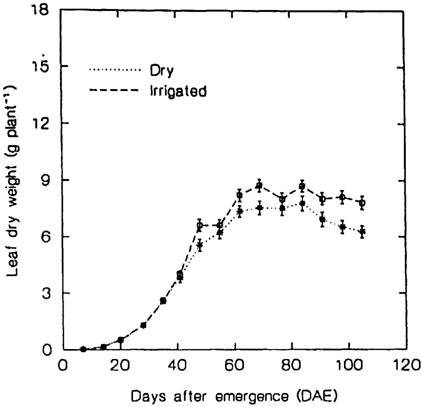
The interaction of nitrogen * DAE highly significant (P<0.01) for both years indicates that, the 120 kg N ha^{-1} treatment had a significantly higher leaf dry weight when compared to other N treatments (Figure A 1.36). The 20 and 40 kg N ha^{-1} treatments had similar leaf dry weights in 1990-91 after 63 DAE, while in 1991-92 the 0 and 20 kg N ha^{-1} were similar after 70 DAE.

In 1990-91, both SPV 783 and M 35-1 had significantly higher (P<0.01), leaf dry weight than ICSH 86646 from 63 DAE to harvest but in 1991-92 there were was no definite trend among the genotypes (Figure A 1.37).

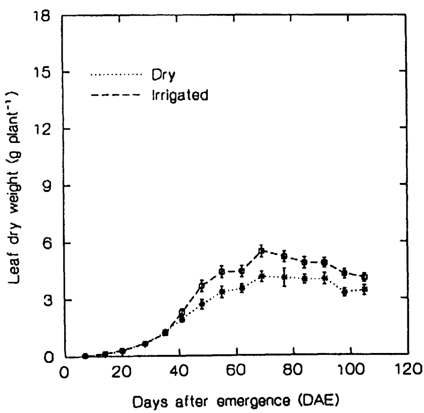
The interaction of water * nitrogen * DAE was significant (P<0.01), in 1991-92. In dry plots, (Figure A 1.38), the 120 kg N ha^{-1} treatment had a significantly higher leaf dry weight than the three lower N rates (0, 20 and 40 kg N ha^{-1}). In irrigated plots, the 40 and 120 kg N ha^{-1} treatments were similar, while the 0 and 20 kg N ha^{-1} treatments were alike.

Fig : 1.35. **Leaf dry weight of sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)



The interaction of water * genotype * DAE highly significant ($P<0.01$), in 1991-92, indicate that both the improved genotypes (ICSH 86646 and SPV 783) had a higher leaf dry weight than the local genotype M 35-1 in irrigated plots up to 80 DAE, but there after only ICSH 86646 retained higher leaf dry weight than M 35-1 (Figure A 1.39). In dry plots, differences were not significant up to 70 DAE, but there after M 35-1 had a higher leaf dry weight than the improved genotypes (ICSH 86646 and SPV 783).

The nitrogen * genotype * DAE interaction significant ($P<0.05$), in 1991-92 indicated that, for ICSH 86646, all increasing nitrogen treatments resulted in significantly higher leaf dry weights when compared to the control at most crop growth stages (Figure A 1.40). For SPV 783 only the 40 and 120 kg N ha^{-1} treatments had a significantly higher leaf dry weight, while in M 35-1 the 120 kg N ha^{-1} treatment had a significantly higher leaf dry weight than all nitrogen treatments from 42 DAE to harvest (Figure A 1.41).

Interaction of water * nitrogen * genotype * DAE significant ($P<0.05$), in 1991-92 indicate that, in irrigated plots, all the three genotypes (ICSH 86646, SPV 783 and M 35-1), at N levels of 40 and 120 kg ha^{-1} had significantly higher leaf dry weight when compared to the 0 and 20 kg N ha^{-1} levels from 42 DAE to harvest (Figure A 1.42 and A 1.43). However in the dry plots, ICSH 86646 and M 35-1 had significantly higher leaf dry weight only at the 120 kg N ha^{-1} level when compared to other nitrogen treatments (Figures A 1.44 and A 1.45).

Table : 4. Mean total dry leaf weight of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total dry leaf weight (g $plant^{-1}$)		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	7.83 A	4.09 A	5.96 A
Dry	6.29 A	3.42 A	4.86 A
LSD (0.05)	2.14	1.28	1.40
Nitrogen (N) :			
0 kg N ha^{-1}	6.15 B	2.71 C	4.43 C
20 kg N ha^{-1}	6.71 B	3.23 BC	4.97 CB
40 kg N ha^{-1}	6.97 B	3.79 B	5.38 B
120 kg N ha^{-1}	8.42 A	5.30 A	6.86 A
LSD (0.05)	1.26	0.76	0.66
Genotypes (G) :			
ICSH 86646	6.09 B	3.29 B	5.01 B
SPV 783	6.30 B	3.94 A	5.17 B
M 35-1	8.80 A	4.04 A	6.05 A
LSD (0.05)	0.70	0.49	0.40
Interactions : SE			
YEAR (Y)	-	-	0.36 **
W * Y	-	-	0.50 *
N * Y	-	-	0.71
G * Y	-	-	0.62 **
W * N * Y	0.55	1.47	1.01
W * G * Y	0.48	1.27	0.87
N * G * Y	0.67	1.80 *	1.24
W * N * G * Y	0.96	2.55	1.76
CV %	16.78	22.32	23.90

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

4.1.4.2 Measured at harvest :

At harvest, the 120 kg N ha^{-1} treatment had highly significant ($P<0.01$), leaf dry weight than the 0, 20 or 40 kg N ha^{-1} treamtents (Table 4). Among genotypes M 35-1 in 1990-91 and M 35-1 and SPV 783 in 1991-92 had highly significant ($P<0.01$), leaf dry weight than ICSH 86646. There was a significant ($P<0.05$), nitrogen * genotype interaction in 1991-92 (Table 4). The genotype ICSH 86646 had higher leaf dry weight in the 0, 20 and 40 kg N ha^{-1} treatments, while M 35-1 had a significantly higher leaf dry weight in the 120 kg N ha^{-1} treatment (Figures A 1.46 and A 1.47).

4.1.5 Stem dry weight :

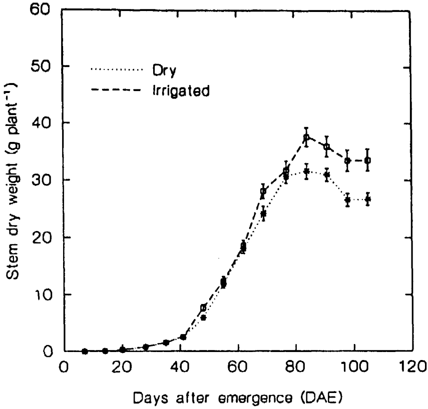
4.1.5.1 Measured at weekly interval :

The interaction water * DAE was highly significant ($P<0.01$), in both years (Appendix table 5). Stem dry weight was significantly higher in irrigated plots (Figure 1.48). These differences were significant from 60 DAE onwards, in 1990-91 and after 40 DAE, in 1991-92. In 1990-91 mean (over nitrogen and genotypes) maximum stem dry weight was 35 g $plant^{-1}$, but in 1991-92 it was 20 g $plant^{-1}$. The maximum stem weight was attained by 85 DAE, which declined to 95 DAE thereafter it remained steady to harvest.

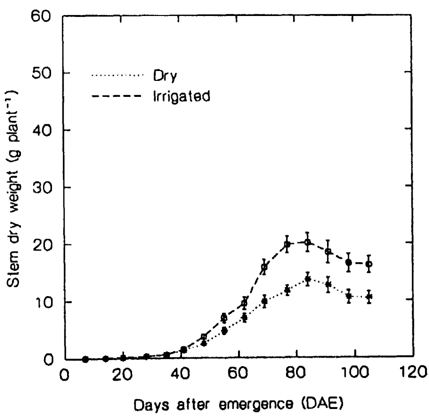
Differences in mean nitrogen treatments across water and genotypes were highly significant ($P < 0.01$) from 40 DAE onwards, in both the years. In 1990-91 all three nitrogen treatments (20, 40 and 120 kg N ha^{-1}), were similar and

Fig : 1.48. Stem dry weight of sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)



significantly higher than the control. In 1991-92 the 120 kg N ha^{-1} treatment had a significantly higher stem dry weight than all the other nitrogen treatments (Figure A 1.49).

The interaction of genotype * DAE highly significant (P<0.01), in both years indicates that, among genotypes, M 35-1 and SPV 783 had significantly higher stem dry weights than ICSH 86646 in 1990-91 from 70 DAE, while in 1991-92 M 35-1 and ICSH 86646 had higher stem dry weights than SPV 783 from 90 DAE to harvest (Figure A 1.50).

The interaction of water * nitrogen * DAE significant (P<0.05), in 1991-92 indicates that, in the dry plots, the 120 kg N ha^{-1} treatment had a significantly higher stem dry weight when compared to other nitrogen treatments. In irrigated plots, the 40 and 120 kg N ha^{-1} and the 0 and 20 kg N ha^{-1} were similar (Figure A 1.51).

The interaction of water * genotype * DAE was highly significant (P<0.01), in 1991-92. In irrigated plots the genotypes M 35-1 and ICSH 86646 had a significantly higher stem dry weight from 84 DAE, but in dry plots only M 35-1 had significantly higher stem dry weight than the other genotypes (Figure A 1.52).

The nitrogen * genotype * DAE interaction highly significant (P<0.01), in 1991-92 indicates that, for the 120 kg N ha^{-1} treatment, M 35-1 had a higher stem dry weight after 90 DAE, while in the 0, 20 and 40 kg N ha^{-1} treatments all the genotypes were similar (Figures A 1.53 and A 1.54).

The interaction of water * nitrogen * genotype * DAE was highly significant ($P<0.01$), in 1991-92. Both M 35-1 and ICSH 86646 had a higher stem weight at 20, 40 and 120 kg N ha^{-1} in irrigated plots (Figures A 1.55 and A 1.56), however in the dry plots the 120 kg N ha^{-1} treatment using M 35-1 had significantly, higher stem dry weight than did ICSH 86646 or SPV 783 (Figures A 1.57 and A 1.58).

4.1.5.2 Measured at harvest :

Irrigated plots had a higher total dry stem yield than did the dry plots for both years. Increased dry stem yield in irrigated plots when compared to dry plots was 1.3 t ha^{-1} in 1990-91 and 0.8 t ha^{-1} in 1991-92 (Table 5). Among nitrogen treatments, the 120 kg N ha^{-1} treatment had highly significant ($P<0.01$), total dry stem yield than did the control in both years. Increases in dry stem yield for the 20, 40 and 120 kg N ha^{-1} rates over the control were 0.4, 0.8 and 1.4 t ha^{-1} in 1990-91, and 0.4, 0.7 and 1.6 t ha^{-1} in 1991-92.

Among genotypes, both SPV 783 and M 35-1 had highly significant ($P<0.01$), total dry stem yield than did ICSH 86646 in 1990-91, while in 1991-92 only M 35-1 had a significantly higher ($P<0.05$) total dry stem yield when compared to improved genotypes (ICSH 86646 and SPV 783).

The interaction of water * genotype (Figure 1.59) indicate that, in irrigated plots, all the genotypes had a similar total dry stem yield, but in dry plots, M 35-1 had a significantly ($P < 0.05$), higher total dry stem yield than the other two genotypes (ICSH 86646 and SPV 783).

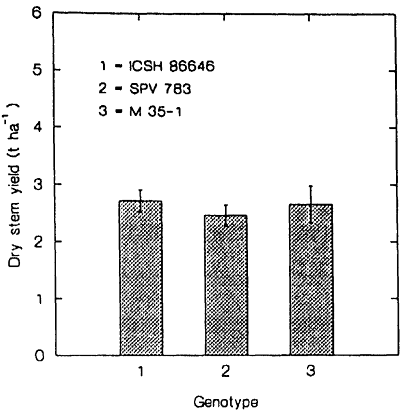
Table : 5. Mean total dry stem yield of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total dry stem yield (t ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	4.39 A	2.62 A	3.50 A
Dry	2.98 B	1.84 B	2.41 B
LSD (0.05)	0.13	0.73	0.35
Nitrogen (N) :			
0 kg N ha^{-1}	3.01 C	1.58 C	2.29 C
20 kg N ha^{-1}	3.49 CB	1.97 B	2.73 B
40 kg N ha^{-1}	3.82 AB	2.25 B	3.04 B
120 kg N ha^{-1}	4.43 AB	3.11 A	3.77 A
LSD (0.05)	0.63	0.36	0.41
Genotypes (G) :			
ICSH 86646	2.78 B	2.14 B	2.46 B
SPV 783	4.17 A	2.11 B	3.14 A
M 35-1	4.11 A	2.43 A	3.27 A
LSD (0.05)	0.33	0.22	0.21
Interactions : SE			
YEAR (Y)	-	-	1.09 **
W * Y	-	-	1.55 *
N * Y	-	-	2.19
G * Y	-	-	1.90 **
W * N * Y	4.07	6.27	3.11
W * G * Y	3.53	5.43 *	2.69 *
N * G * Y	4.99	7.68	3.80
W * N * G * Y	7.05	10.86	5.38
CV %	15.11	17.21	21.01

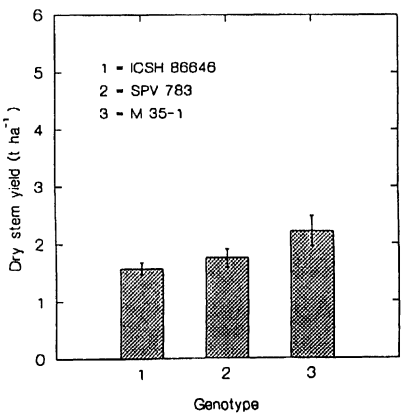
*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Fig : 1.59. **Dry stem yield of sorghum for the interaction effect of water * genotype, in a) irrigated and b) dry plots at harvest during rabi 1991-92.**

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)



4.1.6. Total vegetative dry matter :

4.1.6.1 Measured at weekly interval :

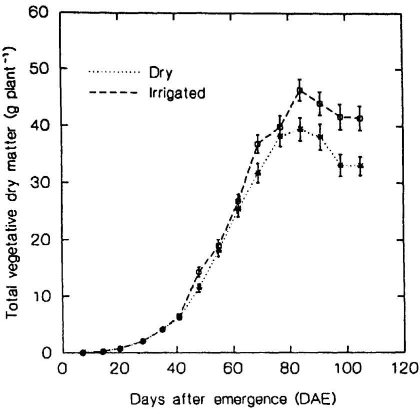
The interaction of water * DAE was highly significant (P<0.01), in both years (Appendix table 6). Total vegetative dry matter production was higher in irrigated plots when compared to dry plots from 42 DAE onwards in both years. These differences were more significant in 1991-92. Total vegetative dry matter production was higher in 1990-91 than in 1991-92. Irrigated plots had a maximum total vegetative dry matter of 48 g $plant^{-1}$ in 1990-91 and 25 g $plant^{-1}$ in 1991-92, while in dry plots it was 40 g and 16 g $plant^{-1}$ for the respective years (Figure 1.60). Maximum total vegetative dry matter production was attained by 84 DAE in both years and there was a decline thereafter. This decline coincided with the grain filling period and represents redistribution of dry matter to grain.

The interaction of nitrogen * DAE highly significant (P<0.01), in both years indicates that, in 1990-91, all three nitrogen treatments had a significantly higher total vegetative dry matter production than the control throughout the crop growth period (Figure 1.61). In 1991-92, only the 120 kg N ha^{-1} treatment had significantly higher total vegetative dry matter than other nitrogen treatments.

M 35-1 and SPV 783 had highly significant (P<0.01), total vegetative dry matter production than did ICSH 86646 in 1990-91 (Figure A 1.62). These differences were significant from 63 DAE onwards. Both M 35-1 and SPV 783 had a mean maximum total vegetative dry matter of 50 g $plant^{-1}$, ICSH 86646 had only

Fig : 1.60. **Total above ground vegetative dry matter sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)

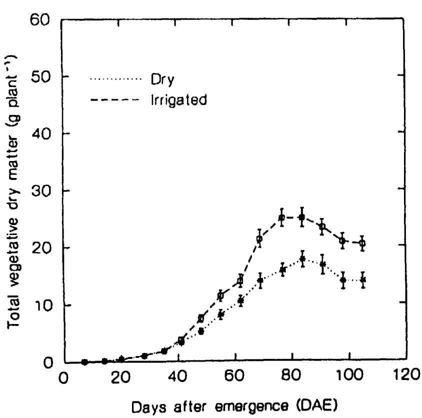
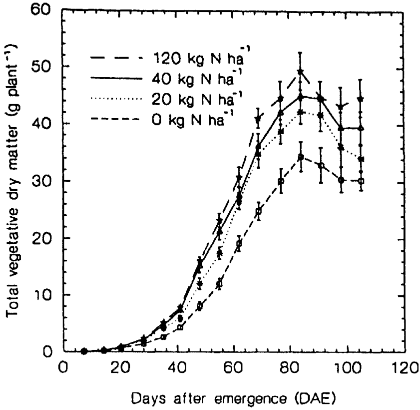
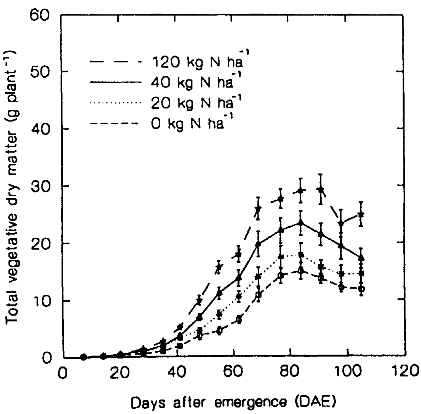


Fig : 1.61. **Total above ground vegetative dry matter of sorghum as a function of time for the interaction effect of nitrogen * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)



30 g plant^{-1}. In 1991-92 both ICSH 86646 and M 35-1 had highly significant ($P<0.01$), total vegetative dry matter than SPV 783 after 84 DAE (Figure A 1.62).

The interaction of water * nitrogen * DAE significant ($P<0.05$), in 1990-91 indicates that total vegetative dry matter production in irrigated plots, both the 40 and 120 kg N ha^{-1} treatments were similar, while the 20 kg N ha^{-1} treatment had an intermediate value between the 0 and 40 kg N ha^{-1} rates (Figure A 1.63a). In the dry plots, only the 120 kg N ha^{-1} treatment had significantly higher total vegetative dry matter production when compared to other nitrogen treatments (Figure A 1.63b).

The water * genotype * DAE interaction highly significant ($P<0.01$), in 1991-92 indicates that, in irrigated plots ICSH 86646 and SPV 783 reached maximum vegetative dry matter production levels earlier than M 35-1 and re-distribution to grain started earlier (Figure A 1.64a). While in M 35-1 total vegetative dry matter increased to 90 DAE, and later declined. In dry plots, M 35-1 had significantly (P higher total vegetative dry matter production than ICSH 86646 and SPV 783 after anthesis (Figure A 1.64b).

The interaction of nitrogen * genotype * DAE highly significant ($P<0.01$), in 1991-92 indicates that, for the 0, 20 and 40 kg N ha^{-1} treatments ICSH 86646 and M 35-1 had higher total vegetative dry matter production than SPV 783. However for the 120 kg N ha^{-1} treatment, M 35-1 had significantly higher total vegetative dry matter production than other genotypes at harvest (Figures A 1.65 and A 1.66).

The water * nitrogen * genotype * DAE interaction highly significant (P<0.01), in 1991-92 indicates that, in irrigated plots, ICSH 86646 and M 35-1 at the 20, 40 and 120 kg N ha^{-1} had significantly higher total vegetative dry matter production than the control. While for SPV 783 the 0 and 20 kg N ha^{-1} treatments were similar, while the 40 and 120 kg N ha^{-1} had significantly higher total vegetative dry matter production (Figures A 1.67 and A 1.68). In dry plots, the 0, 20 and 40 kg N ha^{-1} treatments had mean maximum total vegetative dry matter values of 30 g $plant^{-1}$ for all genotypes (Figures A 1.69 and A 1.70), but in the 120 kg N ha^{-1} treatment M 35-1 had a significantly higher mean maximum vegetative dry matter of 45 g $plant^{-1}$.

4.1.6.2 Measured at harvest :

Differences between irrigated and dry plots were not significant in both years (Table 6). The 40 and 120 kg N ha^{-1} treatments among nitrogen levels had highly significant (P<0.01), total vegetative dry matter in 1990-91, while in 1991-92 only the 120 kg N ha^{-1} had significantly higher total vegetative dry matter than all other N treatments. Among genotypes M 35-1 had highly significant (P<0.01), total vegetative dry matter production than ICSH 86646 and SPV 783 in 1990-91, while in 1991-92 it had highly significant (P<0.01), total vegetative dry matter than SPV 783.

The interaction of water genotype significant (P<0.05), in 1991-92 indicates that, in irrigated plots, both ICSH 86646 and M 35-1 had higher total

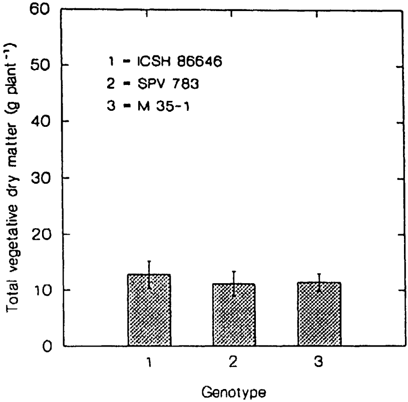
Table : 6. Mean total above ground vegetative dry matter of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total above ground vegetative dry matter (g $plant^{-1}$)		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	41.42 A	20.28 A	30.85 A
Dry	33.03 A	13.87 A	23.45 A
LSD (0.05)	12.51	7.75	8.73
Nitrogen (N) :			
0 kg N ha^{-1}	30.33 C	11.77 C	21.05 C
20 kg N ha^{-1}	34.18 CB	14.49 BC	24.34 BC
40 kg N ha^{-1}	39.58 AB	17.17 B	28.37 B
120 kg N ha^{-1}	44.81 A	24.88 A	34.84 A
LSD (0.05)	6.88	4.16	4.07
Genotypes (G) :			
ICSH 86646	26.86 C	17.86 A	22.36 C
SPV 783	40.43 B	13.29 B	26.86 B
M 35-1	44.38 A	20.08 A	32.23 A
LSD (0.05)	3.33	2.43	1.98
Interactions : SE			
YEAR (Y)	-	-	1.39 **
W * Y	-	-	1.96
N * Y	-	-	2.78
G * Y	-	-	2.40 **
W * N * Y	4.29	7.62	3.93
W * G * Y	3.71	6.59 *	3.40
N * G * Y	5.25	9.33 *	4.81
W * N * G * Y	7.43	13.19 *	6.80
CV %	15.22	24.25	22.91

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Fig : 1.72. **Total above ground vegetative dry matter of sorghum for the interaction effect of nitrogen * genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest during rabi 1991-92.**

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

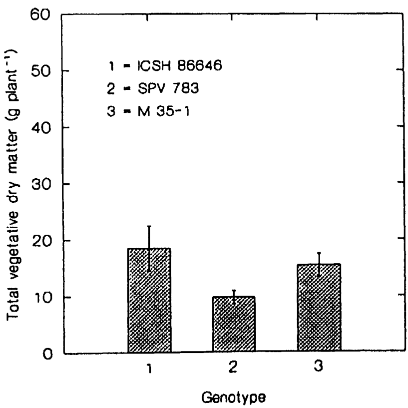
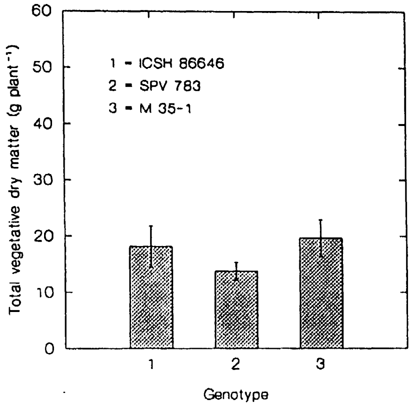


Fig : 1.73. **Total above ground vegetative dry matter of sorghum for the interaction effect of nitrogen * genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest during rabi 1991-92.**

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

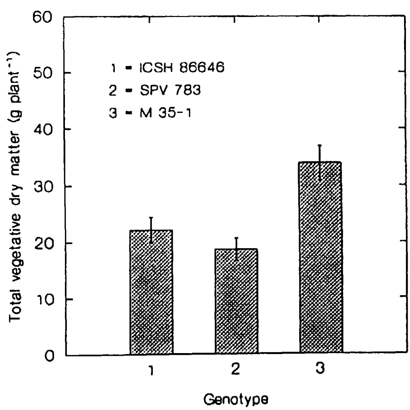
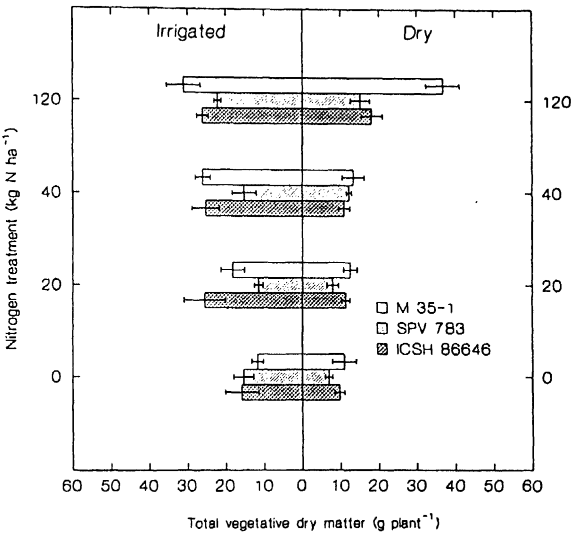


Fig : 1.74. **Total above ground vegetative dry matter of sorghum for the interaction effect of water, nitrogen and genotype, in irrigated and dry plots at harvest during rabi 1991-92.**



vegetative dry matter production, but in dry plots only M 35-1 had higher total vegetative dry matter production (Figure A 1.71).

At N application rates of 0 and 20 kg N ha^{-1} ICSH 86646 had significantly higher ($P<0.05$), total vegetative dry matter production, while in the 40 and 120 kg N ha^{-1} treatments M 35-1 had significantly higher ($P<0.05$), total vegetative dry matter production (Figures 1.72 and 1.73).

The interaction of water * nitrogen * genotype significant ($P<0.05$), in 1991-92 indicates that in dry plots, M 35-1 had higher total vegetative dry matter production for all nitrogen treatments, while in irrigated plots it had higher total vegetative dry matter production in the 40 and 120 kg N ha^{-1} treatments (Figure 1.74). Higher redistribution of dry matter in the improved genotypes in to grain formation resulted in lower total vegetative dry matter.

4.1.7 Dry matter distribution pattern :

4.1.7.1 Measured at harvest :

For both years and in all nitrogen treatments the contribution of leaf to total vegetative dry matter production was the least. Leaf and stem dry weights were higher in 1990-91. Nitrogen significantly influenced plant dry weight in both years, and the 120 kg N ha^{-1} treatment had the maximum dry weights (Figure A 1.75).

In 1990-91, total leaf weight was highest in SPV 783, but was similar in all genotypes in 1991-92 (Figure A 1.76). The stem weight of SPV 783 and M 35-1 was significantly higher than ICSH 86646 in 1990-91, but in 1991-92 both ICSH 86646 and M 35-1 had higher stem weight than SPV 783.

The interaction of water * nitrogen indicates higher stem and vegetative dry matter production in response to nitrogen in irrigated plots (Figure A 1.77). In dry plots, only the 120 kg N ha^{-1} treatment had significantly ($P < 0.05$) higher leaf, stem and total dry vegetative matter production.

The water * genotype interaction indicates that M 35-1 accumulated more leaf, stem and total dry vegetative matter than ICSH 86646 and SPV 783 in dry plots, but in irrigated plots both ICSH 86646 and M 35-1 had higher dry weights when compared to SPV 783 (Figure A 1.78).

Dry matter distribution was similar in all genotypes for the 0 kg N ha^{-1} treatment, while in the 20 and 40 kg N ha^{-1} treatments ICSH 86646 and SPV 783 had higher dry weights. In the 120 kg N ha^{-1} treatment M 35-1 had higher leaf, stem and total vegetative dry matter production at harvest (Figures A 1.79 and A 1.80).

In irrigated check plots ICSH 86646 and SPV 783 had higher leaf, stem and total vegetative dry matter production, while in the 20, 40 and 120 kg N ha^{-1} treatments both ICSH 86646 and M 35-1 had higher dry weights than SPV 783 (Figures A 1.81 and A 1.82). In dry plots, the 0, 20 and 40 kg N ha^{-1} treatments for all genotypes had a similar dry matter distribution, but for the 120 kg N ha^{-1} treatment, M 35-1 had significantly higher ($P<0.05$) leaf, stem and total dry vegetative matter than ICSH 86646 and SPV 783 (Figures A 1.83 and A 1.84).

4.1.8 Earhead and grain weight :

4.1.8.1 Measured at weekly interval :

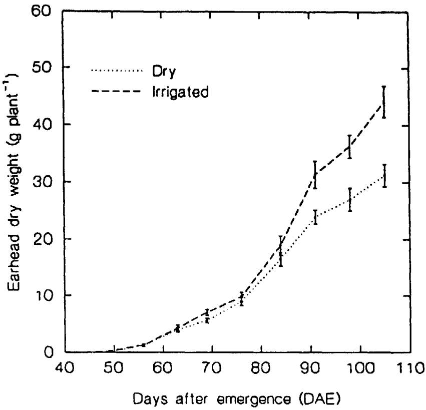
Earhead growth started at 50 DAE, while grain growth started at 70 DAE (Figure 1.85). The interaction of water * DAE highly significant ($P<0.01$), in 1990-91 (Appendix table 7), indicates significant differences between irrigated and dry plots in earhead formation from 63 DAE to harvest and for grain formation from 84 DAE onwards. Mean earhead weight in irrigated plots across nitrogen and genotype treatments was 44 g plant^{-1} at harvest, in dry plots it was 30 g plant^{-1}. The respective grain weights were 38 and 25 g plant^{-1} (Figure 1.85).

The interaction of nitrogen * DAE highly significant ($P<0.01$), in 1990-91 indicates that the 20, 40 and 120 kg N ha^{-1} treatments had a significantly higher earhead weight from 56 DAE onwards, and grain weight from 70 DAE to harvest when compared to the control. From 91 DAE the 40 and 120 kg N ha^{-1} had significantly higher earhead and grain weight than the 20 kg N ha^{-1} treatment. At harvest the 120 kg N ha^{-1} treatment had significantly higher earhead and grain dry weights when compared to other nitrogen treatments (Figure 1.86).

Among genotypes ICSH 86646 had a highly significant ($P<0.01$) higher earhead and grain weight than SPV 783 and M 35-1 during the entire grain development period. Earhead weight was similar for all genotypes up to 69 DAE, and there after was higher for ICSH 86646 when compared to SPV 783 and M 35-1. Grain filling started a week earlier in ICSH 86646 and maintained higher grain dry matter production up to 91 DAE (Figure A 1.87).

Fig : 1.85. Total dry earhead and grain weight of sorghum as a function of time for the interaction effect of water * time, during rabi 1990-91.

a) Earhead (Mean of nitrogen and genotype treatments in 1990-91)



b) Grain (Mean of nitrogen and genotype treatments in 1990-91)

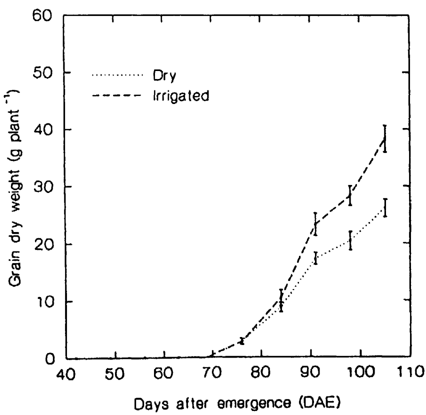
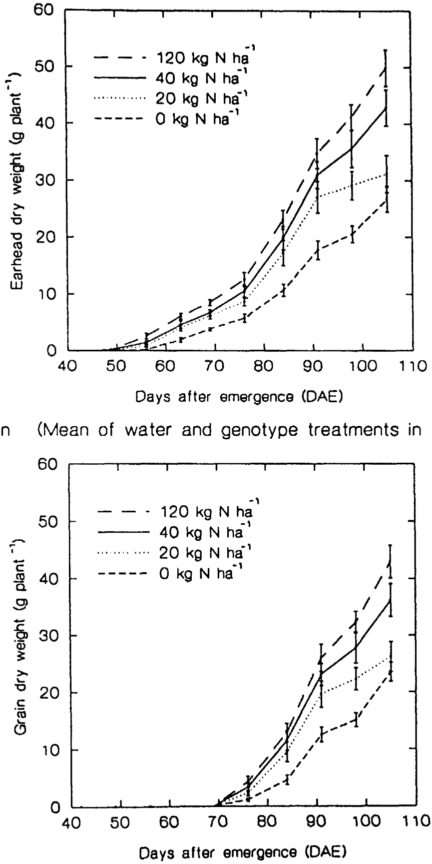


Fig : 1.86. Total dry earhead and grain weight of sorghum as a function of time for the interaction effect of nitrogen * time, during rabi 1990-91.

a) Earhead (Mean of water and genotype treatments in 1990-91)

b) Grain (Mean of water and genotype treatments in 1990-91)



4.1.9 Total dry earhead yield :

4.1.9.1 Measured at harvest :

Main effect of water was significant ($P<0.05$), in 1990-91 and highly significant ($P<0.01$), in 1991-92 (Table 7). Irrigated plots had a significantly higher earhead yield than dry plots, the difference being 1.0 t ha^{-1} in both years.

All nitrogen treatments (20, 40 and 120 kg N ha^{-1}) had highly significant ($P<0.01$), earhead yield than the control at harvest for both years.

ICSH 86646 had a highly significant ($P<0.01$) earhead yield than M 35-1 in 1990-91, while SPV 783 had highly significant ($P<0.01$), earhead yield than M 35-1 in 1991-92. Earhead yield increase for ICSH 86646 was 0.92 t ha^{-1} when compared to M 35-1 in 1990-91, while in 1991-92 SPV 783 had an increase of 0.31 t ha^{-1} over M 35-1.

The interaction of water * nitrogen significant ($P<0.05$), in both years indicates that, in 1990-91 in irrigated plots the 20, 40 and 120 kg N ha^{-1} treatments had a significantly higher earhead yield than the control, while the 40 and 120 kg N ha^{-1} treatments were similar and significantly, higher than the 20 kg N ha^{-1}. In dry plots, the 0 and 20 kg N ha^{-1} and 20 and 40 kg N ha^{-1} treatments had similar earhead yield. Only the 120 kg N ha^{-1} treatment had a significantly higher earhead yield when compared to the other nitrogen treatments (Figure 1.88).

In 1991-92, all nitrogen treatments (20, 40 and 120 kg N ha^{-1}), had a significantly ($P<0.05$) higher earhead yield than the control in irrigated plots, while,

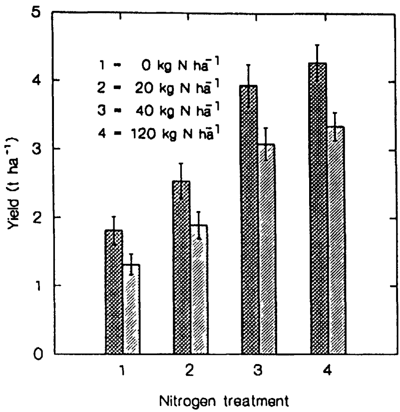
Table : 7. Mean total dry earhead yield of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total dry earhead yield (t ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	3.14 A	1.93 A	2.54 A
Dry	2.04 B	0.72 B	1.38 B
LSD (0.05)	0.51	0.29	0.40
Nitrogen (N) :			
0 kg N ha^{-1}	1.67 D	0.67 D	1.17 D
20 kg N ha^{-1}	2.18 C	1.06 C	1.62 C
40 kg N ha^{-1}	3.00 B	1.36 C	2.18 B
120 kg N ha^{-1}	3.51 A	2.23 A	2.87 A
LSD (0.05)	0.46	0.23	0.26
Genotypes (G) :			
ICSH 86646	2.98 A	1.29 B	2.13 A
SPV 783	2.74 A	1.50 A	2.12 A
M 35-1	2.06 B	1.19 B	1.62 B
LSD (0.05)	0.26	0.12	0.14
Interactions : SE			
YEAR (Y)	-	-	0.08 **
W * Y	-	-	0.11
N * Y	-	-	0.16 *
G * Y	-	-	0.14 **
W * N * Y	0.23 *	0.49 *	0.22
W * G * Y	0.19	0.43 **	0.19
N * G * Y	0.28	0.61	0.27
W * N * G * Y	0.40	0.86 *	0.39
CV %	17.10	15.33	22.21

Significant at p = <0.05 and 0.01 % level, respectively.

Fig : 1.88. **Total earhead and grain yield of sorghum for the interaction effect of water * nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.**

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

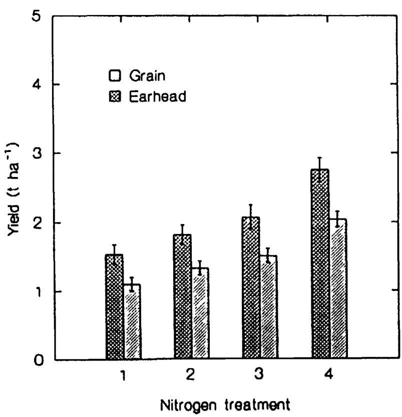
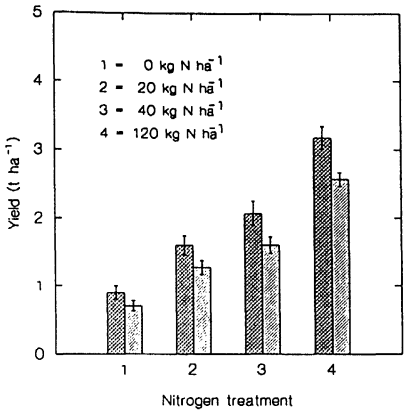


Fig : 1.89. **Total earhead and grain yield of sorghum for the interaction effect of water * nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.**

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

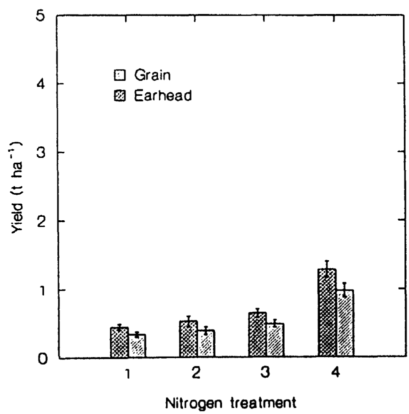
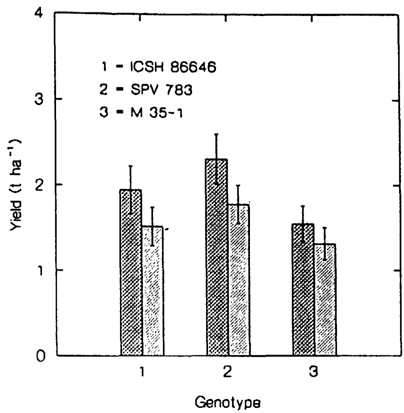


Fig : 1.90. **Total earhead and grain yield of sorghum for the interaction effect of water * genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.**

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

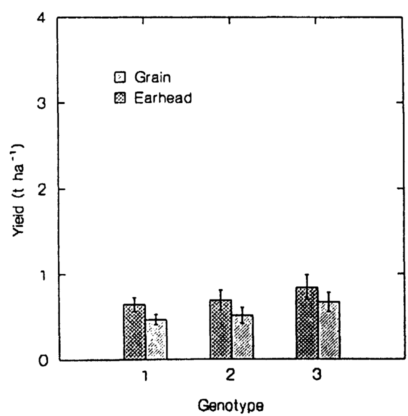
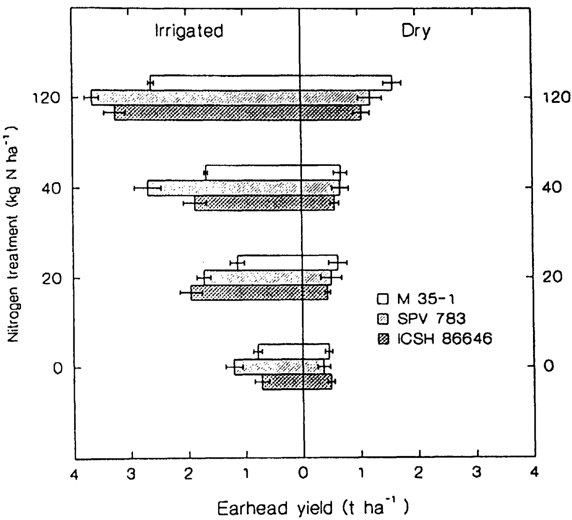


Fig : 1.91. **Total earhead yield of sorghum in irrigated and dry plots for the interaction effect of water * nitrogen * genotype, at harvest during rabi 1991-92.**



in dry plots, the 0, 20 and 40 kg N ha^{-1} rates were similar and only the 120 kg N ha^{-1} had a significantly higher earhead yield (Figure 1.89).

The interaction of water and genotype highly significant ($P<0.01$), in 1991-92 indicates that, in the irrigated plots, both the improved genotypes ICSH 86646 and SPV 783 had a higher earhead yield than M 35-1, while in dry plots, M 35-1 had a higher earhead yield than ICSH 86646 or SPV 783 (Figure 1.90).

The three way interaction of water * nitrogen * genotype (Figure 1.91), in 1991-92 indicates that SPV 783, at all the nitrogen rates except the 20 kg N ha^{-1}, had a significantly ($P<0.05$), higher earhead yield in irrigated plots. In dry plots, all three genotypes had similar earhead yield in the 0, 20 and 40 kg N ha^{-1}, while in the 120 kg N ha^{-1} treatment M 35-1 had a significantly higher earhead yield than ICSH 86646 or SPV 783.

4.1.10 Total dry grain yield :

4.1.10.1 Measured at harvest :

Water, nitrogen and genotype main effects and the interaction of water * nitrogen were significant in both years, while the water * genotype and water * nitrogen * genotype were significant only in 1991-92 (Table 8).

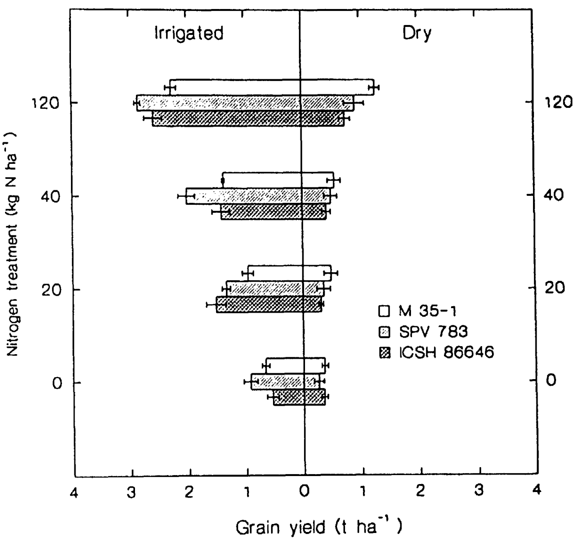
Irrigated plots had a 0.92 t ha^{-1} (mean of nitrogen and genotype treatments) increase in grain yield when compared to dry plots in 1990-91, while in 1991-92 this increase was 0.98 t ha^{-1}. Increased grain yield from the 120 kg N ha^{-1} treatment over the 40 kg N ha^{-1} treatment was 0.39 t ha^{-1} in 1990-91 and 0.73 t ha^{-}

Table : 8. **Mean total dry grain yield of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).**

Treatment	Total dry grain yield (t ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	2.41 A	1.53 A	1.97 A
Dry	1.49 B	0.55 B	1.02 B
LSD (0.05)	0.42	0.21	0.31
Nitrogen (N) :			
0 kg N ha^{-1}	1.20 D	0.52 D	0.86 D
20 kg N ha^{-1}	1.61 C	0.83 C	1.22 C
40 kg N ha^{-1}	2.30 B	1.04 B	1.67 B
120 kg N ha^{-1}	2.69 A	1.77 A	2.23 A
LSD (0.05)	0.38	0.18	0.21
Genotypes (G) :			
ICSH 86646	2.10 A	0.99 B	1.54 A
SPV 783	2.07 A	1.14 A	1.61 A
M 35-1	1.68 B	0.99 B	1.33 B
LSD (0.05)	0.26	0.09	0.13
Interactions : **SE**			
YEAR (Y)	-	-	0.06 **
W * Y	-	-	0.08
N * Y	-	-	0.11 *
G * Y	-	-	0.10 *
W * N * Y	0.21 *	0.36 **	0.16
W * G * Y	0.18	0.31 **	0.14
N * G * Y	0.25	0.44	0.19
W * N * G * Y	0.36	0.62 *	0.28
CV %	22.48	14.88	24.97

Significant at p = <0.05 and 0.01 % level, respectively.

Fig : 1.92. **Total grain yield of sorghum in irrigated and dry plots for the interaction effect of water * nitrogen * genotype, at harvest during rabi 1991-92.**



$^{-1}$ in 1991-92. The grain yield increase for ICSH 86646 over M 35-1 was 0.42 t ha^{-1} in 1990-91 and in 1991-92 the increase for SPV 783 was 0.15 t ha^{-1}. The interaction effects on grain yield (Figures 1.87 to 1.92), were similar to the effects on earhead yield as indicated section 4.14.1 and hence not repeated.

4.1.11 Earhead number :

4.1.11.1 Measured at harvest :

The nitrogen main effect was significant ($P<0.05$), only in 1990-91, while that of genotype was significant ($P<0.05$), for both years (Table 9). The 40 kg N ha^{-1} had significantly higher earhead number than the control in 1990-91, while in 1991-92 the differences between nitrogen treatments were not significant. Similarity of data for earhead number indicate a uniform plant stand in different nitrogen treatments. The genotype SPV 783 had a significantly higher earhead number when compared to the other genotypes (ICSH 86646 and M 35-1) in 1990-91, while in 1991-92 M 35-1 had a significantly higher earhead number than ICSH 86646.

4.1.12 Earhead characters :

Earheads harvested in 1990-91, were characterized for the following variables, secondary rachis number, rachis weight, and grain number (Table 10). Main effects of water had no significant influence on secondary rachis or grain

Table : 9. Mean total earhead number of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Earhead number per m^{-2}		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	10.44 A	14.70 A	12.57 A
Dry	10.04 A	12.43 A	11.23 A
LSD (0.05)	2.15	2.75	2.44
Nitrogen (N) :			
0 kg N ha^{-1}	9.52 B	12.82 A	11.17 A
20 kg N ha^{-1}	10.29 AB	13.79 A	11.90 A
40 kg N ha^{-1}	10.97 A	12.84 A	12.04 A
120 kg N ha^{-1}	10.18 AB	14.81 A	12.49 A
LSD (0.05)	1.36	2.03	1.36
Genotypes (G) :			
ICSH 86646	9.87 B	12.52 B	11.20 B
SPV 783	10.83 A	13.72 AB	12.27 A
M 35-1	10.01 B	14.45 A	12.23 A
LSD (0.05)	0.69	1.36	0.78
Interactions : SE			
YEAR (Y)	-	-	0.34 **
W * Y	-	-	0.48 *
N * Y	-	-	0.68 *
G * Y	-	-	0.59
W * N * Y	1.71	1.57	0.96
W * G * Y	1.48	1.36	0.83
N * G * Y	2.10	1.92	1.18
W * N * G * Y	2.97	2.72	1.67
CV %	11.40	17.00	16.06

Significant at p = <0.05 and 0.01 % level, respectively.

Table : 10. Mean rachis number, rachis weight and grain number of sorghum as affected by water, nitrogen and genotype, for the interaction effects, at harvest in 1990-91 season.

Treatment	1990-91		
	All variables per earhead		
	Rachis number	Rachis weight	Grain number
Water (W) :			
Irrigated	58.28 A	47.32 A	1104.66 A
Dry	55.36 A	33.86 B	898.01 A
LSD (0.05)	3.01	9.99	285.89
Nitrogen (N) :			
0 kg N ha^{-1}	52.78 C	28.22 C	708.10 C
20 kg N ha^{-1}	54.22 CB	34.09 CB	847.30 C
40 kg N ha^{-1}	58.67 AB	44.84 AB	1103.10 B
120 kg N ha^{-1}	61.61 A	55.21 A	1346.80 A
LSD (0.05)	5.02	11.14	235.32
Genotypes (G) :			
ICSH 86646	58.71 A	45.63 A	1219.16 A
SPV 783	52.58 B	39.39 B	902.21 B
M 35-1	59.17 A	36.74 B	882.64 B
LSD (0.05)	3.71	5.10	131.62
Interactions : SE			
W * N	5.38	7.20	202.05
W * G	4.66	6.24	174.98
N * G	6.59	8.82	247.45
W * N * G	9.32	12.48	349.95
CV %	11.10	21.36	22.35

' = Significant at p = <0.05 and 0.01 % level, respectively.

number, but significantly ($P<0.05$) influenced secondary rachis weight. This indicates that when water is limiting grain filling would be affected.

Among nitrogen treatments, the 40 and 120 kg N ha^{-1} treatments had highly significant ($P<0.01$), secondary rachis number, secondary rachis weight and grain number than the control. Nitrogen application resulted in an increase in these reproductive variables which was reflected in higher grain yield. The lower rate of 20 kg N ha^{-1} was similar to the control and had no significant influence on these characters.

ICSH 86646 had a highly significant ($P<0.01$) grain number and secondary rachis weight than the other two genotypes (SPV 783 and M 35-1). These two characters resulted in a highly significant ($P<0.01$) grain yield in ICSH 86646 in 1990-91 (Table 8).

4.2.1 Leaf nitrogen content :

4.2.1.1 Measured at 14, 21, 35, 48, 63 and 105 DAE :

The interaction of water * DAE was significant ($P<0.05$), in 1990-91 and hihgly significant ($P<0.01$), in 1991-92 (Appendix table 8). Leaf nitrogen content declined from a mean maximum of 4.0 % at 14 DAE to 0.75 % at harvest. Up to 21 DAE, in both the years, leaf nitrogen content was similar in irrigated and dry plots. Thereafter the decline in leaf nitrogen content was faster in dry plots when compared to irrigated plots. Differences in leaf nitrogen content between irrigated and dry plots were greater in 1991-92 than in 1990-91 throughout much of the plant growth (Figure A 2.1).

The interaction of nitrogen * DAE was highly significant ($P<0.01$), in 1990-91 and significant ($P<0.05$), in 1991-92. The control treatment (0 kg N ha^{-1}) had the lowest leaf nitrogen content when compared to the other nitrogen treatments, while the 120 kg N ha^{-1} treatment had the highest leaf nitrogen content at all the crop growth stages in 1990-91 (Figure A 2.2a). The 20 and 40 kg N ha^{-1} treatments had an intermediary leaf nitrogen content values when compared to the 0 and 120 kg N ha^{-1} treatments. Difference between the 0 and 120 kg N ha^{-1} treatments was 0.6 % at the two early samplings, but remained at a constant value of 0.9 % thereafter up to anthesis stage, which later declined to 0.3 % by harvest. In 1991-92 from 35 DAE onwards the 0, 20 and 40 kg N ha^{-1} treatments had similar leaf nitrogen content. The 120 kg N ha^{-1} treatment had significantly higher leaf nitrogen content over the crop growth period, but by harvest all nitrogen treatments had a similar leaf nitrogen content (Figure A 2.2b).

Interaction of genotype * DAE highly significant ($P<0.01$), in 1991-92 indicates that, among genotypes, M 35-1 had a higher leaf nitrogen content than ICSH 86646 and SPV 783 at all stages of crop growth in 1990-91 and except the 49 DAE in 1991-92 (Figure A 2.3).

The interaction of water * nitrogen * DAE significant ($P<0.05$), in both years indicates that, in 1990-91 the differences in leaf nitrogen content between nitrogen treatments, in irrigated plots, started after 21 DAE, while in dry plots it commenced from 14 DAE. The 120 kg N ha^{-1} treatment had a significantly higher leaf nitrogen content than the other nitrogen treatments in both irrigated and dry plots. The 20 and 40 kg N ha^{-1} treatments had intermediate values in the irrigated plots, while, in dry plots, they were similar to the 0 kg N ha^{-1}. Differences in leaf nitrogen content between the 0 and 120 kg N ha^{-1} treatments were greater in irrigated plots than in dry plots (Figure A 2.4). In 1991-92, the 120 kg N ha^{-1} treatment had significantly higher leaf nitrogen content than all other nitrogen treatments at most stages in irrigated plots, while, in dry plots, it was higher only at 21 and 35 DAE (Figure A 2.5).

The interaction of water * genotype * DAE highly significant ($P<0.01$), in 1991-92 indicates that in irrigated plots, there was no definite trend in leaf nitrogen content among genotypes. At 14, 21 DAE and harvest stages M 35-1 had higher leaf nitrogen content, while at 35, 49 and 63 DAE, ICSH 86646 and SPV 783 had a higher leaf nitrogen content. In dry plots M 35-1 had significantly ($P < 0.05$) higher leaf nitrogen content than all other genotypes from 21 DAE to harvest (Figure A 2.6).

The interaction of nitrogen * genotype * DAE significant ($P<0.01$), in 1991-92 indicates that for the 0, 20 and 40 kg N ha^{-1} treatments, all three genotypes (ICSH 86646, SPV 783 and M 35-1), had a similar leaf nitrogen content at most crop growth stages. However, for the 120 kg N ha^{-1} treatment, M 35-1 had the highest and SPV 783 the lowest leaf nitrogen content while ICSH 86646 had an intermediary value from 21 DAE to harvest (Figures A 2.7 and A 2.8).

<u>4.2.1.2</u> <u>Measured at harvest :</u>

The main effect of water was significant ($P<0.05$), in 1991-92 and that of nitrogen and genotype were highly signficant ($P<0.01$), in 1990-91 (Table 12).

Irrigated plots, among water treatments, the 120 kg N ha^{-1} treatment among nitrogen treatments and M 35-1 among genotypes had a significantly higher leaf nitrogen content at harvest. There was 0.24 % increase in leaf nitrogen content with water and nitrogen, when compared to respective control treatments. M 35-1 had 0.10 and 0.19 % higher leaf nitrogen content than ICSH 86646 and SPV 783 respectively (Table 12).

The interaction of water * nitrogen significant ($P<0.05$), in 1990-91 indicates that, in irrigated plots, only the 120 kg N ha^{-1} treatment had a significantly higher leaf nitrogen content (1.0 %), when compared to the other nitrogen treatments,

Table : 11. **Mean leaf nitrogen content of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).**

Treatment	Leaf nitrogen content (%)		
	1990-91	**1991-92**	**Pooled**
Water (W) :			
Irrigated	0.71 A	0.53 A	0.62 A
Dry	0.57 A	0.37 B	0.47 A
LSD (0.05)	0.48	0.12	0.20
Nitrogen (N) :			
0 kg N ha^{-1}	0.58 B	0.47 A	0.52 B
20 kg N ha^{-1}	0.56 B	0.47 A	0.51 B
40 kg N ha^{-1}	0.62 B	0.39 A	0.50 B
120 kg N ha^{-1}	0.82 A	0.47 A	0.65 A
LSD (0.05)	0.13	0.14	0.08
Genotypes (G) :			
ICSH 86646	0.64 B	0.50 A	0.53 B
SPV 783	0.55 C	0.42 A	0.48 B
M 35-1	0.74 A	0.42 A	0.62 A
LSD (0.05)	0.06	0.11	0.06
Interactions : SE			
YEAR (Y)	-	-	0.06 **
W * Y	-	-	0.08
N * Y	-	-	0.12 *
G * Y	-	-	0.10
W * N * Y	0.13 *	0.24	0.17
W * G * Y	0.11	0.21	0.14
N * G * Y	0.16	0.30	0.20
W * N * G * Y	0.22	0.43	0.29
CV %	17.14	41.38	31.20

* = Significant at p = <0.05 and 0.01 % level, respectively.

while in dry plots all the nitrogen treatments had a similar leaf nitrogen content at harvest (Figure A 2.9).

4.2.2 Stem nitrogen content :

4.2.2.1 Measured at 14, 21, 35, 48, 63 and 105 DAE :

The interaction of water * DAE was highly significant ($P<0.01$), in 1990-91 and significant ($P<0.05$), in 1991-92 (Appendix table 9). Stem nitrogen content pooled over all treatments declined from 3.4 % to 0.6 % by anthesis stage in 1990-91 and from 2.7 % to 0.3 % in 1991-92. Irrigated plots had a higher stem nitrogen content than dry plots at most crop growth stages, but by harvest their values were similar (Figure A 2.10).

The interaction of nitrogen * DAE was highly significant ($P<0.01$), in both years. Among nitrogen treatments the 120 kg N ha^{-1} treatment had a higher stem nitrogen content than all other treatments when pooled over water and genotye treatments throughout the crop growth period. The 20 and 40 kg N ha^{-1} treatments had an intermediary value in 1990-91 (Figure A 2.11a), while in 1991-92 (Figure A 2.11b), their values were similar to those of the 0 kg N ha^{-1} treatment.

The interaction of genotype * DAE highly significant ($P<0.01$), in 1991-92 indicates that all genotypes had similar stem nitrogen content values in 1990-91, while in 1991-92 ICSH 86646 and SPV 783 had a higher stem nitrogen content than M 35-1 at 35 and 48 DAE. However by harvest in both the years, all three genotypes had similar stem nitrogen content values (Figure A 2.13).

The interaction of water * genotype * DAE significant ($P<0.05$), in 1990-91 indicates that in irrigated plots, ICSH 86646 and SPV 783 had a higher stem nitrogen content than M 35-1 at 35, 48 and 63 DAE, while in dry plots there were no differences among genotypes at most sampling dates (Figure105).

The interaction of water * nitrogen * genotype * DAE significant ($P<0.05$), in 1991-92 indicates that, in irrigated plots, ICSH 86646 and SPV 783 had a higher stem nitrogen content than M 35-1 in the 0 and 20 kg N ha^{-1} treatments (Figure A 2.14) at 35 and 48 DAE, while in the 40 and 120 kg N ha^{-1} treatments (Figure A 2.15), they were higher at 35, 48 and 63 DAE. In dry plots, for the 0 and 20 kg N ha^{-1} treatments, M 35-1 had a higher stem nitrogen content at 14 and 21 DAE, while in the 120 kg N ha^{-1} treatment it was higher at 48 and 63 DAE (Figures A 2.16 and A 2.17).

4.2.2.2 Measured at harvest :

Water had significant ($P<0.05$) influence on stem nitrogen content in 1991-92 (Table 13). Irrigated plots had a 0.04 % higher stem nitrogen content than dry plots. The main effect of nitrogen significant ($P<0.05$), in both years indicates that, among nitrogen treatments the 120 kg N ha^{-1} treatment had 0.08 % higher stem nitrogen content in 1990-91 and 0.04 % in 1991-92 than all other nitrogen treatments. The main effect of genotype was highly significant ($P<0.01$), in 1991-92. The genotype M 35-1 had a 0.03 % higher stem nitrogen content than ICSH 86646.

Table : 12. Mean stem nitrogen content of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Stem nitrogen content (%)		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	0.27 A	0.17 A	0.22 A
Dry	0.23 A	0.13 B	0.18 A
LSD (0.05)	0.19	0.04	0.10
Nitrogen (N) :			
0 kg N ha^{-1}	0.23 B	0.14 B	0.18 B
20 kg N ha^{-1}	0.23 B	0.14 B	0.19 B
40 kg N ha^{-1}	0.23 B	0.14 B	0.18 B
120 kg N ha^{-1}	0.31 A	0.18 A	0.25 A
LSD (0.05)	0.07	0.02	0.04
Genotypes (G) :			
ICSH 86646	0.25 A	0.13 B	0.19 B
SPV 783	0.24 A	0.15 A	0.20 B
M 35-1	0.26 A	0.16 A	0.21 A
LSD (0.05)	0.03	0.01	0.01
Interactions : SE			
YEAR (Y)	-	-	0.01 **
W * Y	-	-	0.02
N * Y	-	-	0.02
G * Y	-	-	0.02
W * N * Y	0.06	0.04 *	0.03
W * G * Y	0.05	0.03 *	0.03
N * G * Y	0.07	0.04 *	0.04
W * N * G * Y	0.10	0.06 *	0.06
CV %	17.94	12.94	26.70

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

The interaction of water * nitrogen significant ($P<0.05$), in 1991-92 indicates that, in dry plots, all nitrogen treatments had a similar stem nitrogen content, while in the irrigated plots, the 120 kg N ha^{-1} treatment had a significantly higher stem nitrogen content (0.09 %), when compared to other nitrogen treatments (Figure A 2.18b).

In irrigated plots (Figure 111a), M 35-1 had a significantly ($P<0.05$) higher stem nitrogen content than ICSH 86646, while, in dry plots, (Figure A 2.19b) both M 35-1 and SPV 783 had significantly ($P<0.05$) higher stem nitrogen content than ICSH 86646.

The interaction of nitrogen and genotype significant ($P<0.05$) in 1991-92 indicates that, in the 0 and 40 kg N ha^{-1} treatments genotypes did not significantly differ in stem nitrogen content, but at the 20 kg N ha^{-1} treatment both SPV 783 and M 35-1 had significantly higher stem nitrogen values than ICSH 86646. At the 120 kg N ha^{-1} level only M 35-1 had a significantly higher stem nitrogen content than ICSH 86646 (Figures A 2.20 and A 2.21).

The interaction of water * nitrogen * genotype in 1991-92 indicates that, in dry plots, both SPV 783 and M 35-1 had a higher stem nitrogen content than ICSH 86646 in all the nitrogen treatments, in irrigated plots, these varieties had higher stem nitrogen content in the 20 and 120 kg N ha^{-1} treatments (Figure A 2.22).

4.2.3 Grain nitrogen content :

4.2.3.1 Measured at harvest :

Main effect of water had no significant influence on grain nitrogen content but nitrogen and genotype effects were highly significant (P<0.01) at harvest in 1990-91 (Table 17).

Among nitrogen treatments the 120 kg N ha^{-1} treatment had significantly higher grain nitrogen content when compared to other nitrogen treatments. Increases in grain nitrogen content for the 120 kg N ha^{-1} treatment were 0.44, 0.35 and 0.34 % over the 0, 20 and 40 kg N ha^{-1} treatments, respectively. Both M 35-1 and SPV 783 had a significantly higher grain nitrogen content when compared to ICSH 86646. M 35-1 had an 0.18 % higher grain nitrogen content than ICSH 86646. Interaction effects were not significant.

4.2.4 Total nitrogen uptake by above ground biomass :

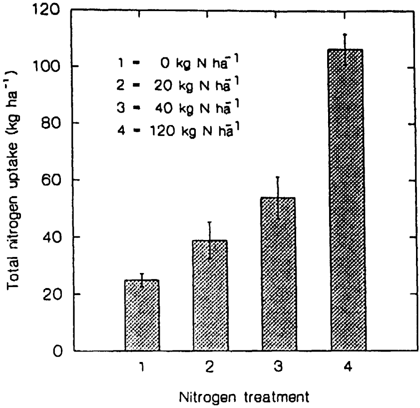
4.2.4.1 Measured at harvest :

Differences between years were highly significant (P<0.01) in terms of total nitrogen uptake by above ground biomass (Table 13). Increases in nitrogen uptake due to irrigation were significant (P<0.05), 52 kg N ha^{-1} in 1990-91 and 25 kg N ha^{-1} in 1991-92.

The main effect of nitrogen was very highly significant (P<0.001) in both years. Total nitrogen uptake for the 120 kg N ha^{-1} treatment was 90 and 50 kg ha^{-1}

Fig : 2.23. **Total nitrogen uptake by above ground biomass of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.**

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

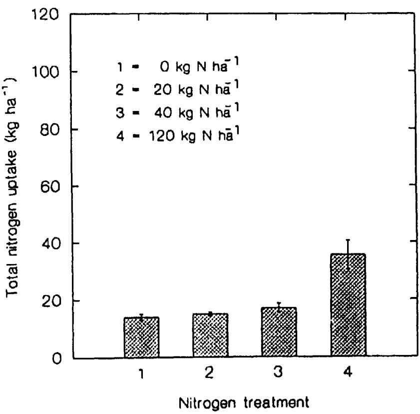


Fig : 2.24. **Total nitrogen uptake by above ground biomass of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.**

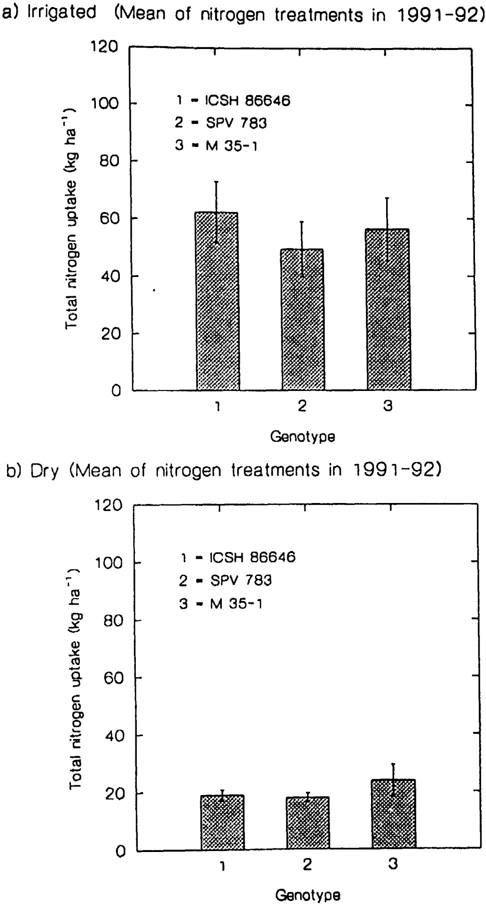


Table : 13. Mean total nitrogen uptake by above ground biomass of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total nitrogen uptake (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	124.95 A	56.14 A	90.54 A
Dry	72.58 B	20.23 B	46.40 B
LSD (0.05)	26.46	26.99	18.16
Nitrogen (N) :			
0 kg N ha^{-1}	63.35 C	19.36 C	41.35 C
20 kg N ha^{-1}	73.79 C	26.93 BC	50.36 C
40 kg N ha^{-1}	102.76 B	35.46 B	69.11 B
120 kg N ha^{-1}	155.15 A	70.99 A	113.07 A
LSD (0.05)	25.61	11.78	12.51
Genotypes (G) :			
ICSH 86646	98.91 A	40.62 A	69.72 A
SPV 783	100.16 A	33.76 B	66.96 A
M 35-1	97.31 A	40.18 A	68.74 A
LSD (0.05)	15.81	5.11	8.23
Interactions : SE			
YEAR (Y)	-	-	6.38 **
W * Y	-	-	9.03 *
N * Y	-	-	12.77 *
G * Y	-	-	11.06
W * N * Y	23.12	12.58 *	18.06
W * G * Y	20.02	10.89 *	15.64
N * G * Y	28.32	15.41 *	22.12
W * N * G * Y	40.05	21.79	31.29
CV %	27.23	22.76	35.57

* , ** = Significant at p = <0.0and 0.01 % level, respectively.

for the 1990-91 and 1991-92 respectively, while the 40 kg N ha^{-1} treatment was 40 and 16 kg ha^{-1}, and the 20 kg N ha^{-1} treatment was 10 and 7 kg ha^{-1}.

Genotypes did not differ significantly in total nitrogen uptake in the above-ground biomass in 1990-91, but in 1991-92 both ICSH 86646 and M 35-1 had significantly ($P<0.05$) higher nitrogen uptake than SPV 783.

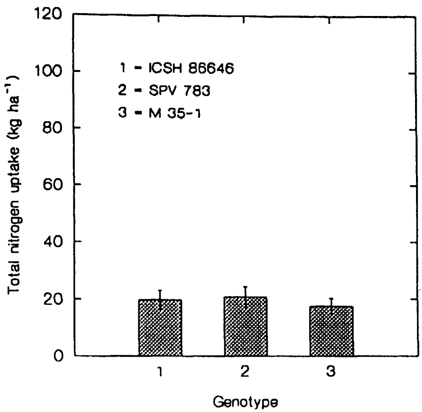
The interaction of water * nitrogen was significant ($P<0.05$) in 1991-92. Total nitrogen uptake for all nitrogen treatments was higher in irrigated plots when compared to dry plots (Figure 2.23). Increases in nitrogen uptake attributed to irrigation were 10, 32, 34 and 75 kg N for the 0, 20, 40 and 120 kg N ha^{-1} nitrogen rates when compared to those in dry plots. Although increases in nitrogen uptake for the 40 and 120 kg N ha^{-1} treatments were different, total above-ground biomass for these nitrogen treatments was not different indicating luxury consumption. Total nitrogen uptake in the 20 and 40 kg N ha^{-1} treatments, in dry plots, was similar to the control with only the 120 kg N ha^{-1} treatment having a significantly higher total nitrogen uptake value when compared to the other nitrogen treatments.

The interaction of water * genotype significant ($P<0.05$) in 1991-92, indicates that, in irrigated plots, both ICSH 86646 and M 35-1 had higher total nitrogen uptake than SPV 783, while in dry plots, only M 35-1 had a higher total nitrogen uptake value than SPV 783 (Figure 2.24).

The interaction of nitrogen and genotype was significant ($P<0.05$) in 1991-92. While ICSH 86646 had higher total nitrogen uptake at N rates of 0, 20 and 40

Fig : 2.25. **Total nitrogen uptake by above ground biomass of sorghum for the interaction effect of nitrogen and genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest during rabi 1991-92.**

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

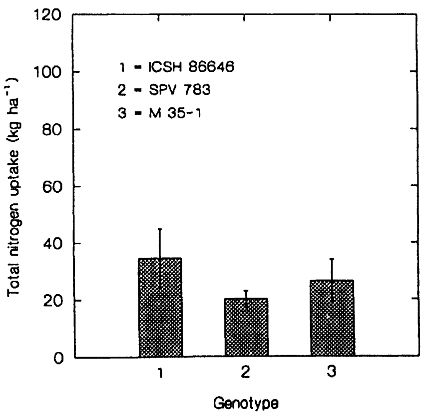
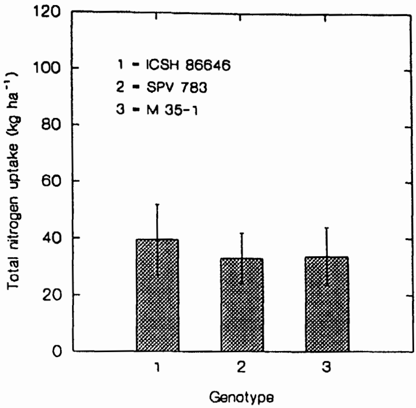
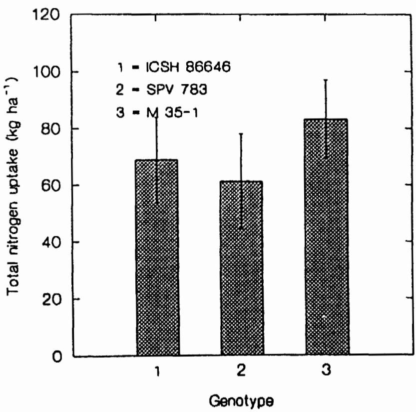


Fig : 2.26. **Total nitrogen uptake by above ground biomass of sorghum for the interaction effect of nitrogen and genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest during rabi 1991-92.**

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)



kg N ha^{-1} M 35-1 had the highest total nitrogen uptake for the 120 kg N ha^{-1} treatment (Figure 2.25 and 2.26).

4.2.5 Leaf nitrogen uptake :

4.2.5.1 Measured at 14, 21, 35, 48, 63 and 105 DAE :

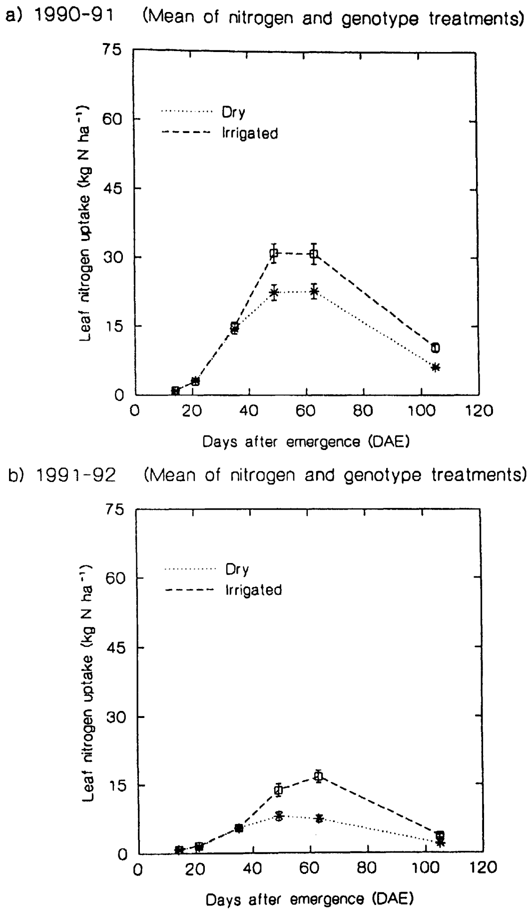
The interaction of water * DAE was highly significant (P<0.01) in both years (Appendix table 10). In both the years, differences between irrigated and dry plots were significant from 38 DAE to harvest. Maximum total leaf nitrogen uptake was attained at 48 DAE in 1990-91 and 63 DAE in 1991-92. In both years, the decline in leaf nitrogen started at anthesis. Redistribution of leaf nitrogen after anthesis in 1990-91 in irrigated and dry plots was 17 and 15 kg N ha^{-1}, while in 1991-92 it was 15 and 5 kg N ha^{-1} respectively (Figure 2.27).

Differences in leaf nitrogen uptake between nitrogen treatments were highly significant (P < 0.01) from 21 DAE onwards while the 120 kg N ha^{-1} treatment had a significantly higher leaf nitrogen uptake value than when compared to other nitrogen treatments. The 20 and 40 kg N ha^{-1} treatments had intermediary values in both years (Figure A 2.28).

Among genotypes, ICSH 86646 and SPV 783 had sifnificantly higher (P<0.05) leaf nitrogen uptake at 48 and 63 DAE when compared to M 35-1 in 1991-92 (Figure A 2.29).

The interaction of water * nitrogen * DAE significant (P<0.05), in both years indicates that the 40 and 120 kg N ha^{-1} treatments had similar leaf nitrogen uptake

Fig : 2.27. **Total leaf nitrogen uptake of sorghum as a function of time for the interaction effect of water and time, during rabi 1990-91 and 1991-92.**



values in irrigated plots up to 48 DAE, but there after the 120 kg N ha^{-1} treatment had significantly higher leaf nitrogen uptake than all other nitrogen treatments (Figure A 2.30a). In dry plots, the 120 kg N ha^{-1} treatment had significantly ($P < 0.05$) higher leaf nitrogen uptake than all the other nitrogen treatments from 21 DAE to harvest (Figure A 2.30b).

In 1991-92, in dry plots, the 20 and 40 kg N ha^{-1} treatments had a similar leaf nitrogen uptake as the 0 kg N ha^{-1} treatment, while in irrigated plots, they had an intermediary value between the 0 and 120 kg N ha^{-1} treatments (Figure A 2.31).

The interaction of water * genotype * DAE highly significant ($P<0.01$), in 1991-92 indicates that, in irrigated plots, ICSH 86646 and SPV 783 had significantly higher leaf nitrogen uptake when compared to M 35-1, while in dry plots M 35-1 had higher leaf nitrogen uptake than either ICSH 86646 or SPV 783 after 35 DAE to harvest (Figure A 2.32).

The interaction of water * nitrogen * genotype * DAE was highly significant ($P<0.01$) in 1991-92. In irrigated plots, ICSH 86646 and SPV 783 had higher leaf nitrogen uptake than M 35-1 for all the nitrogen treatments except the 20 kg N ha^{-1} treatment at 48 and 63 DAE (Figures A 2.33 and A 2.34). In dry plots, all the three genotypes had similar leaf nitrogen uptake for the 0, 20 and 40 kg N ha^{-1} treatments, however, in the 120 kg N ha^{-1} treatment M 35-1 had significantly higher leaf nitrogen uptake after 35 DAE (Figures A 2.35 and A 2.36).

4.2.5.1 Measured at harvest :

The main effect of nitrogen had a highly significant ($P<0.01$) influence on leaf nitrogen uptake in both the years, while the water and genotype effects were significant ($P<0.05$) only in 1991-92 (Table 14).

In 1991-92, irrigated plots had significantly higher leaf nitrogen uptake than dry plots, while the 120 kg N ha^{-1} level among the nitrogen treatments and M 35-1 and ICSH 86646 among genotypes had significantly higher leaf nitrogen uptake.

The interaction of water * nitrogen significant ($P<0.05$) in both years, indicates that, in irrigated plots, the 120 kg N ha^{-1} treatment had significantly higher leaf leaf nitrogen uptake than all other nitrogen treatments, while, in dry plots, it had significantly higher leaf nitrogen uptake when compared to the 0 and 20 kg N ha^{-1} treatments in 1990-91 (Figure A 2.37). In 1991-92, (Figure A 2.38), the 120 kg N ha^{-1} treatment had significantly higher leaf nitrogen uptake when compared to all other nitrogen treatments in both irrigated and dry plots.

The interaction of water * genotype significant ($P<0.05$) in 1991-92 indicates that M 35-1 and ICSH 86646 had higher leaf nitrogen uptake than SPV 783 in both irrigated and dry plots (Figure A 2.39). They also had higher leaf nitrogen uptake in the 0, 20 and 40 kg N ha^{-1} treatments, however in the 120 kg N ha^{-1} treatment M 35-1 had significantly higher leaf nitrogen uptake than either ICSH 86646 or SPV 783 (Figures A 2.40 and A 2.41).

Table : 14. Mean total leaf nitrogen uptake of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total leaf nitrogen uptake (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	10.33 A	3.59 A	6.96 A
Dry	6.02 A	1.98 B	4.00 A
LSD (0.05)	6.59	0.70	3.24
Nitrogen (N) :			
0 kg N ha^{-1}	6.02 B	2.14 B	4.08 B
20 kg N ha^{-1}	6.42 B	2.35 B	4.39 B
40 kg N ha^{-1}	7.51 B	2.48 B	5.00 B
120 kg N ha^{-1}	12.74 A	4.17 A	8.46 A
LSD (0.05)	1.98	0.74	0.94
Genotypes (G) :			
ICSH 86646	7.26 A	2.82 A	5.04 B
SPV 783	8.83 A	2.17 B	5.50 AB
M 35-1	8.43 A	3.36 A	5.90 A
LSD (0.05)	1.78	0.64	0.79
Interactions : SE			
YEAR (Y)	-	-	0.47 **
W * Y	-	-	0.67 *
N * Y	-	-	0.95 *
G * Y	-	-	0.82
W * N * Y	1.93 *	1.43 *	1.34 *
W * G * Y	1.67	1.24 *	1.16
N * G * Y	2.37	1.76 *	1.65
W * N * G * Y	3.35	2.48	2.32
CV %	37.01	39.06	50.48

* = Significant at p = <0.05 and 0.01 % level, respectively.

4.2.6 Stem nitrogen uptake :

4.2.6.1 Measured at 14, 21, 35, 48, 63 and 105 DAE :

The interaction of water * DAE was highly significant (P<0.01) in both years (Appendix table 12). Differences in irrigated and dry plots were significant from 35 DAE to harvest in both years. In 1990-91, there was no decline in total stem nitrogen uptake after anthesis (Figure 2.42a), while in 1991-92 the total stem nitrogen uptake declined from 13 kg N ha^{-1} at anthesis to 6 kg N ha^{-1} at harvest (Figure 2.42b).

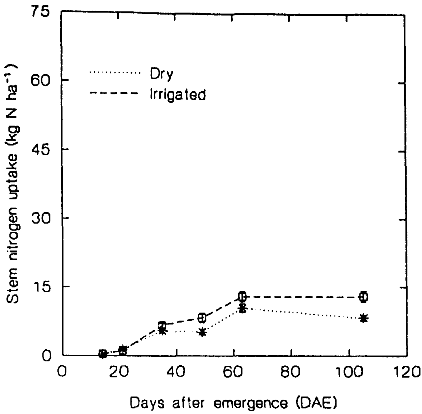
The interaction of nitrogen * DAE highly significant in both years indicates that, the 120 kg N ha^{-1} treatment had higher total stem nitrogen uptake from 21 DAE to harvest when compared to all other nitrogen treatments in both years (Figure 135).

The interaction of genotype * DAE was highly significant in both years. In 1990-91, M 35-1 among genotypes, had higher total stem nitrogen uptake when compared to the other genotypes, while in 1991-92 both ICSH 86646 and SPV 783 had higher total stem nitrogen uptake than M 35-1 at 35, 48 and 63 DAE (Figure A 2.44).

The interaction of water * nitrogen * DAE highly significant (P<0.01) in 1991-92 indicates that in irrigated plots, the 20, 40 and 120 kg N ha^{-1} treatments had significantly higher total stem nitrogen uptake than the control after 35 DAE. In dry plots, the 20 and 40 kg N ha^{-1} treatments were similar to the 0 kg N ha^{-1} while the

Fig : 2.42. **Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of water and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)

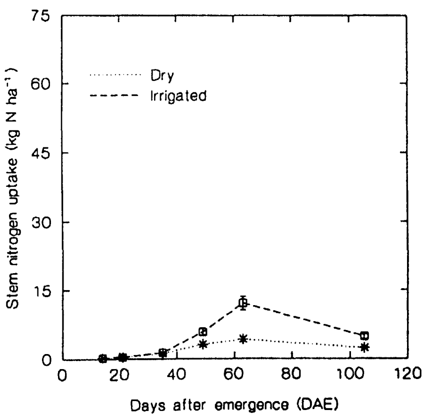
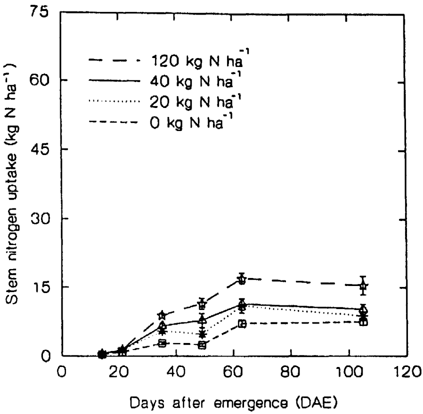
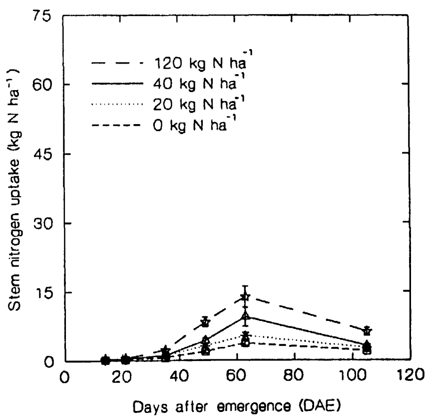


Fig : 2.43. **Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of nitrogen and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)



120 kg N ha^{-1} treatment had significantly higher total stem nitrogen uptake than the other nitrogen treatments (Figure A 2.45).

The interaction of water * genotype * DAE highly significant ($P<0.01$) in 1991-92 indicates that, the improved genotypes ICSH 86646 and SPV 783 had significantly higher total stem nitrogen uptake in irrigated plots up to anthesis stage, while in dry plots, M 35-1 had higher total stem nitrogen uptake after 49 DAE (Figure A 2.46).

The interaction of nitrogen * genotype * DAE highly significant ($P<0.01$) in 1991-92 indicates that, in all nitrogen treatments, total stem nitrogen uptake by ICSH 86646 and SPV 783 declined after anthesis stage, while in M 35-1 this decline was not present (Figure A 2.47 and A 2.48). High demand for nitrogen during grain development in improved genotypes results in greater redistribution of stem nitrogen.

In M 35-1, in irrigated plots the decline in total stem nitrogen uptake was not significant (Figures A 2.49 and A 2.50), however, in dry plots, for the 120 kg N ha^{-1} treatment there was a decline in stem nitrogen uptake in M 35-1 (Figures A 2.52 and A 2.52).

4.2.6.2 Measured at harvest :

The main effect of water was significant ($P<0.05$) in 1991-92, while nitrogen and genotype effects were highly significant ($P<0.01$) in both years (Table 15).

Table : 15. Mean total stem nitrogen uptake of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total stem nitrogen uptake (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	12.88 A	4.72 A	8.80 A
Dry	8.13 A	2.26 B	5.19 B
LSD (0.05)	6.84	1.66	3.45
Nitrogen (N) :			
0 kg N ha^{-1}	7.51 C	1.98 C	4.74 C
20 kg N ha^{-1}	8.81 BC	2.66 BC	5.74 BC
40 kg N ha^{-1}	10.25 B	3.10 B	6.67 B
120 kg N ha^{-1}	15.46 A	6.20 A	10.83 A
LSD (0.05)	2.07	0.87	1.01
Genotypes (G) :			
ICSH 86646	6.60 C	3.17 B	4.89 C
SPV 783	10.52 B	2.65 B	6.59 B
M 35-1	14.40 A	4.64 A	9.52 A
LSD (0.05)	2.13	0.63	0.89
Interactions : SE			
YEAR (Y)	-	-	0.72 **
W * Y	-	-	1.03 *
N * Y	-	-	1.46
G * Y	-	-	1.26 **
W * N * Y	3.39 *	1.02 *	2.06
W * G * Y	2.94	0.88 *	1.79
N * G * Y	4.16	1.25 **	2.53
W * N * G * Y	5.88	1.76	3.58
CV %	34.48	30.78	44.07

= Significant at p = <0.05 and 0.01 % level, respectively.

Total stem nitrogen uptake in irrigated plots was twice that of dry plots in 1991-92. Among nitrogen treatments the 120 kg N ha^{-1} treatment and M 35-1 among genotypes had significantly higher total stem nitrogen uptake when compared to all other treatments in both the years.

The interaction of water * nitrogen significant ($P<0.05$) in both years indicates that, in 1990-91, in irrigated plots, (Figure A 2.53a) both the 40 and 120 kg N ha^{-1} treatments had significantly higher total stem nitrogen uptake than the control, while in dry plots (Figure A 2.53b) only the 120 kg N ha^{-1} treatment had significantly higher total stem nitrogen uptake when compared to other nitrogen treatments. In 1991-92 all three nitrogen treatments (20, 40 and 120 kg N ha^{-1}) had significantly higher total stem nitrogen uptake than the control in irrigated plots, while, in dry plots, only the 120 kg N ha^{-1} treatment had significantly higher total stem nitrogen uptake (Figure A 2.54).

The interaction of water * genotype was significant ($P<0.05$) in 1991-92. In irrigated plots both ICSH 86646 and M 35-1 had higher total stem nitrogen uptake, while, in dry plots, only M 35-1 had higher total stem nitrogen uptake (Figure A 2.55).

The interaction of nitrogen * genotype highly significant ($P<0.01$) in 1991-92 indicates that, for the 0 kg N ha^{-1} treatment all three genotypes had similar total stem nitrogen uptake. For the 20 and 40 kg N ha^{-1} treatments both ICSH 86646 and M 35-1 had higher total stem nitrogen uptake than SPV 783, while in the 120 kg N ha^{-1} treatment only M 35-1 had significantly higher total stem nitrogen uptake than both ICSH 86646 and SPV 783 (Figures A 2.56 and A 2.57).

4.2.7 Nitrogen uptake by vegetative dry matter :

<u>4.2.7.1</u> <u>Measured at 14, 21, 35, 48, 63 and 105 DAE :</u>

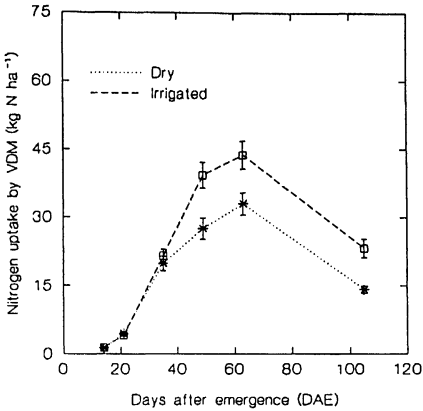
The interaction of water * DAE was highly significant (P<0.01) for both years (Appendix table 13). Differences in total nitrogen uptake by vegetative matter in irrigated and dry plots were significant from 35 DAE to harvest in both years (Figure 2.58). Maximum nitrogen uptake was attained by 63 DAE in both the years, which later declined to harvest in both irrigated and dry plots. Redistribution of nitrogen from the vegetative matter after anthesis was 20 kg N ha^{-1} and 18 kg N ha^{-1} in irrigated and dry plots respectively in 1990-91, while in 1991-92 it was 20 and 6 kg N ha^{-1} for the respective treatments.

The interaction of nitrogen * DAE highly significant (P<0.01) for both years indicates that, in both years, the 120 kg N ha^{-1} treatment had significantly higher total nitrogen uptake by vegetative matter when compared to other nitrogen treatments (Figure 2.59). The 20 and 40 kg N ha^{-1} treatments had significantly higher total nitrogen uptake by vegetative matter than the control after 21 DAE.

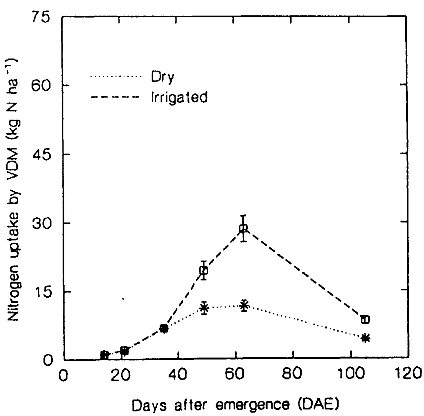
The interaction of genotype * DAE highly significant (P<0.01) for both years indicates that, among genotypes M 35-1 had higher total nitrogen uptake by vegetative matter after 35 DAE in 1990-91, but only at harvest in 1991-92 (Figure 2.60).

Fig : 2.58. **Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of water and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)



The water * nitrogen * DAE interaction significant ($P<0.05$) in 1990-91 (Figure 2.61), indicates that in irrigated plots, the 20, 40 and 120 kg N ha^{-1} treatments had similar total nitrogen uptake by vegetative matter up to 35 DAE, while the 40 and 120 kg N ha^{-1} treatments were similar up to 48 DAE. Thereafter the 120 kg N ha^{-1} treatment had significantly higher nitrogen uptake by vegetative matter up to harvest. In all nitrogen treatments after anthesis total nitrogen uptake by vegetative matter declined to harvest. However in 1991-92 (Figure 2.62), the 120 kg N ha^{-1} treatment had highly significant ($P<0.01$) nitrogen uptake by vegetative matter after 21 DAE in both irrigated and dry plots, when compared to all other nitrogen treatments. The 20 and 40 kg N ha^{-1} treatments had an intermediary value between the 0 and 120 kg N ha^{-1} treatments in irrigated plots, but in dry plots, these values were similar to the control treatment (0 kg N ha^{-1}). Increased total nitrogen uptake by the vegetative matter in the 120 kg N ha^{-1} treatment when compared to the control was 30 kg N ha^{-1} in irrigated plots and 20 kg N ha^{-1} in dry plots.

The interaction of water * genotype * DAE highly significant ($P<0.01$) in 1991-92 indicates that, the improved genotypes (ICSH 86646 and SPV 783), had higher total nitrogen uptake by vegetative matter in the irrigated plots, while M 35-1 had higher total nitrogen uptake in the dry plots (Figure A 2.63), after 35 DAE.

The intearaction of nitrogen * genotype * DAE was significant ($P<0.05$) in 1991-92. In the 0, 20 and 40 kg N ha^{-1} treatments, ICSH 86646 and SPV 783 had higher total nitrogen uptake by vegetative matter than M 35-1 between 35 and 100

DAE , while in the 120 kg N ha^{-1} treatment they had higher total nitrogen uptake only at 63 DAE (Figures A 2.64 and A 2.65). The decline in total nitrogen uptake by vegetative matter after anthesis in the 120 kg N ha^{-1} treatment was greater for ICSH 86646 and SPV 783 than it was for M 35-1.

The interaction of water * nitrogen * genotype * DAE highly significant ($P<0.01$) in 1991-92 indicates that, in irrigated plots (Figures A 2.66 and A 2.67), ICSH 86646 and SPV 783 in the 0, 20, 40 and 120 kg N ha^{-1} treatments had higher total nitrogen uptake by vegetative matter than M 35-1 between 38 DAE and harvest. Declining total nitrogen uptake in vegetative matter was greater in ICSH 86646 and SPV 783 in all the nitrogen treatments, when compared to M 35-1 after anthesis. In dry plots (Figures A 2.68 and A 2.69), the three genotypes had similar total nitrogen uptake by vegetative matter at most crop growth stages in the 0, 20 and 40 kg N ha^{-1} treatments. But in the 120 kg N ha^{-1} treatment M 35-1 had higher total nitrogen uptake by vegetative matter from 35 DAE to harvest, when compared to ICSH 86646 and SPV 783.

4.2.7.2 Measured at harvest :

The main effect of nitrogen and genotype were highly significant ($P<0.01$) in both years, while water was significant ($P<0.05$) only in 1991-92.

Total nitrogen uptake by vegetative matter in irrigated plots was twice that of dry plots in 1991-92. Increase total nitrogen uptake in the 120 kg N ha^{-1} treatment over the control was 15 kg N ha^{-1} in 1990-91, and 6 kg N ha^{-1} in 1991-

Table : 16. Mean total nitrogen uptake by above ground vegetative matter of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total nitrogen uptake by above ground vegetative matter (kg ha^{-1})		
	1990-91	**1991-92**	**Pooled**
Water (W) :			
Irrigated	23.21 A	8.31 A	15.76 A
Dry	14.15 A	4.23 B	9.19 B
LSD (0.05)	13.41	2.36	6.64
Nitrogen (N) :			
0 kg N ha^{-1}	13.53 C	4.12 C	8.82 C
20 kg N ha^{-1}	15.24 BC	5.01 BC	10.12 C
40 kg N ha^{-1}	17.76 B	5.59 B	11.67 B
120 kg N ha^{-1}	28.20 A	10.37 A	19.29 A
LSD (0.05)	3.17	1.34	1.37
Genotypes (G) :			
ICSH 86646	13.86 B	5.99 B	9.93 C
SPV 783	19.35 A	4.82 C	12.09 B
M 35-1	22.84 A	8.01 A	15.42 A
LSD (0.05)	3.70	1.12	1.54
Interactions : SE			
YEAR (Y)	-	-	0.80 **
W * Y	-	-	1.13 *
N * Y	-	-	1.60 *
G * Y	-	-	1.39
W * N * Y	4.31 *	2.08 *	2.27
W * G * Y	3.73	1.80	1.96
N * G * Y	5.28	2.55 **	2.78
W * N * G * Y	7.46	3.60	3.93
CV %	33.71	30.33	42.58

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

92. Among genotypes, M 35-1 had an increase of 9 kg ha^{-1} of nitrogen in vegetative matter in 1990-91 and 2 kg ha^{-1} nitrogen in vegetative matter in 1991-92 over ICSH 86646 (Table 16).

The interaction of water * nitrogen significant ($P<0.05$) in both years indicates that, increases in total nitrogen uptake by vegetative matter due to water was 5, 6, 5 and 20 kg N ha^{-1} in the 0, 20, 40 and 120 kg N ha^{-1} treatments, respectively in 1990-91 (Figure A 2.70), while in 1991-92 it was 2, 3, 3 and 6 kg N ha^{-1} for the respective nitrogen treatments (Figure A 2.71).

The interaction of nitrogen * genotype highly significant ($P<0.01$) in 1991-92 indicates that, ICSH 86646 and M 35-1 had higher total nitrogen uptake by vegetative matter in the 0, 20 and 40 kg N ha^{-1} treatments, but in the 120 kg N ha^{-1} treatment M 35-1 had significantly higher total nitrogen uptake by vegetative matter when compared to ICSH 86646 and SPV 783 (Figures A 2.72 and A 2.73).

4.2.8 Grain nitrogen uptake :

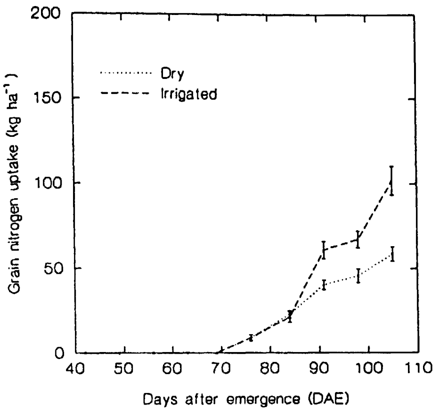
4.2.8.1 Measured at 14, 21, 35, 48, 63 and 105 DAE :

The interactions of water * DAE, nitrogen * DAE, genotype * DAE and water * nitrogen * DAE were highly significant ($P<0.01$) in 1990-91 (Appendix table 14).

Differences in grain nitrogen uptake between in irrigated and dry plots were significant from 84 DAE onwards (Figure 2.74a). The 20, 40 and 120 kg N ha^{-1} treatments had significantly higher grain nitrogen uptake than the control from 70 DAE while the 120 kg N ha^{-1} treatment had significantly higher grain nitrogen

Fig : 2.74. **Total grain nitrogen uptake of sorghum as a function of time for the interaction effect of a) water * time and b) nitrogen * time during rabi 1990-91.**

a) Mean of nitrogen and genotype treatments in 1990-91



b) Mean of water and genotype treatments in 1990-91

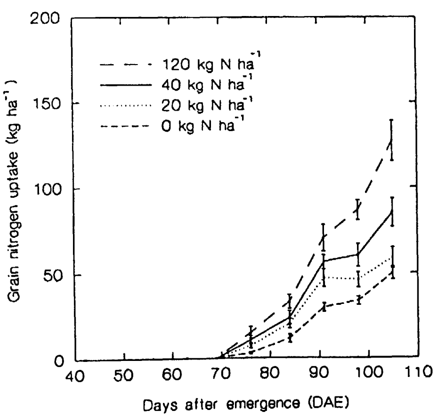


Fig : 2.75. **Total grain nitrogen uptake of sorghum as a function of time for the interaction effect of genotype and time, during rabi 1990-91.**

a) Mean of water and nitrogen treatments in 1990-91

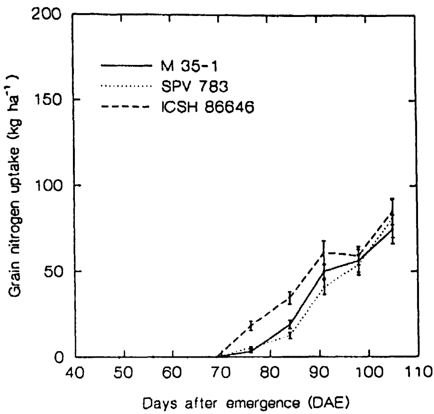
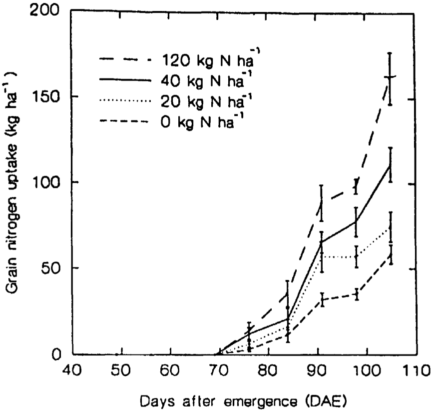
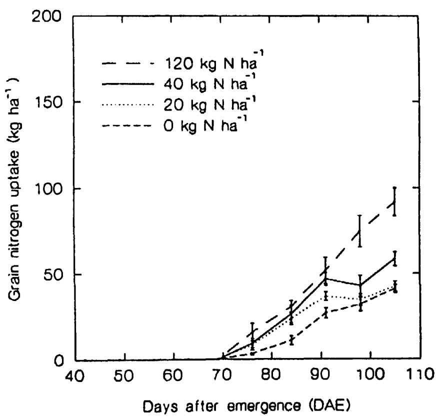


Fig : 2.76. **Total grain nitrogen uptake of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1990-91.**

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)



uptake than all other nitrogen treatments from 84 DAE to harvest (Figure 2.74b). Among genotypes, nitrogen uptake by grain started early in ICSH 86646 and was higher than SPV 783 and M 35-1 up to 91 DAE, but thereafter all three genotypes had similar grain nitrogen uptake till harvest (Figure 2.75).

The interaction of water * nitrogen * DAE significant ($P<0.05$) in 1990-91 indicates that, the 120 kg N ha^{-1} treatment had significantly higher grain nitrogen uptake than all other nitrogen treatments from 84 DAE onwards in the irrigated plots and from 91 DAE onwards in the dry plots (Figure 2.76). In the irrigated plots, the 20, 40 and 120 kg N ha^{-1} treatments and in dry plots the 40 and 120 kg N ha^{-1} treatments had significantly higher grain nitrogen uptake than the control (0 kg N ha^{-1}).

4.2.8.2 Measured at harvest :

Main effects of water had significant ($P<0.05$) and that of nitrogen had highly significant ($P<0.01$) influence on grain nitrogen uptake at harvest, while the genotypes did not differ significantly (Table 17).

The contribution of redistributed nitrogen from vegetative dry matter was 20 kg N ha^{-1} in irrigated plots and 18 kg N ha^{-1} in dry plots (Section 4.2.7.1). Thus the increase in grain nitrogen uptake due to water was 48 kg N ha^{-1} when compared to dry plots. The 120 kg N ha^{-1} treatment had significantly higher grain nitrogen uptake than all the other nitrogen treatments. This increase in grain nitrogen

Table : 17. Mean grain nitrogen content and uptake of sorghum as affected by water, nitrogen and genotype, for the interaction effects, at harvest in 1990-91.

Treatment	1990-91	
	Grain nitrogen content (%)	**Grain nitrogen uptake (kg ha^{-1})**
Water (W) :		
Irrigated	1.55 A	107.73 A
Dry	1.33 A	58.43 B
LSD (0.05)	0.30	19.13
Nitrogen (N) :		
0 kg N ha^{-1}	1.29 B	49.81 C
20 kg N ha^{-1}	1.35 B	58.56 C
40 kg N ha^{-1}	1.39 B	85.01 B
120 kg N ha^{-1}	1.73 A	126.95 A
LSD (0.05)	0.15	24.63
Genotypes (G) :		
ICSH 86646	1.33 B	84.95 A
SPV 783	1.47 A	80.82 A
M 35-1	1.51 A	74.48 A
LSD (0.05)	0.09	13.36
Interactions : SE		
W * N	0.12	20.96
W * G	0.10	18.15
N * G	0.15	25.67
W * N * G	0.21	36.30

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

uptake was 77, 68 and 42 kg N ha^{-1} over the 0, 20 and 40 kg N ha^{-1} treatments respectively. Interaction effects were not significant.

4.3.1 Leaf potassium content :

4.3.1.1 Measured at harvest :

The main effect of nitrogen was significant (P<0.05) in 1990-91 and highly significant (P<0.01) in 1991-92, the genotype effect was highly significant (P<0.01) in 1990-91 and the nitrogen * genotype interaction was significant (P<0.05) in 1990-91 (Table 18).

The 120 kg N ha^{-1} treatment had significantly higher leaf potassium content when compared to other nitrogen treatments in 1990-91 and higher than the 0 and 20 kg N ha^{-1} treatments in 1991-92. Among genotypes, M 35-1 had significantly higher leaf potassium content than ICSH 86646 and SPV 783 in 1990-91.

The interaction of nitrogen * genotype in 1990-91 (Figures A 3.3 and A 3.4), indicates that, in all nitrogen treatments M 35-1 and SPV 783 had a significantly higher leaf potassium content than ICSH 86646 at harvest.

4.3.2 Stem potassium content :

4.3.2.1 Measured at harvest :

The main effect of water was significant (P<0.05) in 1991-92. Irrigated plots had significantly higher stem potassium content than dry plots (Table 20). The main effect of nitrogen significant (P<0.05) in both years indicates that, the 120 kg

N ha^{-1} treatment had significantly higher stem potassium content than the 20 kg N ha^{-1} treatments in 1990-91 and was higher than the 0 and 20 kg N ha^{-1} treatments in 1991-92. The genotype effect was highly significant ($P<0.01$) in both years. ICSH 86646 had significantly higher stem potassium content than SPV 783 and M 35-1 in 1990-91, while in 1991-92 it was significantly higher than M 35-1.

The interaction of water * nitrogen significant ($P<0.05$) in 1991-92 indicates that, in irrigated plots, the 120 kg N ha^{-1} treatment had significantly higher stem potassium content than the 0 or 20 kg N ha^{-1} treatments. In dry plots all the nitrogen treatments were similar in stem potassium content (Figure A 3.1).

The interaction of water * genotype significant ($P<0.05$) in 1991-92 indicates that, both ICSH 86646 and SPV 783 had significantly higher stem potassium content than M 35-1 in both irrigated and dry plots (Figure A 3.2).

4.3.3 Grain potassium content :

4.3.3.1 Measured at harvest :

The main effect of genotype was highly significant ($P<0.01$) in 1991-92 (Table 24). The varieties SPV 783 and M 35-1 had a significantly higher grain potassium content than the hybrid ICSH 86646 at harvest.

4.3.4 Total potassium uptake by above ground biomass :

4.3.4.1 Measured at harvest :

Nitrogen had a highly significant ($P<0.01$) influence on total potassium uptake by above ground biomass. The 120 kg N ha^{-1} treatment significantly increased total potassium uptake by above ground biomass in both years (Table 20). The increase in potassium uptake pooled over water and genotype treatments was 70 kg K ha^{-1} in 1990-91 and 58 kg K ha^{-1} in 1991-92.

The main effect of genotype highly significant ($P<0.01$) in both years indicates that, among genotypes, SPV 783 and M 35-1 had significantly higher total potassium uptake than ICSH 86646 in 1990-91. While in 1991-92 ICSH 86646 had significantly higher total potassium uptake than SPV 783 and M 35-1. These differences in the years can be explained from the nitrogen uptake pattern, wherein higher nitrogen uptake by ICSH 86646 and M 35-1 in 1991-92 resulted in associated higher potassium uptake by these genotypes.

The interaction of water * genotype highly significant ($P<0.01$) in 1991-92 indicates that, ICSH 86646 had significantly higher potassium uptake in irrigated plots, while M 35-1 had higher potassium uptake in dry plots (Figure 3.5). The increase in potassium uptake due to irrigation was 20, 40 and 60 kg K ha^{-1} for M 35-1, SPV 783 and ICSH 86646 respectively.

ICSH 86646 had significantly ($P<0.05$) higher potassium uptake at the lower N rates of 0, 20 and 40 kg N ha^{-1}, while M 35-1 had significantly ($P<0.05$) higher

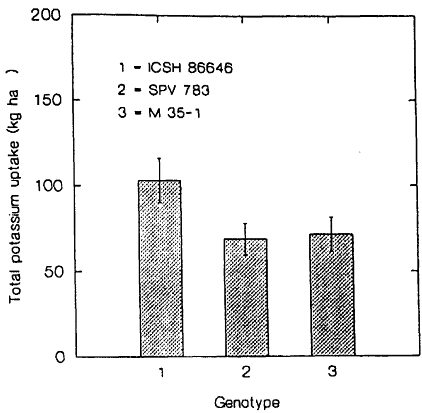
Table : 20. Mean total potassium uptake by above ground biomass of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total potassium uptake (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	136.62 A	81.21 A	108.92 A
Dry	94.22 A	42.55 A	68.38 B
LSD (0.05)	52.90	47.57	46.77
Nitrogen (N) :			
0 kg N ha^{-1}	89.90 B	38.54 C	64.22 C
20 kg N ha^{-1}	93.81 B	49.36 BC	71.58 C
40 kg N ha^{-1}	120.54 B	63.04 B	91.79 B
120 kg N ha^{-1}	157.43 A	96.59 A	127.01 A
LSD (0.05)	32.15	18.33	15.16
Genotypes (G) :			
ICSH 86646	97.01 B	72.44 A	84.72 B
SPV 783	124.49 A	51.83 C	88.16 AB
M 35-1	124.76 A	61.67 B	93.07 A
LSD (0.05)	13.28	7.70	7.84
Interactions : SE			
YEAR (Y)	-	-	4.83 **
W * Y	-	-	6.83
N * Y	-	-	9.66
G * Y	-	-	8.37 **
W * N * Y	18.06	29.77	13.66
W * G * Y	15.64	25.78 **	11.83 *
N * G * Y	22.11	36.46 *	16.73
W * N * G * Y	31.27	51.56 *	23.67
CV %	19.57	21.16	29.77

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Fig : 3.5. **Total potassium uptake by above ground biomass of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.**

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

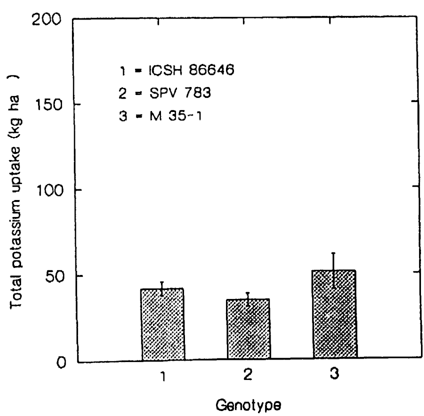


Fig : 3.6. **Total potassium uptake by above ground biomass of sorghum for the interaction effect of nitrogen and genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest during rabi 1991-92.**

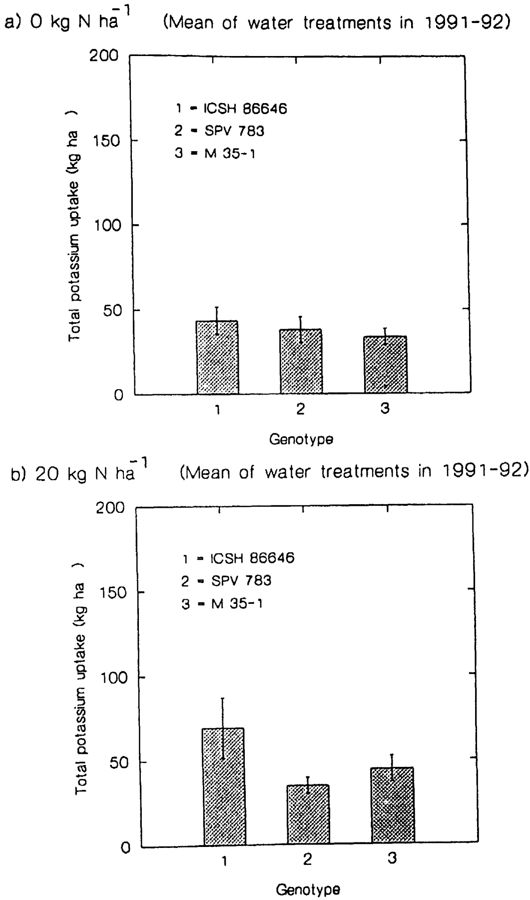
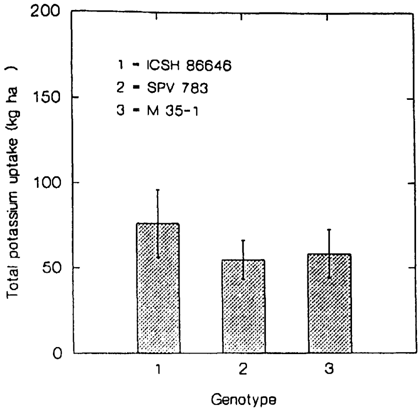


Fig : 3.7. **Total potassium uptake by above ground biomass of sorghum for the interaction effect of nitrogen and genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest during rabi 1991-92.**

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

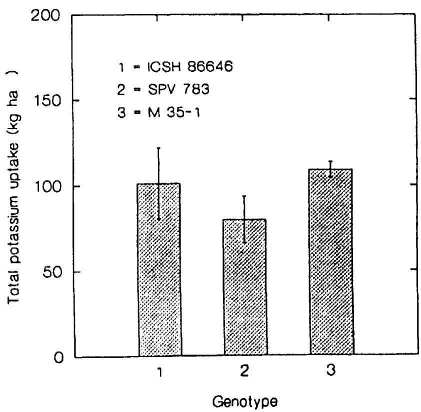
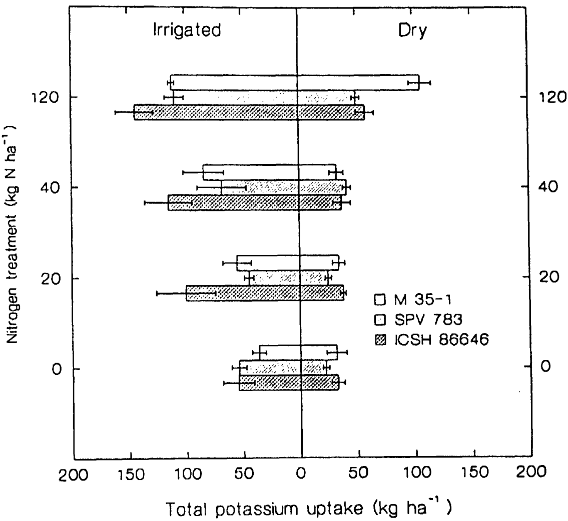


Fig : 3.8. **Total potassium uptake by above ground biomass of sorghum for the interaction effect of water, nitrogen and genotype, in irrigated and dry plots at harvest during rabi 1991-92.**



total potassium uptake in the 120 kg N ha^{-1} treatment in 1991-92 (Figure 3.6 and 3.7).

The interaction of water * nitrogen * genotype significant (P<0.05) in 1991-92 indicates that in irrigated plots, ICSH 86646 had higher total potassium uptake than SPV 783 and M 35-1 for all nitrogen treatments. In dry plots at the lower nitrogen treatment levels (0, 20 and 40 kg N ha^{-1}), differences in total potassium uptake between genotypes were not significant, but with the 120 kg N ha^{-1} treatment, M 35-1 had higher potassium uptake than ICSH 86646 or SPV 783 (Figure 3.8).

4.3.5 Leaf potassium uptake :

4.3.5.1 Measured at harvest :

The main effects of nitrogen and genotype were highly significant (P<0.01) in both years, while the interaction water * genotype was significant (P<0.05) for both years, that of nitrogen * genotype and water * nitrogen * genotype were significant (P<0.05) only in 1991-92 (Table 21).

In both years, the 120 Kg N ha^{-1} treatment had significantly higher leaf potassium uptake than all other nitrogen treatments while among genotypes, in 1990-91, SPV 783 had significantly higher leaf potassium uptake, and in 1991-92 both ICSH 86646 and M 35-1 had significantly higher leaf potassium uptake.

The interaction of water * genotype in 1990-91 (Figure A 3.9), indicates that in irrigated plots, both SPV 783 and M 35-1 had significantly higher leaf potassium

Table : 21. Mean total leaf potassium uptake of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total leaf potassium uptake (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	17.59 A	10.44 A	14.01 A
Dry	13.95 A	8.20 A	11.08 A
LSD (0.05)	10.06	5.62	6.72
Nitrogen (N) :			
0 kg N ha^{-1}	13.00 B	6.14 C	9.57 C
20 kg N ha^{-1}	14.32 B	7.40 C	10.86 C
40 kg N ha^{-1}	15.39 B	9.71 B	12.55 B
120 kg N ha^{-1}	20.37 A	14.02 A	17.20 A
LSD (0.05)	3.42	1.94	1.53
Genotypes (G) :			
ICSH 86646	10.67 C	9.62 A	10.15 B
SPV 783	19.28 A	8.22 B	13.75 A
M 35-1	17.36 B	10.12 A	13.74 A
LSD (0.05)	1.76	1.20	1.04
Interactions : SE			
YEAR (Y)	-	-	1.10 **
W * Y	-	-	1.56
N * Y	-	-	2.20
V * Y	-	-	1.91 **
W * N * Y	2.23	4.33	3.12
W * G * Y	1.94 *	3.75 *	2.70 *
N * G * Y	2.74	5.30 *	3.82
W * N * G * Y	3.87	7.49 *	5.40
CV %	19.00	21.92	27.87

= Significant at p = <0.05 and 0.01 % level, respectively.

uptake than ICSH 86646, however, in dry plots, only SPV 783 had significantly higher leaf potassium uptake than ICSH 86646 or M 35-1. In 1991-92, ICSH 86646 in irrigated plots and M 35-1 in dry plots had significantly higher leaf potassium uptake (Figure A 3.10).

The interaction of nitrogen * genotype in 1991-92 (Figures A 3.11 and A 3.12), indicates that at the three lower nitrogen rates (0, 20 and 40 Kg N ha^{-1}) all three genotypes had similar leaf potassium uptake, however, at the 120 Kg N ha^{-1} treatment, M 35-1 had significantly higher leaf potassium uptake than ICSH 86646 and SPV 783.

The interaction of water * nitrogen * genotype (Figures A 3.13, A 3.14, A 3.15 and A 3.16), did not indicate any definite trend among genotypes in irrigated plots, in nitrogen treatments, but in dry plots, except the 40 Kg N ha^{-1} treatment, M 35-1 had higher leaf potassium uptake when compared to the other nitrogen treatments.

4.3.6. Stem potassium uptake :

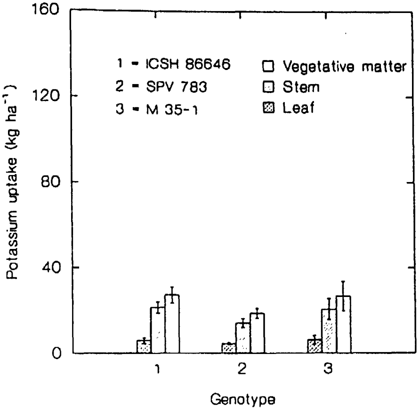
4.3.6.1 Measured at harvest :

At harvest the main effects of nitrogen and genotype had a highly significant ($P<0.01$) influence on stem potassium uptake in both years. All the interactions were significant ($P<0.05$) in 1991-92 (Table 22).

The 120 Kg N ha^{-1} treatment had significantly higher stem potassium uptake in both years. The varieties SPV 783 and M 35-1, had a significantly higher stem

Fig : 3.15. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of water, nitrogen and genotype, in a) 0 kg N ha^{-1} and b)20 kg N ha^{-1} treatments in dry plots at harvest during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

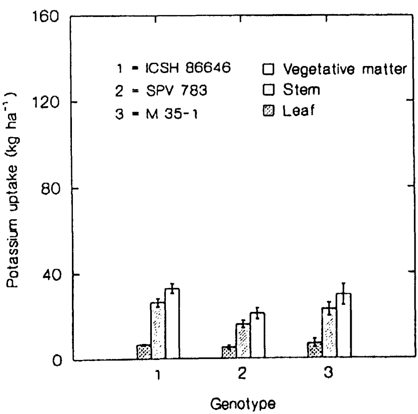
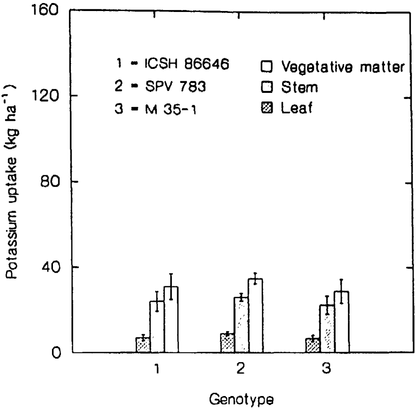


Fig : 3.16. **Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of water, nitrogen and genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments in dry plots at harvest during rabi 1991-92.**

c) 40 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

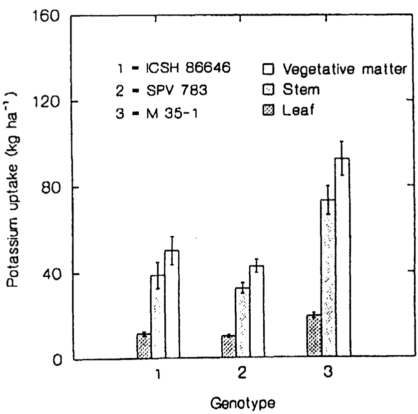


Table : 22. Mean total stem potassium uptake of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total stem potassium uptake (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	94.51 A	57.77 A	76.14 A
Dry	64.92 A	28.09 A	46.51 A
LSD (0.05)	32.31	33.67	31.47
Nitrogen (N) :			
0 kg N ha^{-1}	61.21 B	26.39 C	43.80 C
20 kg N ha^{-1}	63.04 B	33.58 BC	48.31 C
40 kg N ha^{-1}	83.53 B	44.02 B	63.77 B
120 kg N ha^{-1}	111.08 A	67.74 A	89.41 A
LSD (0.05)	25.22	13.53	12.41
Genotypes (G) :			
ICSH 86646	67.42 B	51.74 A	59.58 B
SPV 783	83.37 A	34.43 B	58.90 B
M 35-1	88.36 A	42.62 C	65.49 A
LSD (0.05)	9.91	5.18	5.83
Interactions : SE			
YEAR (Y)	-	-	4.15 **
W * Y	-	-	5.87
N * Y	-	-	8.31
V * Y	-	-	7.19 **
W * N * Y	20.27	21.19 *	11.75
W * G * Y	17.55	18.35 **	10.17 *
N * G * Y	24.82	25.96 *	14.39
W * N * G * Y	35.10	36.71 *	20.35
CV %	21.13	20.53	31.44

= Significant at p = <0.05 and 0.01 % level, respectively.

potassium uptake in 1990-91, while ICSH 86646 had a significantly higher value in 1991-92.

The interaction effect of water * genotype in 1991-92 (Figure A 3.10), indicates that in irrigated plots, ICSH 86646 had significantly higher stem potassium uptake when compared to SPV 783 or M 35-1, but in dry plots, ICSH 86646 and M 35-1 had higher stem potassium uptake when compared to SPV 783.

The interaction of nitrogen * genotype at harvest in 1991-92 (Figures A 3.11 and A 3.12), indicates that at lower nitrogen rates (0, 20 and 40 Kg N ha^{-1}), ICSH 86646 had higher stalk potassium uptake when compared to the other genotypes. However for the 120 kg N ha^{-1} treatment, both ICSH 86646 and M 35-1 had higher stem potassium uptake than SPV 783.

The interaction of water * nitrogen * genotype (Figures A 3.13, A 3.14, A 3.15 and A 3.16), indicates that in irrigated plots, at all nitrogen treatments, ICSH 86646 had significantly higher stalk potassium uptake. In dry plots, the 120 Kg N ha^{-1} treatment and M 35-1 had significantly higher stem potassium uptake than other treatment combinations.

4.3.7 Potassium uptake by vegetative dry matter :

4.3.7.1 Measured at harvest :

Since stem potassium uptake was the main contributor to total potassium uptake by above-ground vegetative dry matter at harvest, influence of the main effects of water, nitrogen and genotype and their interaction on this variable (Table

Table : 23. Mean total potassium uptake by vegetative matter of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Total potassium uptake by above ground vegetative matter (kg ha^{-1})		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	112.10 A	68.21 A	90.15 A
Dry	78.87 A	36.30 A	57.58 A
LSD (0.05)	41.17	39.29	37.54
Nitrogen (N) :			
0 kg N ha^{-1}	74.22 B	32.53 C	53.38 C
20 kg N ha^{-1}	77.37 B	40.98 BC	59.17 C
40 kg N ha^{-1}	98.91 B	53.73 B	76.32 B
120 kg N ha^{-1}	131.46 A	81.76 A	106.61 A
LSD (0.05)	27.54	15.32	13.36
Genotypes (G) :			
ICSH 86646	78.09 B	61.36 A	69.73 B
SPV 783	102.65 A	42.65 C	72.65 B
M 35-1	105.72 A	52.74 B	79.23 A
LSD (0.05)	11.05	6.07	6.56
Interactions : SE			
YEAR (Y)	-	-	4.36 **
W * Y	-	-	6.17
N * Y	-	-	8.72
V * Y	-	-	7.55 **
W * N * Y	20.23	24.43 *	12.33
W * G * Y	17.52	21.16 **	10.68 *
N * G * Y	24.77	29.93 *	15.11
W * N * G * Y	35.04	42.32 *	21.36
CV %	19.69	19.76	29.57

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Table : 24. Mean grain potassium content and uptake of sorghum as affected by water, nitrogen and genotype, at harvest in 1990-91 season.

Treatment	1990-91	
	Grain potassium content (%)	Grain potassium uptake (kg ha^{-1})
Water (W) :		
Irrigated	0.40 A	24.52 A
Dry	0.36 A	16.07 A
LSD (0.05)	0.05	9.99
Nitrogen (N) :		
0 kg N ha^{-1}	0.41 A	15.69 B
20 kg N ha^{-1}	0.38 A	16.44 B
40 kg N ha^{-1}	0.36 A	21.79 AB
120 kg N ha^{-1}	0.38 A	27.26 A
LSD (0.05)	0.07	6.50
Genotypes (G) :		
ICSH 86646	0.32 B	19.88 A
SPV 783	0.43 A	21.84 A
M 35-1	0.40 A	19.17 A
LSD (0.05)	0.05	4.36
Interactions : SE		
W * N	0.12	9.59
W * G	0.11	8.30
N * G	0.15	11.74
W * N * G	0.21	16.61

= Significant at p = <0.05 and 0.01 % level, respectively.

23 and Figures A 3.10 to A 3.16), were similar to those on stem potassium uptake as indicated in section 4.3.6.

4.3.8 Grain potassium uptake :

4.3.8.1 Measured at harvest :

Main effect of nitrogen had a highly significant ($P<0.01$) influence on grain potassium uptake (Table 24). The 120 kg N ha^{-1} treatment, had significantly higher grain potassium uptake when compared to the control, while the 0, 20 and 40 kg N ha^{-1} treatments were similar.

4.4.1 Soil ammonical nitrogen in the 120 cm soil profile :

4.4.1.1 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at sowing :

Total soil ammonical N was measured up to a 120 cm depth only in fallow plots after nitrogen application and irrigation at sowing. The interaction of water * soil depth was significant ($P<0.05$) only in 1991-92 (Appendix table 16). It indicates that ammonical N at sowing (Figure A 4.1a), was higher in irrigated plots when compared to dry plots, at all soil layers except the 30-45 cm layer. These differences were attributed to native soil nitrogen levels because the conditions at sowing in irrigated and dry plots were the same.

The interaction of nitrogen * soil depth was highly significant ($P<0.01$) in both years. In 1990-91 (Figure A 4.2a), ammonical N was highest in the upper layer of soil profile (60 ppm), in the 120 kg N ha^{-1} treatment, while the other nitrogen treatments were less than 15 ppm in all profile layers. In 1991-92 (Figure A 4.3a), in the 120 kg N ha^{-1} treatment, soil ammonical N was 32 ppm in the 0-15 cm profile layer, while below 30 cm all nitrogen treatments had less than 15 ppm. These results indicate that nearly all applied nitrogen was found in the top 30 cm of the soil profile at sowing.

The interaction of water * nitrogen * soil depth significant ($P<0.05$) only in 1991-92 (Figures A 4.4a and A 4.5a), indicates that, in irrigated plots, the 0, 20 and 40 Kg N ha^{-1} treatments had less than 15 ppm in all soil layers at sowing. The 120 kg N ha^{-1} treatment had the highest ammonical N (35 ppm) at sowing. In dry plots, the 20 and 40 kg N ha^{-1} treatments similar NH_4-N (8 ppm) values in the 0-15 cm soil layer, while the 120 kg N ha^{-1} treatment was the highest at 24 ppm and the control treatment lowest at 3 ppm. Below 60 cm all nitrogen treatments had similar ammonical N at sowing.

<u>4.4.1.2 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at anthesis:</u>

The interaction of water * soil depth was significant ($P<0.05$) in 1991-92 (Appendix table 17). It indicates that the dry plots had significantly higher ammonical N at anthesis stage in the top 0-15 cm of the soil profile when compared to irrigated plots. However, below 30 cm, it was similar in both treatments (Figure A 4.7a). The conversion of ammonical to nitrate N was reduced in dry plots due to limited moisture, as the top soil layers dried faster than the lower layers.

Interaction of nitrogen * soil depth significant ($P<0.05$) in 1990-91 indicates that, among all nitrogen treatments in 1991-92, the 120 kg N ha^{-1} treatment had the highest ammonical N in the top 0-15 cm soil layer (Figure A 4.9a). Below the 30 cm depth, all nitrogen treatments had similar ammonical N.

Interaction of genotype * soil depth significant ($P<0.05$) in 1991-92 indicates that, ammonical N in the 0-15 cm depth of fallow plots was higher than in plots containing plants in 1991-92 (Figure A 4.11a), differences between cultivar treatments being 8 ppm. Below a 30 cm soil depth, ammonical N was similar in all treatments indicating non-mobility of ammonical N in the soil.

The interaction of water * genotype * soil depth significant in 1991-92 (P<).05) indicates that, in irrigated plots, (Figure A 4.16a) all genotypes and the fallow plots had similar ammonical N in the soil profile at anthesis. While in dry plots (Figure A 4.17a), the fallow treatment had a higher ammonical N level than cropped plots in the top 0-15 cm soil layer. Below 30 cm, ammonical N was similar for all treatments indicating the low mobility of ammonical N in soil.

At anthesis, major differences in ammonical N occurred across years. In 1990-91 in all treatments, ammonical N declined from sowing to anthesis indicating a faster conversion of ammonical N to nitrate N, while in 1991-92 the nitrification process was slower.

4.4.1.3 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at harvest :

The interaction of water * depth significant ($P<0.05$) in both years (Appendix table 18) indicates that, total ammonical N in dry plots (Figures A 4.18 and A 4.19) was significantly higher than in irrigated plots in the 0-15 cm profile layer. Below 30 cm, treatments did not differ significantly indicating a uniform availability of native nitrogen below that layer.

The interaction of nitrogen * soil depth significant ($P<0.05$) in both years indicates that, among nitrogen treatments, the 120 kg N ha^{-1} treatment had higher ammonical N in the 0-15 cm profile layer at harvest in both years (Figures A 4.20 and A 4.21). Below 30 cm these differences were not significant. This indicates that applied N remained in the upper soil profile and that the conversion of ammonical N to nitrate N was not complete at harvest. Most of the applied nitrogen in the form of ammonical N was still available in the top soil layers even at harvest.

Interaction of water * nitrogen * soil depth significant ($P<0.05$) in 1991-92, indicates that ammonical N in all nitrogen treatments in irrigated plots (Figure A 4.24a), were not significantly different through out the soil profile, while in dry plots (Figure A 4.25a), the 120 kg N ha^{-1} treatment had significantly higher ammonical N in the 0-15 cm and 15-30 cm profile layers. Below 30 cm values were similar for all nitrogen treatments. Transformation of ammonical N to nitrate N resulted in lower residual ammonical N in irrigated plots. In dry plots, ammonical N remained untransformed or unutilized by the crop due to limited soil moisture.

4.4.2 Soil nitrate nitrogen in the 120 cm soil profile :

4.4.2.1 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at sowing :

The interaction of water * soil depth in 1991-92 highly significant ($P<0.01$) in 1991-92 (Appendix table 20), indicates that, at all depths of soil profile, nitrate N was significantly higher in irrigated plots when compared to dry plots at sowing (Figure A 4.1b).

The interaction of nitrogen * soil depth was highly significant ($P<0.01$) in both years. Among nitrogen treatments, 20, 40 and 120 kg N ha^{-1} treatments had significantly higher nitrate N when compared to the control treatment, in the top 0-30 cm layer in 1990-91 (Figure A 4.2b), at sowing.In 1991-92 (Figure A 4.3b), only the 40 and 120 kg N ha^{-1} treatments had significantly higher nitrate N than the 0 and 20 kg N ha^{-1} treatments in the 0-15 cm layer. Soil nitrate N in 1991-92 was lower than in 1990-91, indicating slower conversion of ammonical N to nitrate N. Below 30 cm there were no differences among nitrogen treatments.

The interaction of water * nitrogen * soil depth highly significant ($P<0.010$) in 1991-92, indicates that significantly higher nitrate N was present in both the 20 and 120 kg N ha^{-1} treatments in the top 0-15 cm layer in irrigated plots at sowing (Figure A 4.4b). Below 30 cm, all the nitrogen treatments had similar nitrate N levels. In dry plots (Figure A 4.5b), the 20 and 120 kg N ha^{-1} had significantly higher soil nitrate N in the 0-15 cm profile. Low nitrate nitrogen below 30 cm in all the nitrogen treatments, indicating that the applied nitrogen remained in the top 0-30 cm of the profile at sowing.

4.4.2.2 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at anthesis:

The interaction of water * soil depth was highly signficant (P<0.01) in both years (Appendix table 21). It indicates that the dry plots had higher nitrate N than irrigated plots in the top 0-30 cm soil layer in 1990-91 (Figure A 4.6b). Below 30 cm, all treatments were similar. In 1991-92 (Figure A 4.7b), the trend was similar except that below the 30 cm soil depth, irrigated plots had significantly higher nitrate N than dry plots. Movement of nitrate N down the profile in irrigated plots resulted in higher values in these layers in the soil profile.

The interaction of nitrogen * soil depth highly significant (P<0.01) in both years indicates that, among nitrogen treatments (Figure A 4.8b and A 4.9b), the 120 kg N ha^{-1} treatment had significantly higher nitrate N than other N treatments in the 0-45 cm profile. Below this layer all treatments were similar. The lower nitrogen treatments of 20 and 40 kg N ha^{-1} were similar and had significantly higher nitrate N than the control in the 0-15 cm profile.

The interaction of genotype * soil depth was highly significant (P<0.01) in 1990-91 and significant (P<0.05) in 1991-92. In 1990-91, fallow plots had significantly higher nitrate N at the 0-60 cm soil depth (Figure A 4.10b), while all plots containing plants were not significantly different inidcating similar plant uptake pattern in all genotypes (Table 13). In 1991-92 (Figure A 4.11b), fallow plots had higher nitrate N values than all genotypes down to a 45 cmd soil depth but differences between treatments were not significant below this layer.

The interaction of water * nitrogen * soil depth highly significant ($P<0.01$) in 1990-91 and significant ($P<0.05$) in 1991-92. In 1990-91, in irrigated plots, in the top 0-30 cm soil profile, the 20 and 40 kg N ha^{-1} treatments were similar (Figure A 4.12b). In dry plots, the 20 and 40 kg N ha^{-1} treatments were similar and had significantly higher nitrate N values than the control (Figure A 4.13b). The 120 kg N ha^{-1} treatment had significantly higher nitrate N value than all the other treatments in both irrigated and dry plots.

In 1991-92 in irrigated plots (Figure A 4.14b), the 120 kg N ha^{-1} treatment had significantly higher nitrate N values than all the other nitrogen treatments in the 0-90 cm profile. In dry plots (Figure A 4.15b), the 120 kg N ha^{-1} treatment had significantly higher nitrate N than all other nitrogen treatments in the 0-45 cm soil profile. The 20 and 40 kg N ha^{-1} treatments had significantly higher nitrate N than the control in the top 0-30 cm soil profile. These results indicate a lower uptake of nitrate N by plants in dry plots in both years.

4.4.2.3 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at harvest :

The interaction of water * soil depth was highly significant ($P<0.01$) in both years (Appendix table 22). The interaction indicates that, dry plots had significantly higher nitrate N values in the top 0-30 cm profile, however below 30 cm these differences were not significant at harvest (Figures A 4.18b and A 4.19b). High nitrate N indicates low plant uptake, while low nitrate N in irrigated plots indicates two possibilities i) higher plant uptake and or ii) higher N losses. The differences between these treatments was 20 ppm in 1990-91 and 22 ppm in 1991-92.

The interaction of nitrogen * soil depth highly significant ($P<0.01$) in both years indicantes that, among nitrogen treatments, the 120 kg N ha^{-1} treatment had significantly higher nitrate N in the 0-60 cm profile in 1990-91 (Figure A 4.20b), and was higher in the 0-45 cm profile in 1991-92 (Figure A 4.21b). The 40 kg N ha^{-1} treatment was significantly higher than the 0 and 20 kg N ha^{-1} treatments in 1990-91, but in 1991-92 both the 20 and 40 kg N ha^{-1} treatments were significantly higher than the control. Below 60 cm all treatments were similar indicating lesser movement of nitrate N down the soil profile.

The interaction of water * nitrogen * soil depth highly significant ($P<0.01$) was similar in both years (Figures A 4.22, A 4.23, A 4.24 and A 4.25), with irrigated plots having lower nitrate N than dry plots. As indicated earlier, lower nitrate N in irrigated plots was a result of higher plant uptake and/or higher leaching losses. While in dry plots, the 120 kg N ha^{-1} treatment had significantly higher nitrate N than all other nitrogen treatments in the 0-45 cm profile in both the years. Below the 60 cm soil depth, all the treatments were similar in irrigated and dry plots.

The interaction of water * genotype * soil depth highly significant ($P<0.01$) in 1991-92 (Figures A 4.26b and A 4.27b), indicates that in irrigated plots, only the fallow plots had significantly higher nitrate nitrogen in the 0-30 cm profile, below this all treatments were similar. In dry plots, all treatments were similar in the 0-30 cm soil profile, indicating very low nitrate N uptake.

4.4.3 Total soil available nitrogen (NH_4 + NO_3) in the 120 cm profile :

4.4.3.1 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at sowing :

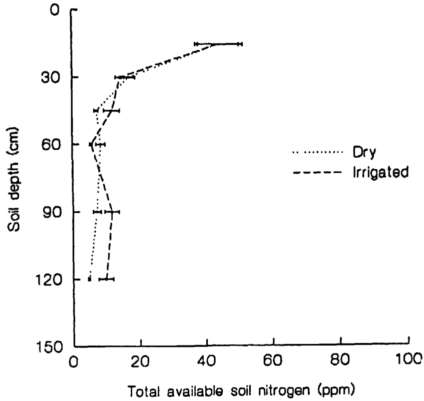
The interaction of water * soil depth was highly significant (P<0.01) in 1991-92 (Appendix table 24). At sowing, total available N in 1990-91 (Figure 4.28a), was similar in irrigated and dry plots in the top 0-30 cm soil profile, while at 45, 90 and 120 cm depths it was significantly higher in irrigated plots. But in 1991-92 (Figure 4.28b), the total available N was significantly lower in dry plots in the 0-45 cm soil profile. Lower total available N in both irrigated and dry plots in 1991-92 as compared to 1990-91 in the top soil profile was a temporary phenomenon.

The interaction of nitrogen * soil depth highly significant (P<0.01) in both years indicates that, the 120 kg N ha^{-1} treatment had significantly higher total available N in the top 0-30 cm soil layer in both years (Figures 4.29a and 4.29b). The major zone of availability was the 0-30 cm soil layer in all nitrogen treatments for both years. Total available N was higher in 1990-91 (Figure 4.29a), than in 1991-92 (Figure 4.29b), for all nitrogen treatments.

The interaction of water * nitrogen * soil depth significant (P<0.05) in both years indicates that, in both years, total available N in irrigated plots was higher in the 0-45 cm profile for all nitrogen treatments. In both years, significantly higher total available N was present in the 120 kg N ha^{-1} treatment (Figures 4.30 and

Fig : 4.28. **Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of water and depth, at sowing during rabi a) 1990-91 and b) 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments at sowing)



b) 1991-92 (Mean of nitrogen and genotype treatments at sowing)

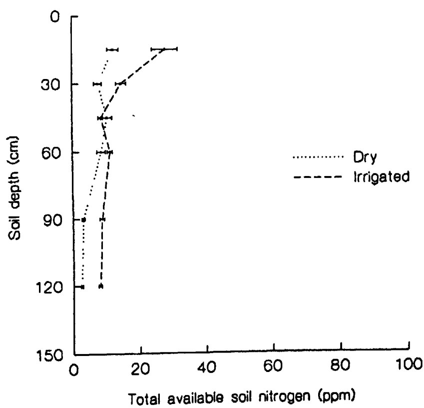
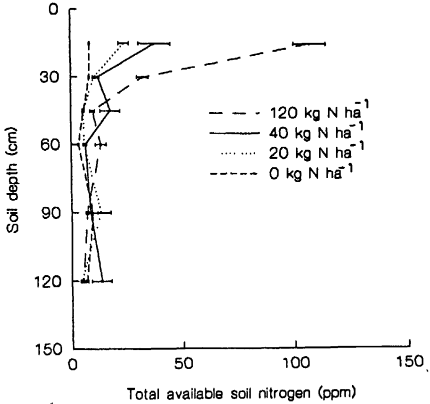


Fig : 4.29. **Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of nitrogen and depth, at sowing during rabi a) 1990-91 and b) 1991-92.**

a) 1990-91 (Mean of water and genotype treatments at sowing)



b) 1991-92 (Mean of water and genotype treatments at sowing)

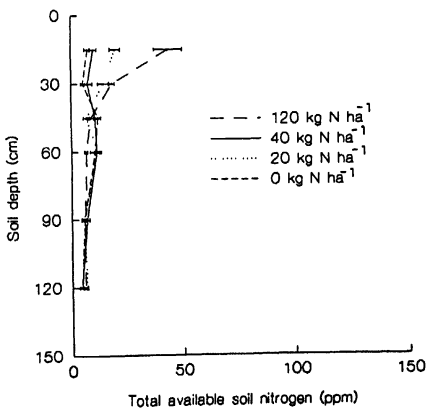
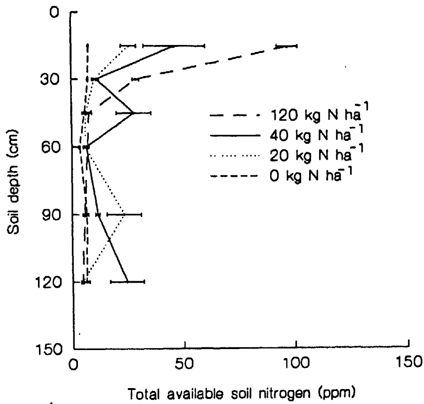
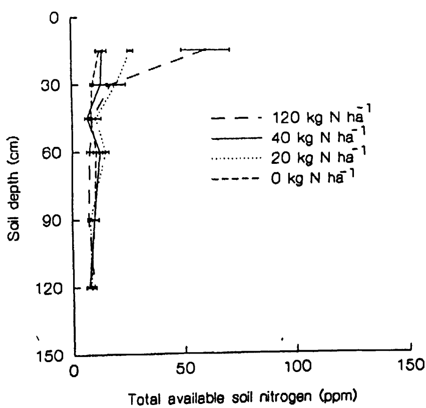


Fig : 4.30. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in irrigated plots for the interaction effect of water, nitrogen and depth, at sowing during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of genotypes in irrigated plots at sowing)



b) 1991-92 (Mean of genotypes in irrigated plots at sowing)



4.31). In 1990-91, the 20 and 40 kg N ha^{-1} had treatments had significantly higher total available N than the control, in 1991-92 only the 20 kg N ha^{-1} had significantly higher total available N than the control in the 0-30 cm soil layer. This trend was similar in dry plots at sowing (Figure 4.31a and 4.31b). The primary difference between years was the low total available N for dry plots in 1991-92 (Figure 4.31b).

<u>4.4.3.2 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at anthesis:</u>

The interaction of water * soil depth was highly significant ($P<0.01$) in both years (Appendix table 25). This interaction (Figure 4.32), indicates that in both years, total available N was significantly higher in dry plots in the top 0-30 cm soil profile. Below 30 cm, the irrigated plots had higher total available N. In dry plots, applied nitrogen remained in the top soil layers indicating lower movement and lower plant uptake in both years.

The interaction of nitrogen * soil depth was highly significant ($P<0.01$) in both years. The 120 kg N ha^{-1} treatment among all nitrogen treatments (Figure 4.33), had significantly higher total available N than the control in the 0-60 cm soil profile. Total available N was higher in all nitrogen treatments in 1991-92 (Figure 4.33a), than in 1990-91 (Figure 4.33b) at anthesis stage indicating higher plant uptake in 1990-91. The 0 kg N ha^{-1} treatment in 1990-91, had less than 5 ppm at all the soil depths, while in 1991-92 it had more than 10 ppm.

Fig : 4.31. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in dry plots for the interaction effect of water, nitrogen and depth, at sowing during rabi a) 1990-91 and b) 1991-92.**

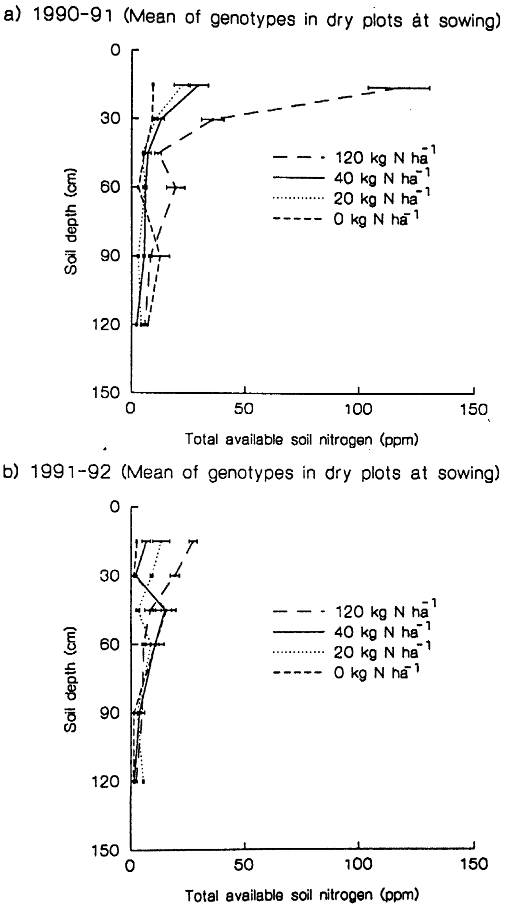
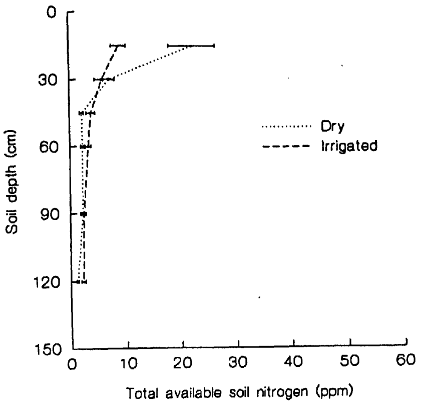


Fig : 4.32. **Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of water and depth, at anthesis during rabi a) 1990-91 and b) 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments at anthesis)



b) 1991-92 (Mean of nitrogen and genotype treatments at anthesis)

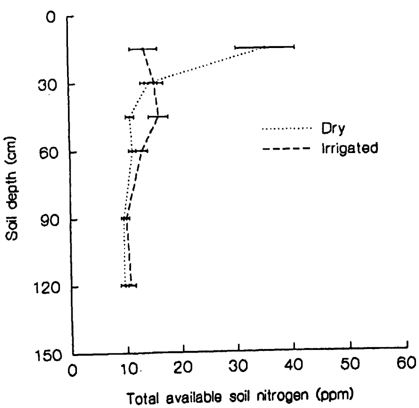
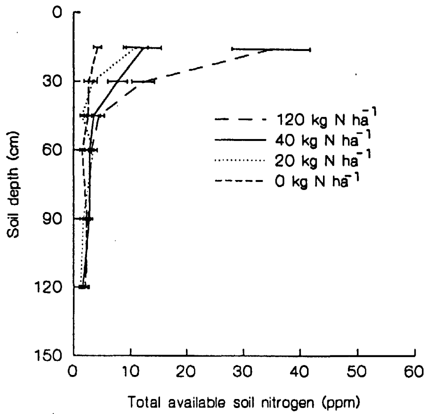
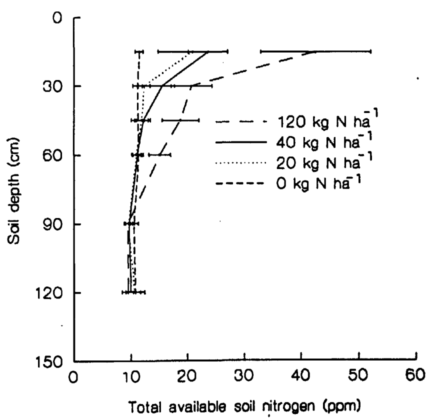


Fig : 4.33. **Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of nitrogen and depth, at anthesis during rabi a) 1990-91 and b) 1991-92.**

a) 1990-91 (Mean of water and genotype treatments at anthesis)



b) 1991-92 (Mean of water and genotype treatments at anthesis)



The interaction of genotype * soil depth was highly significant ($P<0.01$) in 1990-91 and signifcant ($P<0.05$) in 1991-92. Fallow plots had higher total available N at anthesis than plots containing plants in both years in the 0-60 cm soil profile. Among genotypes differences were not distinct and there was no definite trend in either year (Figure 4.34).

The interaction water * nitrogen * soil depth highly significant ($P<0.01$) in 1990-91 and significant ($P<0.05$) in 1991-92 indicates, that in irrigated and dry plots the 120 kg N ha^{-1} treatment had significantly higher total available N than the control in both years. At anthesis, total available N was higher in all nitrogen treatments in dry plots (Figure 4.36) when compared to irrigated plots (Figure 4.35) indicating reduced plant N uptake and/or low leaching losses. While total available N was similar in the 20 and 40 kg N ha^{-1} treatments, it was significantly higher for the 120 kg N ha^{-1} treatment in the top soil profile. High N availability at anthesis in dry plots indicates low plant uptake and/or low losses through other means.

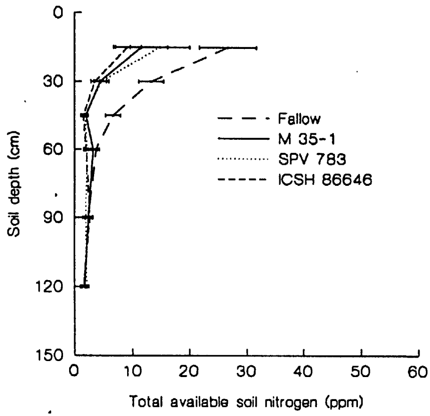
<u>4.4.3.3 Measured at 15, 30, 45, 60, 90 and 120 cm soil depths at harvest :</u>

The interaction of water * soil depth was highly significant ($P<0.01$) in both years (Appendix table 26). It indicates higher total available N in the dry plots for both years in the 0-30 cm profile. Below this layer, differences were not very distinct (Figure 4.37).

The interaction of nitrogen * soil depth was highly significant ($P<0.01$) in both years. Among nitrogen treatments, the 120 kg N ha^{-1} treatment had

Fig : 4.34. **Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of genotype and depth, at anthesis during rabi a) 1990-91 and b) 1991-92.**

a) 1990-91 (Mean of water and nitrogen treatments at anthesis)



b) 1991-92 (Mean of water and nitrogen treatments at anthesis)

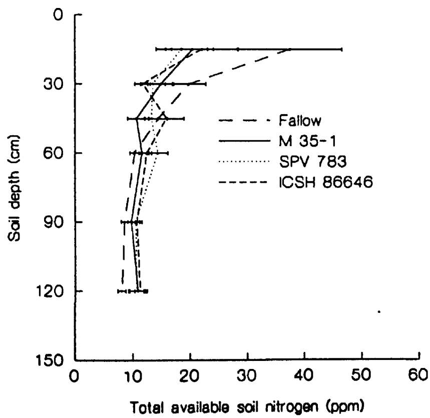
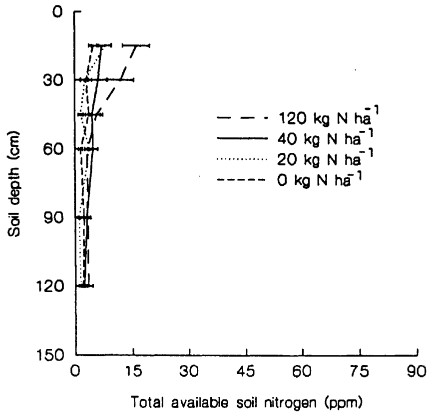


Fig : 4.35. Total available nitrogen in 1.2 m soil profile as a function of soil depth in irrigated plots for the interaction effect of water, nitrogen and depth, at anthesis during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of genotypes in irrigated plots at anthesis)



b) 1991-92 (Mean of genotypes in irrigated plots at anthesis)

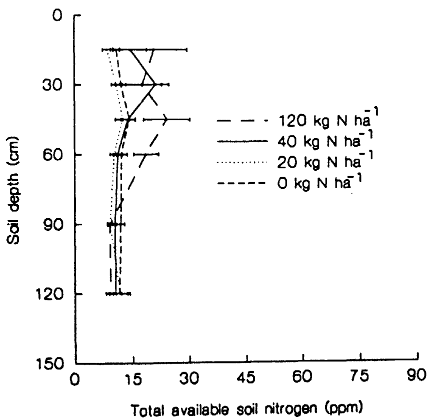
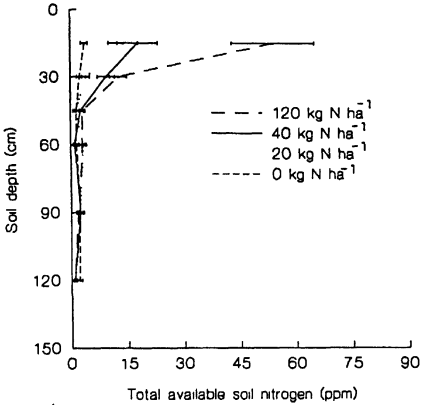


Fig : 4.36. Total available nitrogen in 1.2 m soil profile as a function of soil depth in dry plots for the interaction effect of water, nitrogen and depth, at anthesis during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of genotypes in dry plots at anthesis)



b) 1991-92 (Mean of genotypes in dry plots at anthesis)

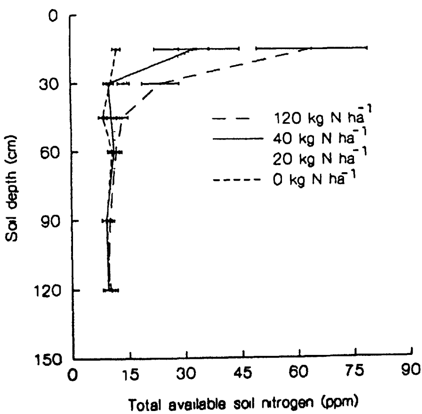
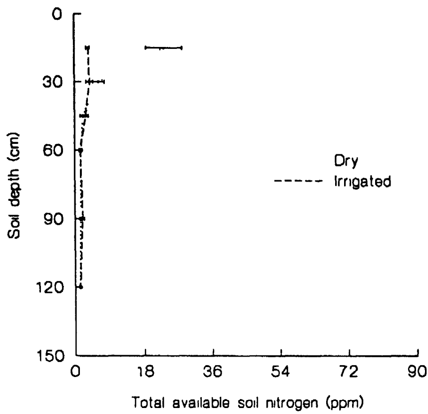
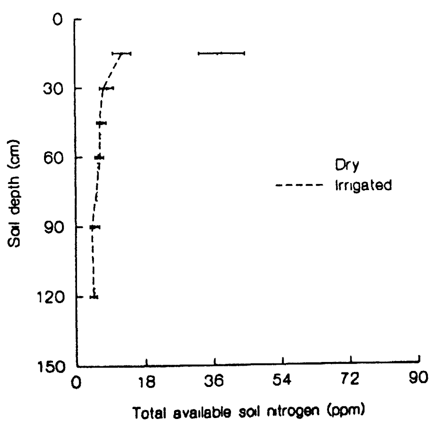


Fig : 4.37. Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of water and depth, at harvest during rabi a) 1990-91 and b) 1991-92.

a) 1990-91 (Mean of nitrogen and genotype treatments at harvest)



b) 1991-92 (Mean of nitrogen and genotype treatments at harvest)



significantly higher total available N in the 0-60 cm soil profile in 1990-91 (Figure 4.38a), and in the 0-45 cm soil profile in 1991-92 (Figure 4.38b), when compared to all other nitrogen treatments.

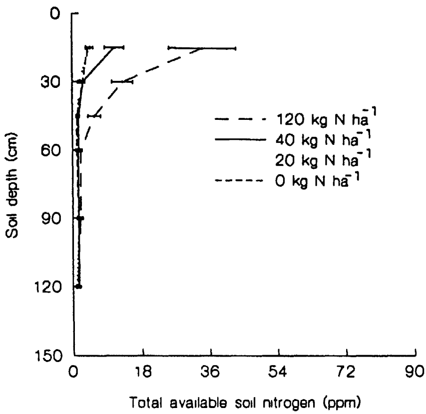
The interaction of genotype * soil depth significant ($P<0.05$) in 1991-92 indicates that the differences among genotype were not very distinct at harvest in terms of total available N, fallow plots indicated a higher total available N at harvest in both years (Figure 4.39).

The interaction of water * nitrogen * soil depth was highly significant ($P<0.01$) in both years. At harvest, irrigated plots (Figure 4.40), had lower total available N in all nitrogen treatments compared to dry plots (Figure 4.41), and the 120 kg N ha^{-1} treatment among all nitrogen treatments had higher total available N. In dry plots, at-harvest, significantly higher total available N was present in the 0-45 cm soil profile for the 120 kg N ha^{-1} treatment, while the 0 and 20 kg N ha^{-1} treatments were similar in 1990-91 (Figure 4.41a). The 20 and 40 kg N ha^{-1} treatments were similar in 1991-92 (Figure 4.41b). Lower total available N in irrigated plots indicates increased plant uptake and/or higher leaching losses than in dry plots.

The interaction of water * genotype * soil depth was highly significant in 1991-92 and it indicates that higher total available N in dry plots than in irrigated plots for all treatments. In irrigated plots, differences between genotypes and fallow plots were not distinct in 1990-91 (Figure 4.42a), but in 1991-92 (Figure 4.42b), fallow plots had significantly higher total available N in the 0-30 cm soil profile.

Fig : 4.38. **Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of nitrogen and depth, at harvest during rabi a) 1990-91 and b) 1991-92.**

a) 1990-91 (Mean of water and genotype treatments at harvest)



b) 1991-92 (Mean of water and genotype treatments at harvest)

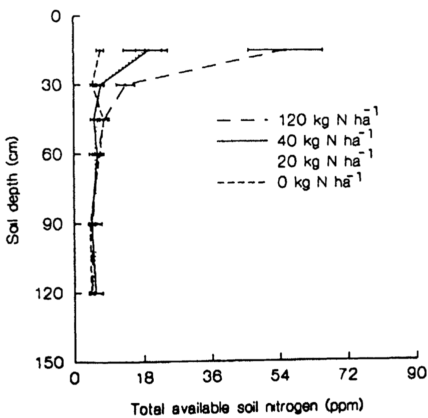


Fig : 4.39. Total available nitrogen in 1.2 m soil profile as a function of soil depth for the interaction effect of genotype and depth, at harvest during rabi a) 1990-91 and b) 1991-92.

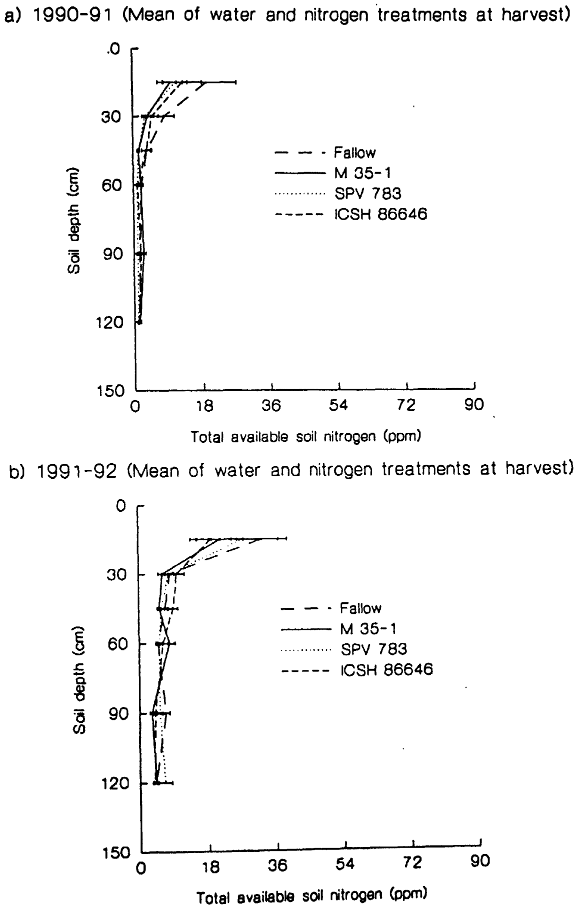
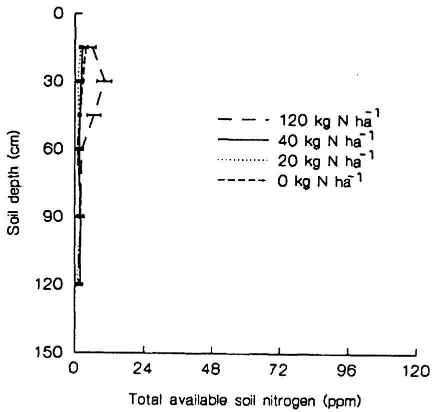


Fig : 4.40. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in irrigated plots for the interaction effect of water, nitrogen and depth, at harvest during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of genotypes in irrigated plots at harvest)



b) 1991-92 (Mean of genotypes in irrigated plots at harvest)

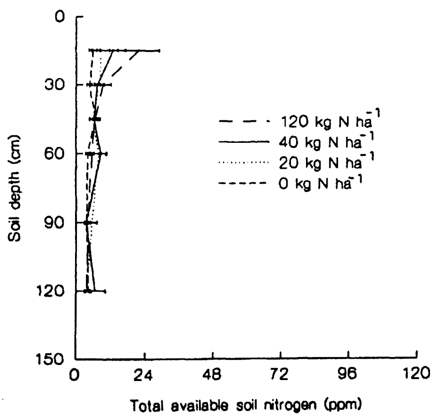
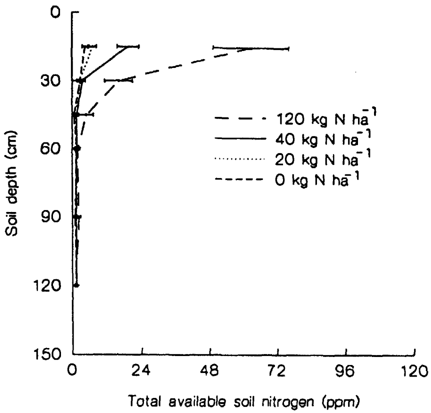


Fig : 4.41. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in dry plots for the interaction effect of water, nitrogen and depth, at harvest during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of genotypes in dry plots at harvest)



b) 1991-92 (Mean of genotypes in dry plots at harvest)

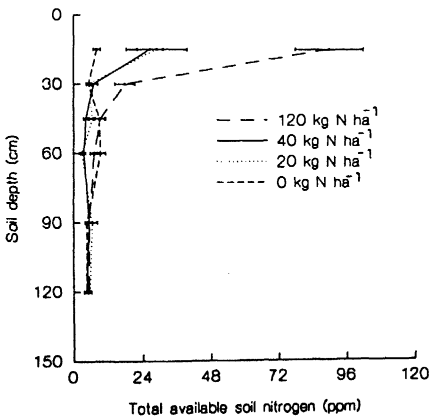
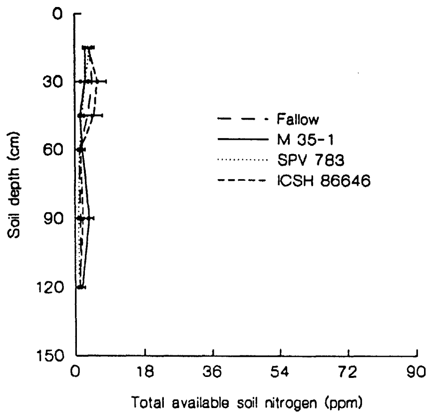
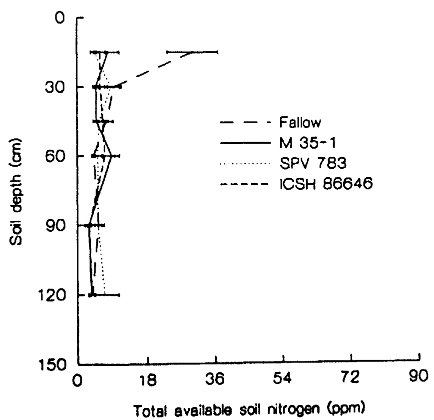


Fig : 4.42. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in irrigated plots for the interaction effect of water, genotype and depth, at harvest during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen treatments in irrigated plots at harvest)



b) 1991-92 (Mean of nitrogen treatments in irrigated plots at harvest)



High volume irrigation used in 1990-91 resulted in higher losses in fallow plots. In dry plots in 1990-91 (Figure 4.43a), fallow plots had higher total available N in the 0-60 cm soil profile but in 1991-92 the treatments had similar total available N throughout the profile.

The interaction of water * nitrogen * genotype * soil depth significant ($P<0.05$) in 1991-92 indicates that, in irrigated plots, in all nitrogen treatments, fallow plots had significantly higher total available N in the top soil profile (Figure 4.44 and 4.45). But in dry plots (Figures 4.46 and 4.47), in all nitrogen treatments, differences between genotypes and fallow plots were not significant, indicating lower and similar nitrogen uptake by the genotypes under dry conditions.

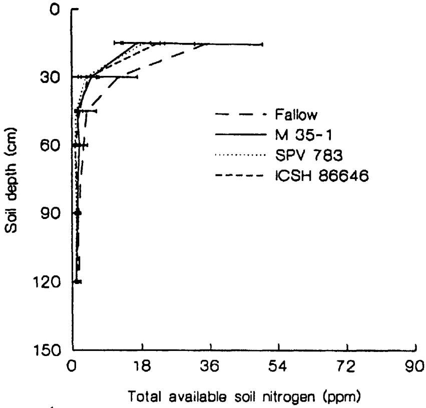
4.4.4 Total soil-water in the 150 cm profile :

<u>4.4.4.1 Soil water use at harvest :</u>

Irrigated plots received a total of 120 mm of water in both years. Total water contained in the soil profile (0-150 cm) in 1990-91 was 700 mm (Table 25), when compared to 1991-92 (Table 26) where it was 550 mm. In irrigated plots, the volume of water used was 245 mm, while in dry plots it was 170 mm. Total water use in irrigated plots was 251, 267, 234 and 239 mm in the 0, 20, 40 and 120 kg N ha^{-1} treatments, respectively. Higher water used for the lower levels of 0 and 20 kg N ha^{-1} treatments was due to higher soil evaporation losses as the leaf area index was lower than in the 40 and 120 kg N ha^{-1} treatments. In the dry plots, total soil water used was 165, 178, 177 and 170 mm in the 0, 20, 40 and 120 kg N ha^{-1}

Fig : 4.43. Total available nitrogen in 1.2 m soil profile as a function of soil depth in dry plots for the interaction effect of water, genotype and depth, at harvest during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of nitrogen treatments in dry plots at harvest)



b) 1991-92 (Mean of nitrogen treatments in dry plots at harvest)

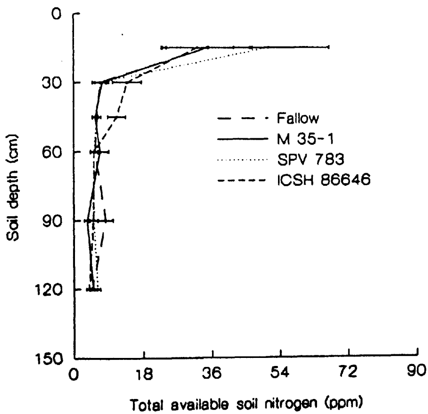
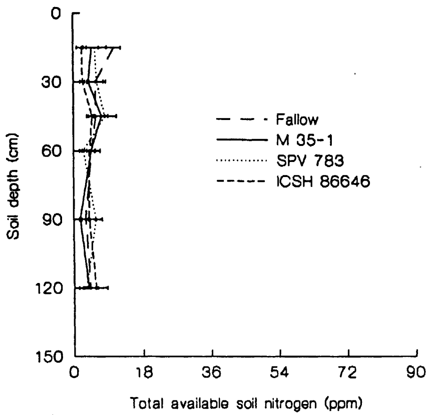


Fig : 4.44. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in irrigated plots, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments for the interaction effect of water, nitrogen, genotype and depth, at harvest during rabi 1991-92.**

a) 0 kg N ha^{-1} (Mean of replications in irrigated plots at harvest in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications in irrigated plots at harvest in 1991-92)

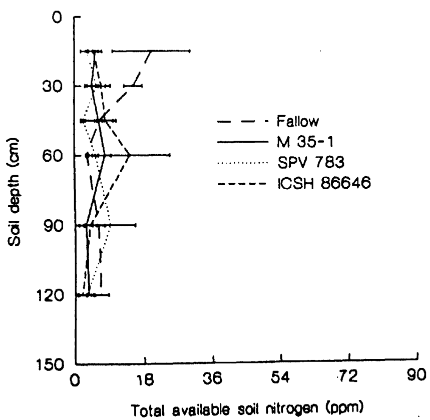
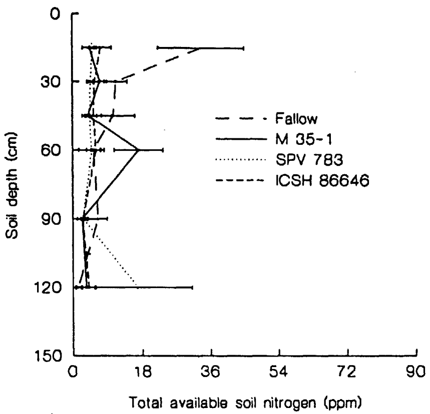


Fig : 4.45. Total available nitrogen in 1.2 m soil profile as a function of soil depth in irrigated plots, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments for the interaction effect of water, nitrogen, genotype and depth, at harvest during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications in irrigated plots at harvest in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications in irrigated plots at harvest in 1991-92)

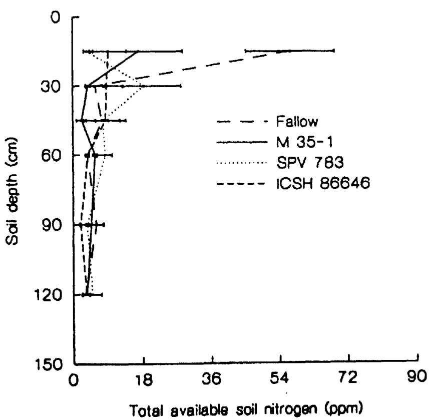
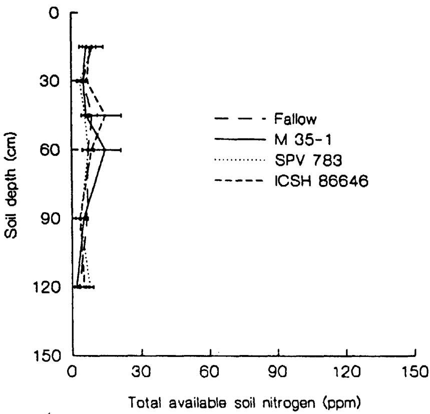


Fig : 4.46. Total available nitrogen in 1.2 m soil profile as a function of soil depth in dry plots, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments for the interaction effect of water, nitrogen, genotype and depth, at harvest during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications in dry plots at harvest in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications in dry plots at harvest in 1991-92)

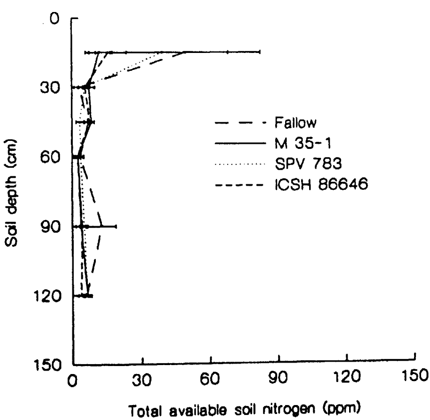
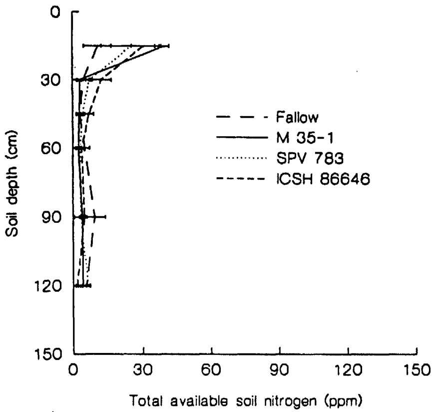


Fig : 4.47. **Total available nitrogen in 1.2 m soil profile as a function of soil depth in dry plots, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments for the interaction effect of water, nitrogen, genotype and depth, at harvest during rabi 1991-92.**

c) 40 kg N ha^{-1} (Mean of replications in dry plots at harvest in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications in dry plots at harvest in 1991-92)

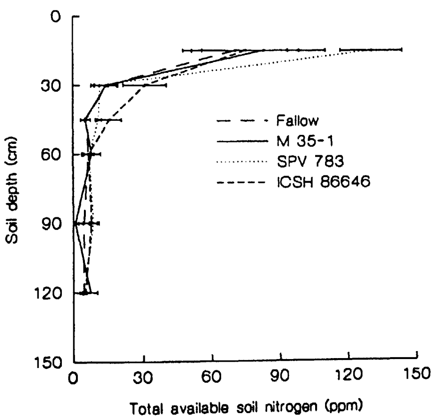


Table : 25. Mean water use (mm) of sorghum for the main and interaction effects of water, nitrogen and genotype at harvest stage in 1990-91.

a) At sowing :

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	M 35-1	Mean	ICSH 86646	M 35-1	Mean	
0 kg N ha^{-1}	703	715	709	708	707	707	708
20 kg N ha^{-1}	711	706	708	702	721	711	710
40 kg N ha^{-1}	719	712	715	711	718	714	715
120 kg N ha^{-1}	697	704	700	707	696	701	701
V-Mean	707	708		707	706		
W-Mean	708			708			

b) At harvest :

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	M 35-1	Mean	ICSH 86646	M 35-1	Mean	
0 kg N ha^{-1}	580	575	577	555	532	543	560
20 kg N ha^{-1}	571	575	573	551	532	542	557
40 kg N ha^{-1}	609	594	601	536	540	538	569
120 kg N ha^{-1}	583	581	582	538	524	531	556
V-Mean	585	581		545	532		
W-Mean	583			538			

Table : 26. Mean water use (mm) of sorghum for the main and interaction effects of water, nitrogen and genotype at harvest stage in 1991-92.

a) At sowing :

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	M 35-1	Mean	ICSH 86646	M 35-1	Mean	
0 kg N ha^{-1}	552	560	556	560	559	559	558
20 kg N ha^{-1}	552	553	552	563	563	563	558
40 kg N ha^{-1}	553	543	548	562	562	562	555
120 kg N ha^{-1}	557	553	555	563	557	560	557
V-Mean	553	552		562	560		
W-Mean	552			561			

b) At harvest :

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	M 35-1	Mean	ICSH 86646	M 35-1	Mean	
0 kg N ha^{-1}	504	531	517	480	466	473	495
20 kg N ha^{-1}	491	519	505	475	467	471	488
40 kg N ha^{-1}	463	490	476	466	464	465	470
120 kg N ha^{-1}	477	472	474	452	457	454	
V-Mean	483	503		468	465		
W-Mean	493			465			

treatments. The 20, 40 and 120 kg N ha^{-1} treatments used more soil water than the control treatment. Higher transpiration loss due to higher leaf area index resulted in greater soil water use at higher nitrogen treatments. Total soil water used by ICSH 86646 in irrigated plots was 242 mm, while in dry plots it was 162 mm, for M 35-1 it was 247 and 174 mm respectively.

In 1991-92 mean total soil water used in irrigated plots was 179 mm, while in dry plots it was 96 mm. In the 0, 20, 40 and 120 kg N ha^{-1} treatments in irrigated plots it was 159, 167, 192 and 201 mm, while in dry plots it was 86, 92, 97 and 106 mm for the respective nitrogen treatments. In dry plots, the trend for total soil water use was similar to 1990-91 but in irrigated plots, the water use pattern was reversed. This change is attributed to low leaf area index in all treatments in 1991-92, when compared to 1990-91. In irrigated plots, ICSH 86646 used 190 mm, while M 35-1 used 169 mm of soil water, in dry plots the respective values were 94 and 95 mm.

4.4.4.2 Soil water extraction pattern :

Soil water extraction in dry plots at different layers of the soil profile is presented in Tables 27 and 28 for 1990-91 and 1991-92 respectively. Maximum soil water removed was in the top 0-30 cm soil layer for most treatments. In 1990-91 in the 0 and 20 kg N ha^{-1} treatments (176 and 189 mm), M 35-1 used more soil water when compared to ICSH 86646 (153 and 152 mm). Soil water extraction in the 45 to 105 cm soil profile layer was higher in M 35-1 when compared to ICSH

Table : 28. Mean water extraction pattern (mm) of sorghum genotypes in dry plots, in different nitrogen treatments and the fallow plots, at various depths in the soil profile at harvest stage in 1991-92.

Soil profile depth	Soil water extraction pattern in dry plots (mm)									
	ICSH 86646					M 35-1				
	0 N	20 N	40 N	120 N	FALLOW	0 N	20 N	40 N	120 N	FALLOW
15 cm	42	37	42	41	42	42	42	34	32	42
30 cm	24	28	28	31	24	25	29	31	36	24
45 cm	3	4	6	4	2	6	4	2	2	2
60 cm	1	2	2	0	1	2	0	0	2	1
75 cm	3	5	6	4	4	3	5	6	0	4
90 cm	3	4	6	2	5	4	5	7	1	5
105 cm	3	5	5	3	4	4	3	6	2	4
120 cm	5	5	6	2	4	3	4	5	2	4
135 cm	3	4	5	4	3	4	4	5	3	3
150 cm	3	2	1	1	3	4	3	5	1	3
Total	90	96	107	92	92	97	99	101	81	92

Table : 27. Mean water extraction pattern (mm) of sorghum genotypes in dry plots, in different nitrogen treatments and the fallow plots, at various depths in the soil profile at harvest stage in 1990-91.

Soil profile depth	Soil water extraction pattern in dry plots (mm)									
	ICSH 86646					M 35-1				
	0 N	20 N	40 N	120 N	FALLOW	0 N	20 N	40 N	120 N	FALLOW
10.cm	17	15	18	13	15	17	18	17	14	15
22 cm	17	14	16	14	15	16	17	16	14	15
30 cm	24	22	25	26	22	24	27	23	24	22
45 cm	14	15	17	16	14	16	20	17	17	14
60 cm	13	13	15	14	11	16	18	16	16	11
75 cm	12	12	14	13	10	16	18	16	14	10
90 cm	11	12	15	14	10	15	17	16	13	10
105 cm	10	12	14	14	10	14	15	15	14	10
120 cm	9	11	13	13	8	12	8	13	14	8
135 cm	8	8	10	11	6	10	10	10	12	6
150 cm	3	3	4	4	2	5	4	4	5	2
	140	138	161	153	125	161	174	164	156	125

8664. In the 40 and 120 kg N ha^{-1} treatments, soil water use was similar in both the genotypes. Soil water lost to evaporation in the fallow plots was 123 mm.

In 1991-92, the amount of soil water used was very low when compared to 1990-91 in all the treatments. Maximum soil water use was from the 0-30 cm soil layer. Soil water lost due to evaporation in the fallow plots was 92 mm.

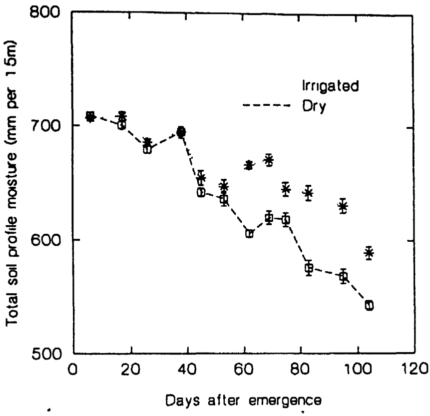
4.4.4.3 Soil water use over time :

In 1990-91 and 1991-92 four irrigations were given at 42, 70, 90 and 105 DAE. The soil drying pattern was similar in irrigated and dry plots upto 56 DAE in 1990-91 and upto 63 DAE in 1991-92 (Figure 4.48). Total soil water content in all nitrogen treatments was similar upto 42 DAE in both years, thereafter the decrease in soil water content in the 40 and 120 kg N ha^{-1} treatments was faster when compared to 0 and 20 kg N ha^{-1} in both the years (Figure 4.49). M 35-1 and ICSH 86646 had a similar soil water depletion pattern throughout the crop growth period, while in the fallow plots the decline in soil water was faster upto 56 DAE, but later it was slower when compared to the two genotypes in 1990-91 (Figure 4.50a).

In 1991-92, the fallow plots had a higher soil water content than plots with plants through out the crop growth period. Among genotypes, the decline in soil water content was higher in M 35-1 upto 91 DAE, when compared to ICSH 86646, thereafter both the genotypes had similar soil water content upto harvest (Figure 4.50b).

Fig : 4.48. **Total soil moisture in 1.5 m soil profile as a function of time for the interaction effect of water and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)

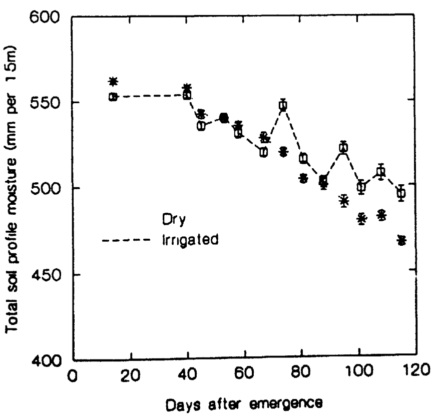
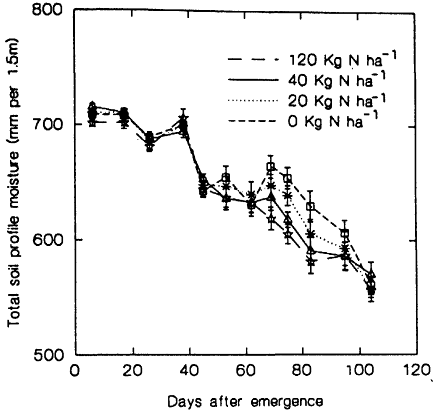


Fig : 4.49. Total soil moisture in 1.5 m soil profile as a function of time for the interaction effect of nitrogen and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

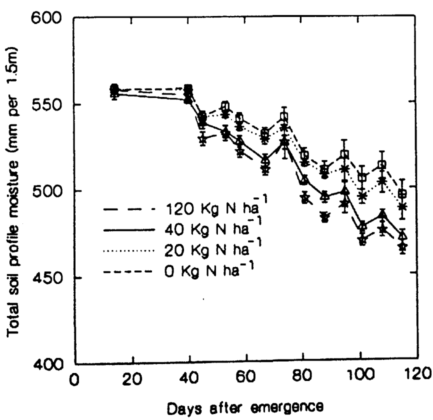
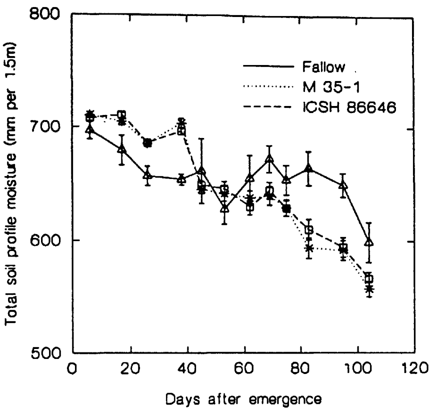
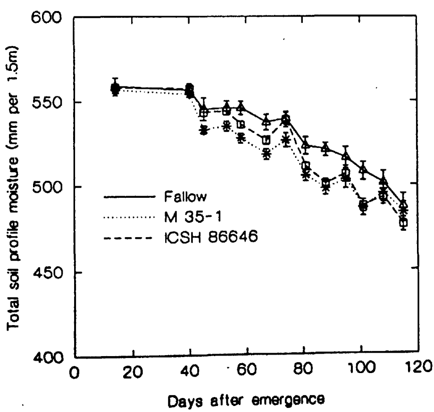


Fig : 4.50. Total soil moisture in 1.5 m soil profile as a function of time for the interaction effect of genotype and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)



4.4.5 Cumulative light interception (MJ m^{-2}) :

4.4.5.1 Total light interception to harvest :

Cumulative light interception for all treatments in 1990-91 was higher than in 1991-92, while the trend was similar for all main effects in both years. Increases in cumulative light interception due to irrigation was 9 % in 1990-91 and 38 % in 1991-92, while for nitrogen treatments the respective increases for the 20, 40 and 120 kg N ha^{-1} over the control were 7, 17 and 23 % in 1990-91 and 16, 26 and 49 % in 1991-92. The increase in cumulative light interception for M 35-1 over ICSH 86646 was 5 %, while over SPV 783 it was 1 % for both years (Table 29).

4.4.5.2 Cumulative light interception over time :

Cumulative light interception in 1990-91 (Figures A 4.51 to A 4.56), did not exceed 1250 MJ over the crop growth period in irrigated plots, while in dry plots it did not exceed 1150 MJ. Among nitrogen treatments the 120 Kg N ha^{-1} treatment had the highest cumulative light interception for all genotypes.

For ICSH 86646, the 40 and 120 Kg N ha^{-1} treatments had similar cumulative light interception in both irrigated and dry plots upto 70 DAE. Thereafter the 120 Kg N ha^{-1} treatment had the maximum cumulative light interception in both irrigated and dry plots. For SPV 783 in irrigated plots, both 40 and 120 Kg N ha^{-1} treatments were similar throughout crop growth while in the dry plots the 20, 40 and 120 Kg N ha^{-1} treatments had similar cumulative light interception values. The local genotype M 35-1 was similar to SPV 783 in irrigated plots, while in dry plots,

Table : 29. Mean radiation interception (MJ m^{-2}) of sorghum for the main and interaction effects of water, nitrogen and genotype at harvest in a) 1990-91 and b) 1991-92.

a) 1990-91

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	1039	874	964	872	836	932	919
20 kg N ha^{-1}	901	1073	1055	915	1031	964	990
40 kg N ha^{-1}	1024	1180	1201	1006	1075	979	1077
120 kg N ha^{-1}	1178	1197	1226	1067	1027	111 3	1135
V-Mean	1000		1036		1054		
W-Mean	1076			985			

b) 1991-92

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	608	665	701	442	515	471	567
20 kg N ha^{-1}	852	767	676	503	591	563	659
40 kg N ha^{-1}	824	849	868	551	550	660	717
120 kg N ha^{-1}	953	991	962	682	706	802	849
V-Mean	676		704		713		
W-Mean	810			586			

the 120 Kg N ha^{-1} treatment had higher cumulative light interception when compared to the other nitrogen treatments from planting to harvest.

These trends indicate that in irrigated plots the 40 Kg N ha^{-1} treatment as a basal application was sufficient to attain the maximum cumulative light interception for both varieties, while in the hybrid, maximum cumulative light interception was with the 120 Kg N ha^{-1} treatment. In dry plots, ICSH 86646 and M 35-1 attained maximum cumulative light interception in the 120 Kg N ha^{-1} treatment, while 40 Kg N ha^{-1} was sufficient to reach the maximum cumulative light interception for SPV 783. When water was not limiting, a lower level of nitrogen (40 Kg N ha^{-1}) was sufficient for maximum cumulative light interception, but in dry plots a higher N level was required. This is because nitrogen has to be absorbed before the zone of application dries and this is possible only when the availability in soil solution is higher.

For 1991-92 (Figures A 4.57 to A 4.62), ICSH 86646 and SPV 783 in irrigated and dry plots at the 20, 40 and 120 kg N ha^{-1} treatments had a higher cumulative light interception than the control. The 20 and 40 kg N ha^{-1} had an intermediary range between the 0 and 120 kg N ha^{-1} treatments. For M 35-1 in irrigated and dry plots, the 0 and 20 kg N ha^{-1} treatments had similar cumulative light interception, while the 40 and 120 kg N ha^{-1} treatments had higher cumulative light interception than the 0 and 20 kg N ha^{-1} treatments. Difference between nitrogen treatments in both irrigated and dry plots started at 40 DAE and continued to harvest.

4.4.6 Radiation use efficiency :

4.6.6.1 Computed at harvest :

Radiation use efficiency (RUE) was higher in 1990-91 (0.59 g MJ^{-1}), than in 1991-92 (0.48 g MJ^{-1}). In irrigated plots (Table 30), RUE was higher by 0.20 g MJ^{-1} than in dry plots, while among nitrogen treatments the 120 kg N ha^{-1} treatment had the highest RUE value (0.69 g MJ^{-1}) in 1990-91 and and in 1991-92 (0.61 g MJ^{-1}). The increase in RUE over control was 0.18 g MJ^{-1} and 0.22 g MJ^{-1} for the respective years. SPV 783 in 1990-91 and M 35-1 in 1991-92 had higher RUE values when compared to ICSH 86646.

For 1991-92 in irrigated plots, receiving 0 and 120 kg N ha^{-1}, the improved genotypes ICSH 86646 and SPV 783 had higher RUE values, while in dry plots M 35-1 had higher RUE value for all N treatments. This indicates that the efficiency of the local genotype in dry matter production was higher when water was limiting, while the improved genotypes were efficient when water was not limiting.

4.4.7 Relation between specific leaf nitrogen and radiation use efficiency :

A linear relationship was observed between specific leaf nitrogen and radiation use efficiency, that was similar for all the three genotypes (ICSH 86646, SPV 783 and M 35-1). The regression coefficient (r^{2}) value for ICSH 86646 and SPV 783 was 0.40, while it was 0.70 for M 35-1. Minimum specific leaf nitrogen required for utilization of intercepted radiation in ICSH 86646 was 0.005 g m^{-2} and in SPV 783 was 0.01 g m^{-2}, while in M 35-1 it was 0.023 g m^{-2} (Figs. 4.63, 4.64

Table : 30. Mean radiation use efficiency (g MJ^{-1}) of sorghum for the main and interaction effects of water, nitrogen and genotype at harvest in a) 1990-91 and b) 1991-92.

a) 1990-91

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	0.45	0.66	0.53	0.42	0.55	0.45	0.51
20 kg N ha^{-1}	0.65	0.64	0.64	0.48	0.50	0.50	0.57
40 kg N ha^{-1}	0.78	0.77	0.71	0.49	0.52	0.48	0.62
120 kg N ha^{-1}	0.75	0.93	0.78	0.50	0.69	0.52	0.69
V-Mean	0.57		0.66		0.58		
W-Mean	0.69			0.50			

b) 1991-92

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	0.43	0.48	0.33	0.39	0.32	0.41	0.39
20 kg N ha^{-1}	0.56	0.50	0.45	0.39	0.34	0.45	0.45
40 kg N ha^{-1}	0.55	0.61	0.55	0.36	0.44	0.42	0.49
120 kg N ha^{-1}	0.70	0.70	0.69	0.46	0.51	0.62	0.61
V-Mean	0.48		0.48		0.61		
W-Mean	0.54			0.42			

Fig : 4.63. Relationship between RUE and specific leaf nitrogen computed over the intervals 34-62 DAE for sorghum (ICSH 86646) in 1991-92.

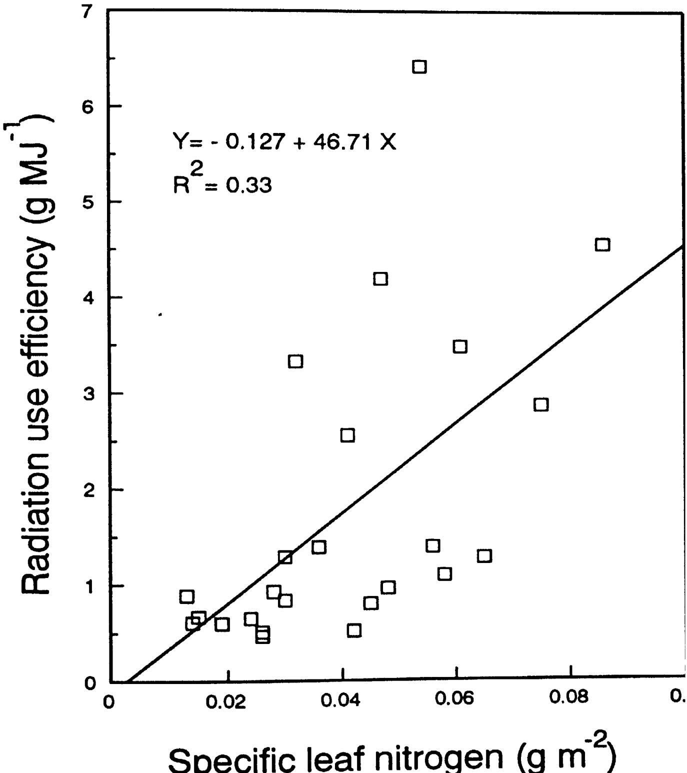


Fig : 4.64. Relationship between RUE and specific leaf nitrogen computed over the intervals 34-62 DAE for sorghum (SPV 783) in 1991-92.

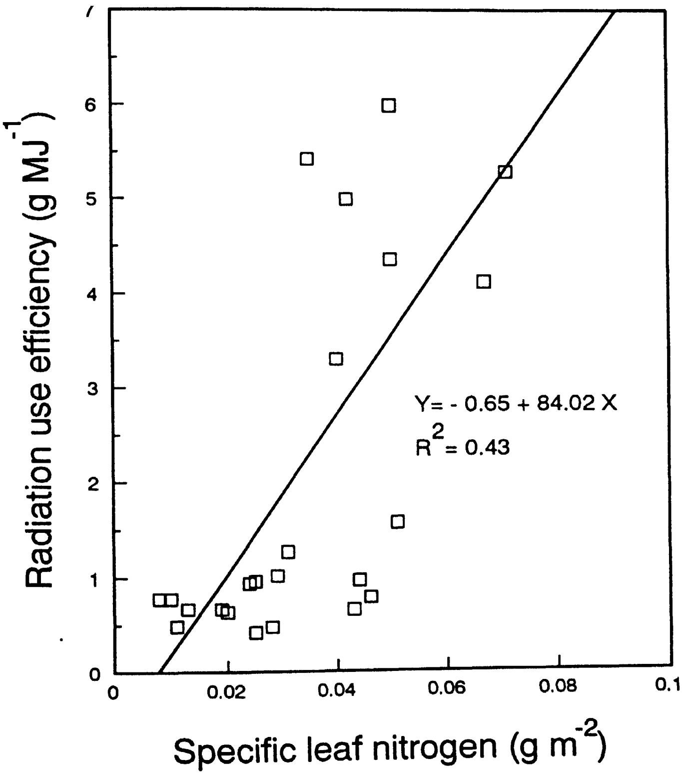
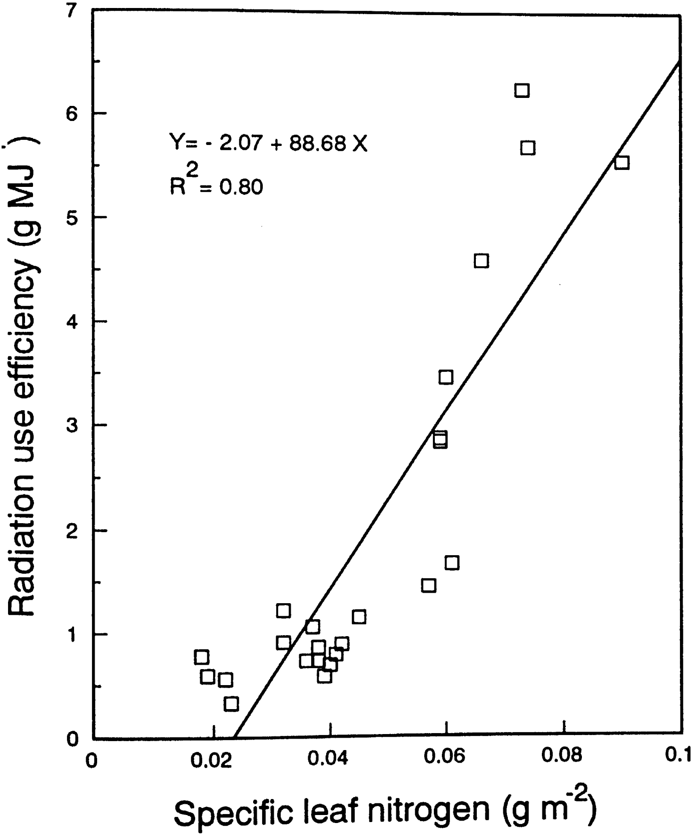


Fig : 4.65. Relationship between RUE and specific leaf nitrogen computed over the intervals 34-62 DAE for sorghum (M 35-1) in 1991-92.



and 4.65). In all three genotypes, when specific leaf nitrogen increased from 0 to 0.1 g m^{-2}, the radiation use efficiency increased linearly from 1 to 6 g MJ^{-1}.

4.4.8 Water use efficiency :

4.4.8.1 Computed at harvest :

The trend in water use efficiency (WUE) in terms of dry matter produced per unit of water (kg mm^{-1}) was similar for both years (Table 31). WUE increased with increasing nitrogen levels and was highest with the 120 kg N ha^{-1} treatment for both years. Increased WUE over the control was 14 kg mm^{-1} in 1990-91, while it was 18 kg mm^{-1} in 1991-92. M 35-1 had higher WUE in 1991-92, while there were no differences between genotypes in 1990-91. In the 120 kg N ha^{-1} treatment in dry plots M 35-1 had a maximum water use efficiency of 49.5 kg mm^{-1} in 1991-92. This high water use efficiency changed the trend among irrigated and dry plots in 1991-92.

4.4.9 Nitrogen use efficiency :

4.4.9.1 Computed at harvest :

Nitrogen use efficiency was higher in 1991-92 than in 1990-91 (Table 32). Low nitrogen uptake in 1991-92 resulted in high nitrogen use efficiency, though the total above ground biomass produced was lower in 1991-92. In both years the dry plots had higher nitrogen use efficiency when compared to irrigated plots. Nitrogen use efficiency increased with 20 kg N ha^{-1} treatment over the control in both years,

Table : 31. Mean water use efficiency (kg mm^{-1}) of sorghum for the main and interaction effects of water, nitrogen and genotype at harvest in a) 1990-91 and b) 1991-92.

a) 1990-91

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	19.34	-	19.50	23.99	-	24.11	21.73
20 kg N ha^{-1}	22.69	-	26.89	29.14	-	25.29	26.00
40 kg N ha^{-1}	34.78	-	35.76	28.34	-	26.40	31.32
120 kg N ha^{-1}	37.99	-	39.26	31.48	-	33.49	35.55
V-Mean	28.33		-			28.33	
W-Mean	29.52			27.78			

b) 1991-92

Treatment	Irrigated		Dry		N-Mean
				M 35-1	
0 kg N ha^{-1}	15.54	15.70	21.63	20.86	18.43
20 kg N ha^{-1}	26.46	19.74	22.39	26.15	23.68
40 kg N ha^{-1}	21.57	27.46	20.52	28.27	24.45
120 kg N ha^{-1}	33.35	33.13	28.20	49.50	36.04
V-Mean	23.45			27.60	
W-Mean	24.12		27.19		

Table : 32. Mean nitrogen use efficiency (kg kg^{-1}) of sorghum for the main and interaction effects of water, nitrogen and genotype at harvest in a) 1990-91 and b) 1991-92.

a) 1990-91

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	65.28	83.04	63.38	70.58	87.69	81.15	75.18
20 kg N ha^{-1}	57.81	77.30	78.49	78.57	110.21	81.02	80.56
40 kg N ha^{-1}	62.50	66.72	64.96	62.00	80.14	69.12	68.22
120 kg N ha^{-1}	49.39	48.60	49.95	45.86	66.79	53.83	52.40
V-Mean	61.49		65.06		67.73		
W-Mean	64.28			73.91			

a) 1991-92

Treatment	Irrigated			Dry			N-Mean
	ICSH 86646	SPV 783	M 35-1	ICSH 86646	SPV 783	M 35-1	
0 kg N ha^{-1}	104.40	112.86	111.43	123.57	128.46	149.23	121.65
20 kg N ha^{-1}	92.12	146.54	80.00	123.13	145.00	193.08	129.98
40 kg N ha^{-1}	73.06	114.67	89.62	123.13	120.50	213.08	122.34
120 kg N ha^{-1}	61.19	71.86	59.46	115.93	150.42	91.67	91.75
V-Mean	102.06		125.03		123.43		
W-Mean	93.10			139.75			

but declined in teh 40 and 120 kg N ha^{-1} treatments. Lowest nitrogen use efficiency was with the highest nitrogen application rate of 120 kg N ha^{-1}. Both SPV 783 and M 35-1 had higher nitrogen use efficiency than ICSH 86646 in both years.

4.4.10 Soil nitrogen balance :

4.4.10.1 Computed at harvest in 1990-91 :

In the irrigated plots nitrogen recovery by ICSH 86646 (Table 33), in the 0, 20, 40 and 120 kg N ha^{-1} rates was 74, 50, 40 and 60 %, while M 35-1 recovered 81, 42, 41 and 64 % respectively, of the total available nitrogen. Soil + crop (ICHS 86646) could account for 105, 58, 46 an 94 % of the total available nitrogen, while soil + M 35-1 recovered 115, 58, 57 and 77 % in the respective nitrogen application rates.

In the dry plots nitrogen recovery by ICSH 86646, in the 0, 20, 40 and 120 kg N ha^{-1} rates was 40, 49, 58 and 28 %, while M 35-1 recovered 40, 51, 48 and 25 % respectively, of the total available nitrogen. Soil + crop (ICHS 86646) could account for 45, 71, 92 and 69 % of the total available nitrogen, while soil + M 35-1 recovered 65, 78, 90 and 51 % in the respective nitrogen application rates.

4.4.10.2 Computed at harvest in 1991-92 :

In the irrigated plots nitrogen recovery by ICSH 86646 (Table 34), in the 0, 20, 40 and 120 kg N ha^{-1} rates was 15, 23, 36 and 44 %, while M 35-1 recovered 13, 17, 31 and 46 % respectively, of the total available nitrogen. Soil + crop (ICHS

Table : 34. **Soil nitrogen balance at harvest in 1991-92.**

a) Irrigated plots :

Nitrogen treatment	Soil nitrogen in fallow plots at sowing (kg ha^{-1})	Soil nitrogen at harvest (kg ha^{-1})		Nitrogen uptake at harvest (kg ha^{-1})		Soil nitrogen in fallow plots at harvest (kg ha^{-1})
		ICSH 86646	M 35-1	ICHS 86646	M 35-1	
0 kg N ha^{-1}	162	70	67	25	21	85
20 kg N ha^{-1}	222	115	84	52	38	135
40 kg N ha^{-1}	171	82	118	62	53	150
120 kg N ha^{-1}	246	82	94	109	112	173

b) Dry plots :

Nitrogen treatment	Soil nitrogen in fallow plots at sowing (kg ha^{-1})	Soil nitrogen at harvest (kg ha^{-1})		Nitrogen uptake at harvest (kg ha^{-1})		Soil nitrogen in fallow plots at harvest (kg ha^{-1})
		ICSH 86646	M 35-1	ICHS 86646	M 35-1	
0 kg N ha^{-1}	86	120	115	14	14	105
20 kg N ha^{-1}	108	89	98	16	13	190
40 kg N ha^{-1}	103	128	120	16	13	109
120 kg N ha^{-1}	144	291	241	27	54	218

Table : 33. **Soil nitrogen balance at harvest in 1990-91.**

a) Irrigated plots :

Nitrogen treatment	Soil nitrogen in fallow plots at sowing (kg ha^{-1})	Soil nitrogen at harvest (kg ha^{-1})		Nitrogen uptake at harvest (kg ha^{-1})		Soil nitrogen in fallow plots at harvest (kg ha^{-1})
		ICSH 86646	M 35-1	ICHS 86646	M 35-1	
0 kg N ha^{-1}	99	31	34	73	80	35
20 kg N ha^{-1}	204	17	33	102	86	16
40 kg N ha^{-1}	320	20	52	128	131	24
120 kg N ha^{-1}	300	103	39	180	191	66

b) Dry plots :

Nitrogen treatment	Soil nitrogen in fallow plots at sowing (kg ha^{-1})	Soil nitrogen at harvest (kg ha^{-1})		Nitrogen uptake at harvest (kg ha^{-1})		Soil nitrogen in fallow plots at harvest (kg ha^{-1})
		ICSH 86646	M 35-1	ICHS 86646	M 35-1	
0 kg N ha^{-1}	129	7	32	52	52	42
20 kg N ha^{-1}	115	26	31	56	59	64
40 kg N ha^{-1}	139	48	57	80	68	69
120 kg N ha^{-1}	419	174	108	116	107	283

86646) could account for 59, 75, 84 and 78 % of the total available nitrogen, while soil + M 35-1 recovered 54, 55, 100 and 84 % in the respective nitrogen application rates.

In the dry plots nitrogen recovery by ICSH 86646, in the 0, 20, 40 and 120 kg N ha^{-1} rates was 16, 15, 15 and 19 %, while M 35-1 recovered 16, 12, 13 and 37 % respectively, of the total available nitrogen. Soil + crop (ICSH 86646) could account for 155, 97, 140 and 221 % of the total available nitrogen, while soil + M 35-1 recovered 150, 102, 129 and 205 % in the respective nitrogen application rates.

4.4.11 Response to applied nitrogen:

Response to nitrogen was linear in irrigated plots in both years (Figures 4.66 and 4.67). In dry plots response in terms of total dry matter produced was negligible for the 20 and 40 kg N ha^{-1} rates in both years, while sorghum did respond to 120 kg N ha^{-1} rate in dry plots in 1991-92. In terms of grain yield response of ICSH 86646 and SPV 783 to nitrogen was greater in irrigated plots for both years (Figures 4.68 and 4.69), while in dry plots M 35-1 performed better in 1991-92.

Fig : 4.66. Response of rabi sorghum to nitrogen
in terms of total dry matter under irrigated
and dry conditions during rabi 1990-91.

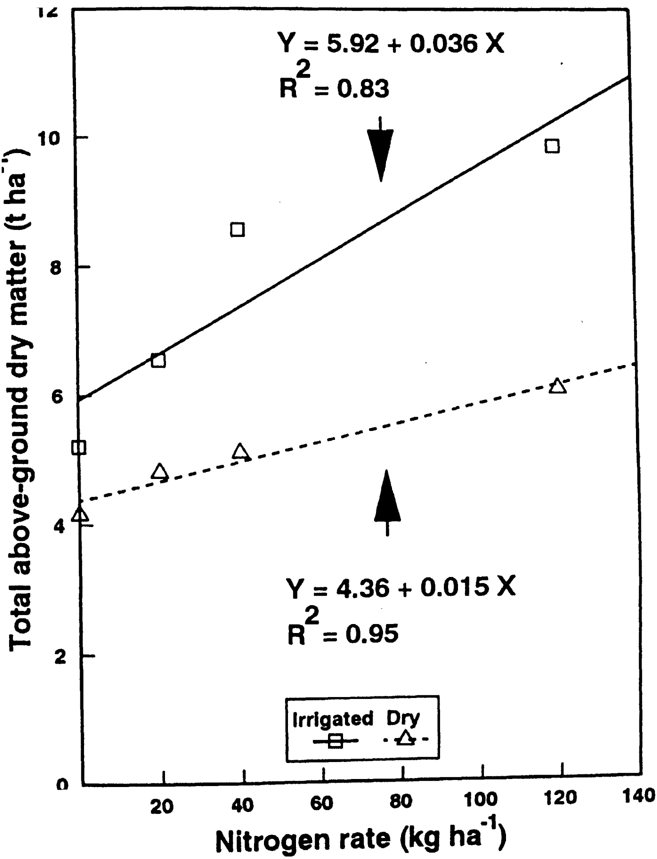


Fig : 4.67. Response of rabi sorghum to nitrogen

in terms of total dry matter under irrigated and dry conditions during rabi 1991-92.

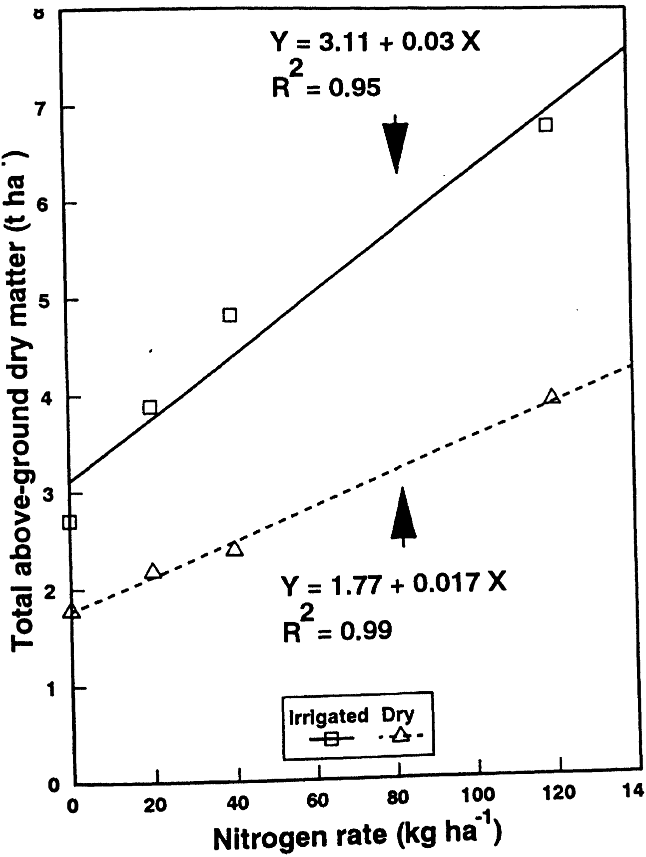


Fig : 4.68. Response of rabi sorghum genotypes to nitrogen in terms of grain yield under irrigated and dry conditions during 1990-91.

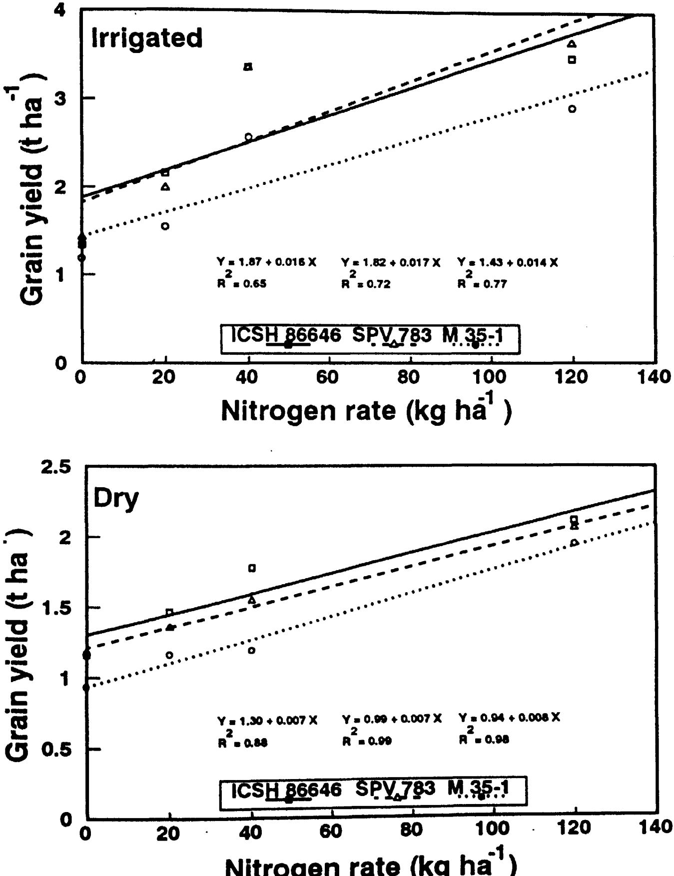
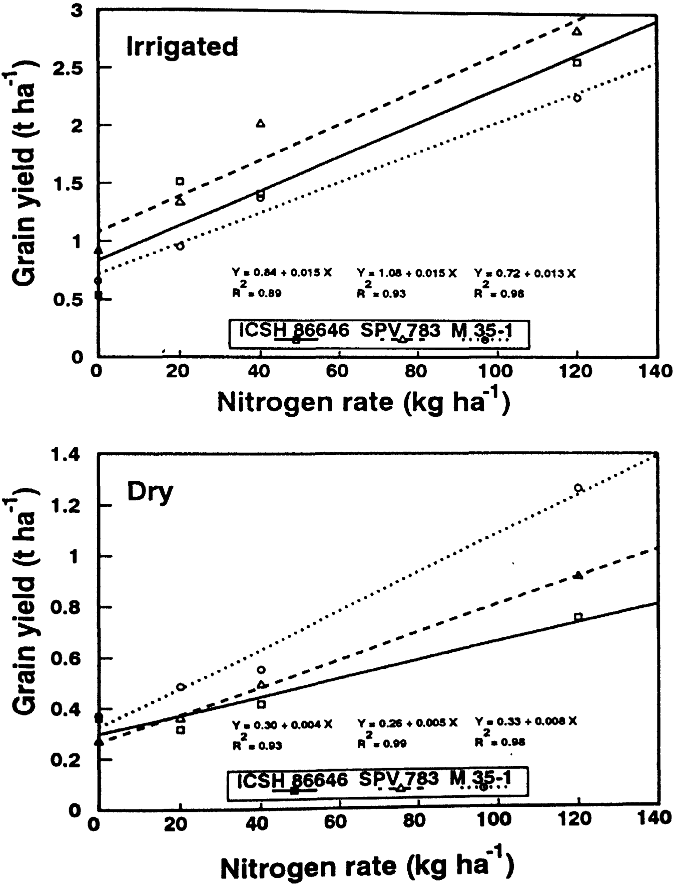


Fig : 4.69. Response of rabi sorghum genotypes to nitrogen in terms of grain yield under irrigated and dry conditions during 1991-92.



4.5 Model validation :

RESCAP model input consisted of agronomy data, weather data and the cultivar coefficients (Table 34). From Figure 4.70, it is evident that the simulated total above-ground biomass (g m^{-2}), was higher than observed values from 20 DAE to 80 DAE in irrigated plots and from 20 DAE to 60 DAE in dry plots. After 80 DAE., in irrigated plots the biomass simulated was similar to observed value, while in dry plots it was very low after 60 DAE. In terms of total dry matter and grain yield (t ha^{-1}), the simulated values were much higher than the observed values (Table 35). The harvest index values were simulated correctly in both irrigated and dry plots.

When simulated total biomass was regressed onto observed values the model over estimation was evident in both irrigated and dry plots (Figures 4.71 and 4.72).

Table : 35. Rescap model Inputs :

Agronomy dat	Description	Weather dat	Units
Location	ICRISAT	Day	-
Year	1990-91	Month	-
Season	Rabi	Precipication	mm
Cultivar	M 35-1	Pane	mm d^{-1}
Soil	Black (BW 4)	Tmax	^0C
Date of emergence	334 (Julian day)	Tmin	^0C
Row spacing	45 cm	Rh7	%
Population	1,66,666	Rh14	%
Latitude	17^0	Sunshine	hrs
Day length	13.6 hrs	Solar radiation	MJ m^{-2} d^{-1}
Soil water	708 mm		
Drained upper limit	708 mm		

Cultivar coefficients :

If Cults$= "M 35-1" then

GS1TT = 365 : GS2TT = 680 : GS3TT = 609 : GNC = 15.0 : GWC = 0.0060

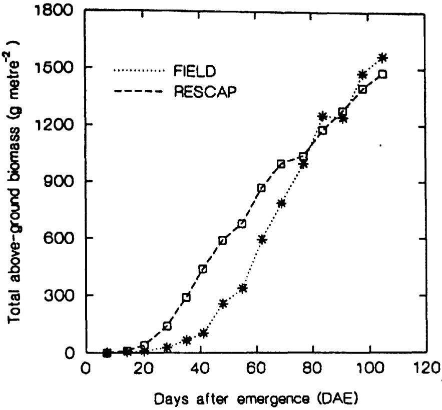
1) GS1TT = Thermal time for growth period 1 (^0C d)
2) GS2TT = Thermal time for growth period 2 (^0C d)
3) GS3TT = Thermal time for growth period 3 (^0C d)
4) GWC = Grain weight constant (d^{-1})
5) GNC = Grain number constant (g)

Table : 36. **Model and field data comparison**

	TDM (t ha^{-1})	GRAIN YIELD (t ha^{-1})	HARVEST INDEX
Irrigated (RESCAP)	14.80	4.40	0.29
Irrigated (FIELD)	9.54	2.91	0.30
Dry (RESCAP)	7.47	2.20	0.30
Dry (FIELD)	5.76	1.94	0.33

Fig : 4.70 **Total above-ground biomass (simulated and field observed) of sorghum (M 35-1) plotted as a fuction of time in irrigated and dry plots during rabi 1990-91.**

a) IRRIGATED (M 35-1)



b) DRY (M 35-1)

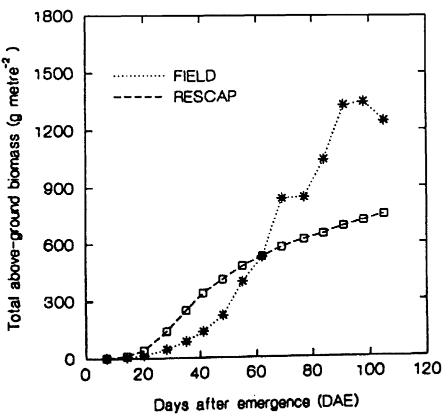


Fig : 4.71 Relation between predicted and observed total dry matter of sorghum (M 35-1) using RESCAP model in irrigated plots.

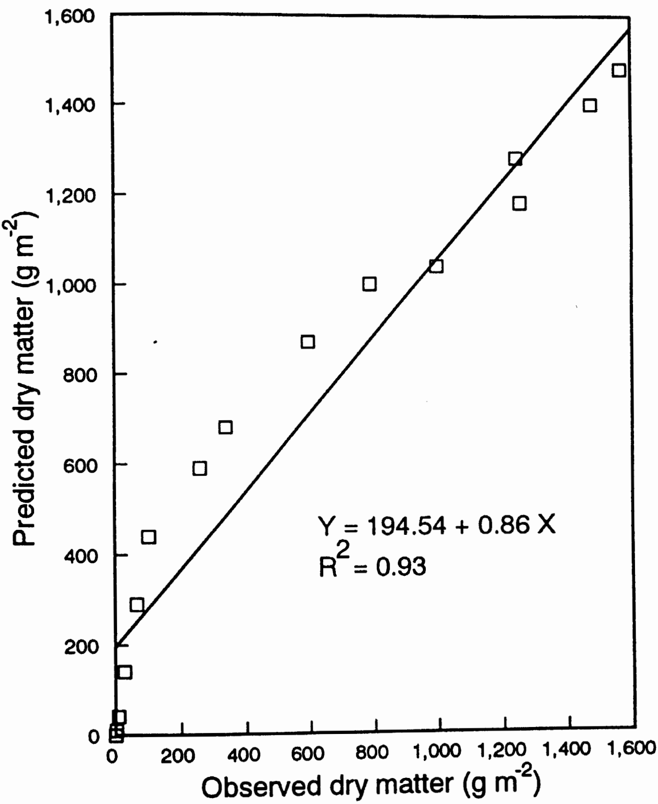
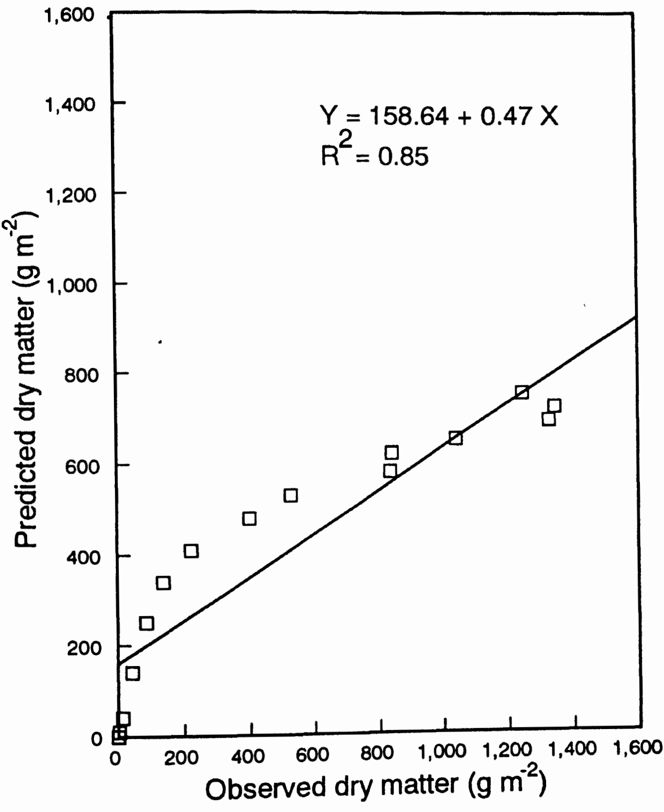


Fig : 4.72 Relation between predicted and observed total dry matter of sorghum (M 35-1) using RESCAP model in dry plots.



Discussion

5.0 DISCUSSION

5.1 Years :

There were significant differences between years for all variables analyzed over time and at harvest. Total soil nitrogen availability, water use and radiation interception differed greatly in both years though the trend in crop response to water and nitrogen was similar. Nutrient uptake and soil water use were higher in 1990-91 than in 1991-92 (Tables:13, 20, 25 and 26), which resulted in a greater photosynthetic area (Table:2, mean LAI=3), higher cumulative radiation interception (mean cumulative radiation interception=1100 MJ, Table:29), and higher total above ground dry biomass (78 g $plant^{-1}$, Table:3).

A higher amount of total soil available nitrogen remained un-utilised in the soil at harvest in 1991-92 as compared to 1990-91 (Fig:4.37). Low nitrogen uptake (Table:13), greatly affected the crop growth during 1991-92. Except for low nutrient uptake, water use and total biomass produced in 1990-91, the response trend of different variables to water and nitrogen were similar in both years.

5.2 Water :

Total above ground biomass production was similar in irrigated and dry plots up to 42 DAE (Figure 19), thereafter irrigated plots maintained higher dry matter production. The influence of limited water supply on crop growth was pronounced in both years. Differences in water use between irrigated and dry plots was similar in both the years (75 mm and 63 mm for 1990-91 and 1991-92 respectively, Table:25,26), but the increase in total biomass production in irrigated plots over dry plots was more pronounced (2.5 t ha^{-1} and 2.0 t ha^{-1} for 1990-91 and 1991-92 respectively, Table:3).

Variables that were significantly sensitive to water stress from 42 DAE included leaf area, leaf weight and total vegetative dry matter (Figures 7,35 and 60), while plant height and stem weight differred significantly from 55 and 60 DAE respectively in 1990-91 (Figures, 1 and 48). Earhead and grain weight were sensitive to water stress from 63 and 84 DAE respectively in 1990-91 (Figure 85). The differentiation in to reproductive organs was less sensitive to water, which was indicated by similar rachis number and grain number in irrigated and dry plots, but the grain filling process was significantly different which was indicated by rachis weight (Table 10).

Increased total nitrogen uptake was significantly higher in irrigated plots for both years (53 and 36 kg N ha^{-1}). Nitrogen use efficienty was higher in 1991-92 than in 1990-91 (80 kg kg^{-1} and 50 kg kg^{-1} nitrogen uptake respectively, Table:31). Differences in total leaf nitrogen uptake and stem nitrogen uptake were significant from 35 DAE (Figures, 119 and 134), while total grain nitrogen uptake was significantly higher in irrigated plots from 84 DAE (Figure 166). Redistribution of N from the leaf to the grain was 17 kg N ha^{-1} in irrigated plots while it was 16 kg N ha^{-1} in dry plots (Figure, 119). From the stem it was <2 kg N ha^{-1} for the respective treatments (Figure 134). Increase of 52 kg ha^{-1} of nitrogen uptake in 1990-91 and 36 kg N ha^{-1} in 1991-92 (Table:3), due to irrigation had a contribution of redistributed nitrogen from vegetative dry matter of 18 kg ha^{-1} in both years (Figure 150).

In terms of fodder and grain quality at harvest, irrigated plots had higher leaf and stem nitrogen content at harvest for both years (Table:11 and 12), and grain nitrogen content in 1990-91 (Table:17). In both years total potassium uptake by the leaf, stem, grain and total biomass did not differ significantly, but the stem potassium content was significantly higher in 1991-92 (Table:19).

Water use, nutrient uptake and cumulative light interception were significantly higher in irrigated plots when compared to dry plots for both years (Tables:25, 26, 13 and 29). In irrigated plots, total water use was higher by 75 mm in 1990-91 and 63 mm in 1991-92, when compared to dry plots. This resulted in a difference in nitrogen uptake between irrigated and dry plots of 52 kg N ha^{-1} in 1990-91 and 36 kg N ha^{-1} in 1991-92. Higher nitrogen uptake was reflected in a significantly higher leaf area index (mean of 15 samplings=1.53 in 199-91 and 0.77 in 1991-92), in irrigated plots when compared to dry plots (1.19 in 1990-91 and 0.49 in 1991-92). Increased leaf area index resulted in increased cumulative light interception (91 MJ in 1990-91 and 224 MJ in 1991-92, Table:29). The 91 MJ increase in 1990-91 resulted in 2.5 t ha^{-1} increase in total above ground biomass and the 224 MJ increase resulted in a 2.0 t ha^{-1} increase in 1991-92. These results are attributed to 38 % increase in radiation use efficiency in 1990-91, compared to a 29 % increase in 1991-92. Therefore radiation use efficiency plays a greater role in biomass production as compared to leaf area which intercepts solar radiation.

Total above-ground biomass produced at harvest was distributed in a ratio of 58:42 (vegetative to reproductive parts) in irrigated plots, while in dry plots the ratio was 60:40 in 1990-91. In 1991-92 the respective ratios were 58:42 and 72:28 (Tables:3 and 7). In both the years when water was not limiting the distribution pattern was similar, but when water was limiting the distribution pattern differed between years.

5.3 Nitrogen :

Nitrogen had a significant influence on all measured growth and nutrient uptake variables in both years. Major differences between years was that the total above ground biomass produced in the plots receiving 0 kg N ha^{-1}, was 4.68 t ha^{-1} in 1990-91, while it was 2.24 t ha^{-1} in 1991-92 (Table:3). The high level of production in 1990-91 indicates the high nutrient status of the soil and hence total biomass production for the two lower levels of 0 and 20 kg N ha^{-1} was similar. In 1991-92 the 20 kg N ha^{-1} treatment resulted in significantly higher total biomass production than those plots receiving no nitrogen. This trend was reflected in the growth parameters of plant height, leaf area index, leaf weight, stem yield and total vegetative dry matter. All nitrogen application rates (20, 40 and 120 kg N ha^{-1}), had significantly higher earhead and grain yield than the control in both years (Tables:7 and 8).

Dry matter accumulation in different plant parts was significantly influenced by nitrogen. The 120 kg N ha^{-1} treatment had a significantly higher leaf dry weight than all other nitrogen treatments. But the stem and total vegetative dry matter were significantly higher in both the 40 and 120 kg N ha^{-1} treatments in 1990-91, while in 1991-92 the 120 kg N ha^{-1} rate had significantly higher weight than all nitrogen treatments (Tables:5 and 6). Differences between nitrogen rates and the control were significant through out the growth period (Figure 61).

In terms of reproductive parts, differences in nitrogen rates started from 56 DAE for earhead weight, and from 70 DAE for grain weight (Figure 86). The 20, 40 and 120 kg N ha^{-1} rates differed significantly from the control treatment. The 40 and 120 kg N ha^{-1} treatments were similar up to 91 DAE, but by harvest the 120 kg N ha^{-1} rate had significantly higher earhead and grain weight when compared to all other nitrogen treatments. The 40 and 120 kg N ha^{-1} rates had significantly higher rachis number, rachis weight and grain number (Table 10), which was reflected in high grain yield in these two treatments (Table 8). The importance of grain number as the main determinant of yield has been pointed out by Thorne et al. (1968) and many others (Yoshida, 1972; Spiertz and Ellen, 1978). The dominant factor contributing to higher grain yield in sorghum is an increase in th number of grain per panicle (Tandon and Kanwar, 1984).

Total nitrogen uptake was significantly higher in the 120 kg N ha^{-1} treatment for both years. The 0 and 20 kg N ha^{-1} rates had similar total N uptake in both years, while the 20 and 40 kg N ha^{-1} treatments were similar in 1991-92. The 120 kg N ha^{-1} rate had significantly higher leaf, stem and grain nitrogen uptake (Table 13). The distribution of total nitrogen in leaf, stem and grain was in the ratio of

2:2:16, 2:2:19, 2:3:28 and 2:3:21 for the 0, 20, 40 and 120 kg N ha^{-1} treatments respectively. At higher nitrogen rates the partioning of dry matter was more towards grain.

Nitrogen had a significant influence on total potassium uptake. The 120 kg N ha^{-1} treatment had significantly higher total potassium uptake when compared to all the other N treatments in both the years (Table:20).

In terms of resource use, nitrogen had a significant influence on water and light use (Tables: 25, 26 and 29). Water use increased with increasing nitrogen rates in 1991-92, while in 1990-91 this increase was only with the 20 kg N ha^{-1} treatment over the control. Soil water use in all the nitrogen treatments was similar up to 42 DAE, in both years, but there after it was greater in the 40 and 120 kg N ha^{-1} treatments when compared to 0 and 20 kg N ha^{-1} rates in both years. Increased water use efficiency with increasing nitrogen rates has been reported by Singh and Bains (1971) and Singh and Ramakrishna, (1974).

Increased water use resulted in significantly higher nitrogen uptake in the 40 and 120 kg N ha^{-1} (102 and 155 kg N ha^{-1} in 1990-91 and 35 and 70 kg N ha^{-1} in 1991-92, Table:13). Increased nitrogen uptake resulted in a greater leaf area index over the crop growth period (Figure 8). Thus all nitrogen rates had a higher cumulative light interception value than the control in both years (Table:29). This increase in total cumulative light interception for the 20, 40 and 120 kg N ha^{-1} treatments was 71, 158 and 216 MJ in 1990-91 and 92, 150 and 182 MJ in 1991-92. Higher light interception resulted in an increase in total biomass production of

1, 2 and 3 t ha^{-1} in 1990-91 and 0.79, 1.36 and 3 t ha^{-1} in 1991-92. Nitrogen has been shown to have a significant effect on biomass accumultion (Muchow and Davis, 1988; Lafitte and Loomis, 1988).

Though the increase in total light interception attributable to N treatments was similar in both years, total biomass production differed in the 20 and 40 kg N ha^{-1} treatments. This indicates that nitrogen not only has a role in increasing the photosynthetic area but also has a functional role in utilizing intercepted light. The relationship between specific leaf nitrogen and radiation use efficiency substantiates the hypothesis that within a certain range of specific leaf nitrogen values there is a linear increase in radiation use efficiency with increasing leaf nitrogen. Muchow and Davis (1988), reported that a reduction in biomass accumulation under nitrogen stress was due to a relatively greater reduction of RUE, than in the amount of radiation intercepted.

5.4 Genotypes :

The genotypes (ICSH 86646, SPV 783 and M 35-1), did not differ significantly in total biomass production up to 56 DAE in both years (Figure 21). At harvest, genotypes differed significantly in total biomass production in 1990-91, while in 1991-92 these differences were not significant (Table 3). M 35-1 had a higher total biomass value than ICSH 86646 or SPV 783 in both years. It had a significantly higher stalk yield than did ICSH 86646 in 1990-91, while in 1991-92 it was significantly higher than SPV 783 or ICSH 86646. Earhead yield was significantly higher than in ICSH 86646 and SPV 783 in 1990-91, while in 1991-92 it was significantly higher only in SPV 783. Partitioning to the earhead was less in M 35-1 (harvest index=0.30), while it was higher in ICSH 86646 (HI=0.52), and intermediary in SPV 783 (HI=0.44).

Total nitrogen uptake did not differ significantly in 1990-91, but in 1991-92 both ICSH 86646 and M 35-1 had significantly higher total nitrogen uptake than SPV 783 (Table 13). Partioning to the leaf was 7, 7 and 8 kg N ha^{-1} in ICSH 86646, SPV 783 and M 35-1, respectively, while to the stem it was 7, 9 and 13 kg N ha^{-1} and to the grain it was 86, 81 and 76 kg N ha^{-1}, for the respective genotypes. Grain was the major contributor to total nitrogen uptake in all three genotypes. In terms of quality M 35-1 had significantly higher leaf and grain nitrogen content in 1990-91 and significantly higher stem nitrogen content in 1991-92. M 35-1 in 1990-91 and ICSH 86646 in 1991-92 had significantly higher potassium uptake (Table 20). Stem was the chief contributor to total potassium uptake.

Total water use was similar in ICSH 86646 and M 35-1 in both years (Table:25 and 26). Total cumulative light interception was 1000, 1036 and 1054 MJ in 1990-91 for ICSH 86646, SPV 783 and M 35-1, respectively, while in 1991-92 it was 676, 704 and 713 for the respective genotypes (Table:29). Thus M 35-1 with its higher cumulative light interception, and higher radiation use efficiency had significantly higher biomass production than ICSH 86646 and SPV 783.

5.5 Water * nitrogen interaction :

Differences in total biomass production in the 40 and 120 kg N ha^{-1} rates were significant from 70 DAE, in irrigated plots, while the differences were significant from 42 DAE in dry plots (Figure 22). In irrigated plots, the 40 kg N ha^{-1} treatment had a similar biomass value as the 120 kg N ha^{-1} treatment up to 70 DAE and there after the demand for nitrogen was greater than the supply, which could be met only by the 120 kg N ha^{-1} rate. In dry plots, though nitrogen was present in the soil through out the growing season, the plant demand for nitrogen could not be met by the 40 kg N ha^{-1} treatment, while in the 120 kg N ha^{-1} rate the nitrogen absorbed up to 42 DAE, was able to sustain higher biomass production though water was limiting. Total biomass production in the 0 and 20 kg N ha^{-1} treatments did not differ significantly in irrigated and dry plots.

There was no significant water * nitrogen interaction in terms of leaf weight and stem weight, but for the earhead and grain yields it was significant. In irrigated plots, the 40 and 120 kg N ha^{-1} rates had similar earhead and grain yields, but in dry plots the 120 kg N ha^{-1} had significantly higher earhead and grain yields when compared to all other nitrogen treatments in both years (Figure 88 and 89). In 1991-92, in irrigated plots, the difference between 40 and 120 kg N ha^{-1} was also significant.

Total nitrogen uptake in all nitrogen treatments was higher in irrigated plots when compared to dry plots. Increased total nitrogen uptake attributable to irrigation was 10, 32, 34 and 75 kg N ha^{-1} for the 0, 20, 40 and 120 kg N ha^{-1} rates when compared to the same N rates in dry plots (Figure 115). Total nitrogen uptake in the 20 and 40 kg N ha^{-1} treatments in the dry plots was similar to the control with only the 120 kg N ha^{-1} having a significantly higher total nitrogen uptake (72 kg N ha^{-1}) value.

The interaction of water * nitrogen in terms of leaf and stem nitrogen uptake was significant, but for grain nitrogen uptake it was not significant. In irrigated plots, the 40 and 120 kg N ha^{-1} treatments had similar stem nitrogen uptake values, while in dry plots only the 120 kg N ha^{-1} rate had a significantly higher stem nitrogen uptake than all other nitrogen treatments (Figure 135).

Water use in irrigated plots increased with nitrogen applications up to 20 kg N ha^{-1}, while in dry plots it increased to 40 kg N ha^{-1} in 1990-91. In 1991-92 water use increased in both irrigated and dry plots up to 120 kg N ha^{-1} (Tables 25 and 26). Increased total cumulative light interception with the 120 kg N ha^{-1} rate over the control was 156 MJ, but the interaction of water and nitrogen resulted in an increase of 241 MJ, the contribution of water being 85 MJ in 1990-91. In 1991-92 increased cumulative light interception due to nitrogen was 220 MJ, due to the interaction of water and nitrogen was 310 MJ, and that of water being 90 MJ (Table 29).

The interaction of water and nitrogen resulted in an increase in radiation use efficiency of 0.28 g MJ^{-1}, while the 120 kg N ha^{-1} treatment increased the radiation use efficiency by 0.10 g MJ^{-1} in 1990-91. In 1991-92 the respective increases were 0.22 and 0.16 g MJ^{-1}. Nitrogen (120 kg N ha^{-1}), increased the water use efficiency by 19 kg mm^{-1} in irrigated plots, while in dry plots it increased by 9 kg mm^{-1} in 1990-91, the respective increases in 1991-92 were 18 and 17 kg mm^{-1} (Table 31).

5.6 Water * genotype interaction :

The interaction of water * genotype for most variables was significant only in 1991-92. Differences in total biomass produced by the genotypes was significant after 49 DAE in irrigated plots, while it was significant after 84 DAE in dry plots (Figure 23). At harvest, the genotypes ICSH 86646 and SPV 783, had higher total biomass in irrigated plots than M 35-1, while M 35-1 had higher total biomass than ICSH 86646 and SPV 783 in dry plots. These differences were also significant in terms of stalk, earhead and grain yield (Figures 59 and 90).

Both ICSH 86646 and M 35-1 had higher total nitrogen uptake in irrigated plots, while in dry plots only M 35-1 had higher total nitrogen uptake (Figure 116). A similar trend was observed in stem nitrogen uptake. In terms of total potassium uptake, ICSH 86646 in irrigated plots and M 35-1 in dry plots had significantly higher values than SPV 783 (Figure 173).

Water use was higher for ICSH 86646 in irrigated plots when compared to M 35-1, while water use was similar for both genotypes in dry plots (Tables 25 and 26). SPV 783 and M 35-1 had higher cumulative light interception than ICSH 86646 in both irrigated and dry plots (Table 29). The major difference was in radiation use efficiency, while ICSH 86646 and SPV 783 had higher radiation use efficiency in irrigated plots, M 35-1 had higher radiation use efficiency in dry plots

(Table 30). Radiation use efficiency was 0.56, 0.56 and 0.50 g MJ^{-1} for ICSH 86646, SPV 783 and M 35-1 in irrigated plots, while it was 0.40, 0.40 and 0.47 g MJ^{-1} in dry plots.

5.7 Nitrogen * genotype interaction :

The interaction of nitrogen and genotype had a significant influence on total biomass and total vegetative dry matter production, while it had no significant influence on reproductive dry matter. At the higher nitrogen rates of 40 and 120 kg N ha^{-1}, SPV 783 and M 35-1 produced higher total biomass than ICSH 86646 (Figure 34). While at 0 and 20 kg N ha^{-1} ICSH 86646 and SPV 783 produced higher total biomass than M 35-1 (Figure 33). In terms of total vegetative dry matter ICSH 86646 in the 0 and 20 kg N ha^{-1} treatments and M 35-1 in the 40 and 120 kg N ha^{-1} treatments had significantly higher values (Figure 72 and 73).

ICSH 86646 in the 0, 20 and 40 kg N ha^{-1} treatments had significantly higher total nitrogen and potassium uptake values, while in the 120 kg N ha^{-1}, M 35-1 had significantly higher total nitrogen and potassium uptake (Figures 118, 174 and 175). Jordan et al. (1979), reported 90 % greater crown root length than 77CS2 grown in hydroponics. Thus M 35-1 has the advantage of a greater root spread in the top layers.

Higher total biomass production by ICSH 86646 and SPV 783 in the 0 and 20 kg N ha^{-1} treatments was due to higher radiation use efficiency (0.41 and 0.47 g MJ^{-1} for ICSH 86646 and 0.40 and 0.45 g MJ^{-1} for SPV 783), when compared to M 35-1 (0.37 and 0.42 g MJ^{-1}). In the 40 and 120 kg N ha^{-1} treatments M 35-1 (0.48 and 0.65) and SPV 783 (0.52 and 0.60), had higher radiation use efficiency when compared to ICSH 86646 (0.45 and 0.58 g MJ^{-1}, Table 30).

5.8 Water * nitrogen * genotype interaction :

Interaction of water * nitrogen * genotype had a significant influence on total vegetative dry matter, earhead and grain yield. In terms of nutrient uptake the interaction effect had a significant influence on stem nitrogen content, total potassium uptake, leaf potassium uptake, stem potassium uptake and potassium uptake by vegetative matter.

In irrigated plots ICSH 86646 and SPV 783 had higher earhead and grain yield in all nitrogen treatments (Figures 91 and 92), while M 35-1 had higher total vegetative matter in the 40 and 120 kg N ha^{-1} treatments (Figure 74). In the dry plots, all the genotypes had similar earhead and grain yield at the lower levels of 0, 20 and 40 kg N ha^{-1}. M 35-1 had higher earhead, grain and total vegetative dry matter in the 120 kg N ha^{-1} treatment. The improved genotypes responded to irrigation and nitrogen and translocated most of the dry matter produced towards grain, while under dry conditions M 35-1 did respond at the 120 kg N ha^{-1} nitrogen rate and produced higher grain and total vegetative dry matter than the improved genotypes.

In terms of nutrient uptake, ICSH 86646 had a higher stem potassium uptake and total potassium uptake by above ground biomass in all nitrogen treatments in irrigated plots (Figures 176, 183 and 184). M 35-1 had higher stem potassium uptake and total potassium uptake by above ground biomass in the 120 kg N ha^{-1} treatment in dry plots. Since these differences were not seen in potassium concentration, a parallel trend in total vegetative dry matter contributed to these differences in potassium uptake (Figures 74).

In 1990-91, in irrigated plots, water use did not increase with nitrogen application in both ICSH 86646 and M 35-1, except in the 20 kg N ha^{-1} in ICSH 86646. While in 1991-92, there was an increase in water use with the 120 kg N ha^{-1} rate for both genotypes (ICSH 86646 = 32 mm and M 35-1 = 52 mm). In dry plots, increased water use with increasing nitrogen application rates was higher in ICSH 86646, when compared to M 35-1 in both the years (Table 25, 26).

Cumulative light interception, radiation use efficiency and water use efficiency increased with nitrogen application in both irrigated and dry plots in all genotypes.

Summary and Conclusions

6.0 SUMMARY AND CONCLUSIONS

1. Total profile soil ammonical N was higher in the 120 kg N ha^{-1} treatment at sowing in both years. There was marked decline in all nitrogen treatments from sowing to anthesis stage in 1990-91 indicating conversion to nitrate N, but in 1991-92 the conversion was slower.
2. In 1990-91 the 20, 40 and 120 kg N ha^{-1} treatments had higher total profile ammonical N in irrigated plots, but in dry plots it was higher only in the 120 kg N ha^{-1} treatment. In 1991-92 only the 120 kg N ha^{-1} had significantly higher ammonical N values in irrigated and dry plots.
3. By harvest, in irrigated plots, most of the ammonical N was converted to nitrate nitrogen, but in dry plots a higher amount of ammonical N remained in the soil profile.
4. Applied nitrogen remained in the upper soil profile (0-30 cm), and the conversion of ammonical N to nitrate N was not complete at harvest.
5. Dry plots had higher nitrate N than irrigated plots at anthesis and harvest stages indicating lower uptake/lower N loss from the soil profile.
6. The 120 kg N ha^{-1} treatment maintained a higher nitrate N value at all stages of sampling and at harvest 78 ppm of nitrate N remained in the soil in dry plots. The remaining nitrate N indicates that N was not fully utilized by the crop. This is attributed to the receding soil moisture in the top soil layers.

7. Below 30 cm, available nitrate N was similar in both irrigated and dry plots, indicating that the differences were restricted to only the 0-30 cm layer.

8. Total available N (NH_4 + NO_3-N), was higher in all nitrogen treatments (20, 40 and 120 kg N ha^{-1}), in irrigated plots, while in dry plots the 40 and 120 kg N ha^{-1} treatments had higher values than the 0 and 20 kg N ha^{-1} treatments at sowing.

9. Dry plots, at harvest, had more than 120 ppm of total available N remaining in the soil profile indicating very low plant uptake and/or nitrogen loss. While in irrigated plots, it was almost half the value (60 ppm), indicating higher plant uptake and/or higher nitrogen loss.

10. Increased total above ground biomass due to water was 2.25 t ha^{-1}, while the difference in water use was 70 mm. Leaf area, leaf weight, stem weight, total vegetative dry matter, earhead and grain weight were all sensitive to water stress.

11. The differentiation in to reproductive organs was less sensitive to water, as indicated by similar secondary rachis number and grain number. The grain filling process, was greatly affected by water stress as indicated by secondary rachis weight.

12. Increased total nitrogen uptake due to irrigation was to an extent of 45 kg N ha^{-1} and most of it was accumulated in the grain. In terms of quality, water increased the leaf, stem and grain nitrogen content.

13. Cumulative light interception and radiation use efficiency increased with irrigation, this resulted in a higher total above ground biomass. The distribution ratio of vegetative and reproductive organs remained similar in irrigated plots, while it differred in dry plots.

14. Nitrogen significantly influenced measured growth parameters like plant height, leaf area index, leaf weight, stem yield, earhead and grain yield. The 40 and 120 kg N ha^{-1} treatments had similar total vegetative dry matter and earhead yields in 1990-91, in 1991-92 only the 120 kg N ha^{-1} treatment had higher values.

15. The 120 kg N ha^{-1} had higher leaf, stem and grain nitrogen uptake with most of the increased nitrogen accumulated in the grain.

16. In both years, cumulative light interception increased with increasing nitrogen application rates, which was due to increased in leaf area index with higher N application rates.

17. A linear relationship was established between specific leaf nitrogen and RUE in M 35-1, which indicates that nitrogen not only increases light interception but also influences RUE, which in turn is related to total biomass production.

18. M 35-1 had a higher total biomass than ICSH 86646 and SPV 783, while partitioning towards earhead was lowest in M 35-1 (HI=0.30), it was highest in ICSH 86646 (HI=0.52) and intermediary in SPV 783 (HI=0.44).

19. Of the total nitrogen uptake, both the improved genotypes ICSH 86646 and SPV 783 had higher nitrogen in the grain when compared to M 35-1 which had higher stem N. In terms of quality M 35-1 had higher leaf, stem and grain nitrogen content when compared to ICSH 86646 and SPV 783.

20. Water use was similar in ICSH 86646 and M 35-1, while cumulative light interception and RUE was higher in M 35-1 which ultimately resulted in higher total above ground biomass.

21. In irrigated plots, the 40 kg N ha^{-1} treatment maintained similar biomass production up to 70 DAE and there after only the 120 kg N ha^{-1} had higher total biomass production. In dry plots only the 120 kg N ha^{-1} had higher total biomass production throughout the crop growth period. In terms of earhead and grain yields, the results were similar to total biomass production.

22. Increased nitrogen uptake due to irrigation was 10, 32, 34 and 75 kg ha^{-1} for the 0, 20, 40 and 120 kg N ha^{-1} rates when compared to the same treatments in dry plots.

23. The interaction of water and nitrogen resulted in an increase in radiation use efficiency and water use efficiency. Nitrogen increased water use efficiency by 19 kg mm^{-1} of water in irrigated plots, while in dry plots it increased by 9 kg mm^{-1}.

24. ICSH 86646 and SPV 783 produced higher total biomass, stalk, earhead and grain yield in irrigated plots when compared to M 35-1, which had

higher values in dry plots. This was due to higher RUE of improved genotypes in irrigated plots, while M 35-1 had higher RUE in dry plots.

25. Both ICSH 86646 and M 35-1 had higher total nitrogen uptake in irrigated plots, while in dry plots only M 35-1 had higher total nitrogen uptake. Since water use was similar in both these genotypes, higher N uptake by M 35-1 is attributed to higher N absorption per unit volume of water intake (i.e., higher root uptake efficiency).

26. At lower levels of nitrogen application (0 and 20 kg N ha^{-1}), ICSH 86646 and SPV 783 produced higher total biomass, while at the higher levels of 40 and 120 kg N ha^{-1} SPV 783 and M 35-1 had higher values.

27. ICSH 86646 at the 0, 20 and 40 kg N ha^{-1} had the highest total nitrogen and potassium uptake, while at the 120 kg N ha^{-1}, M 35-1 had higher values.

28. In irrigated plots, improved genotypes had higher earhead and grain yields at all N application rates, while M 35-1 had higher vegetative dry matter in the 40 and 120 kg N ha^{-1} treatments. In dry plots, all genotypes had similar earhead and grain yields at the lower rates of 0, 20 and 40 kg N ha^{-1} and M 35-1 had higher earhead, grain and total vegetative dry matter in the 120 kg N ha^{-1} treatment.

29. The nutrient uptake pattern (N and K) was governed by the trend in total dry matter production, rather than a trend in nutrient concentration.

30. Nitrogen application increased the water use efficiency and radiation use efficiency in both irrigated and dry plots for all genotypes.

31. RESCAP model over estimated total biomass production (g m^{-2}), in the early stages of crop growth in both irrigated and dry plots. The simulated value were similar to observed value in irrigated plots, but they were different in dry plots.

32. The relationship between simulated and observed total biomass production had a higher regression coefficient value in irrigated plots (0.93), while in dry plots it was 0.85.

33. Total biomass and grain yield (t ha^{-1}), were overestimated by the RESCAP model in both irrigated and dry plots, while harvest index was correctly predicted.

34. Rabi sorghum genotypes did respond to applied nitrogen in terms of total above-ground biomass and grain yield. Irrigation improved the extent of response greatly. In dry plots 20 and 40 kg N ha^{-1} rates had the lowest influence on crop growth and yield. ICSH 86646 and SPV 783 response was greater to irrigation and nitrogen application, while M 35-1 performed better under dry conditions.

35. Applied nitrogen remained unutilised under dry conditions and seasonal application of N fertilizer may not be a good recomendation to farmers as receding moisture leaves the applied nitrogen in the top soil profile. Methods to improve the fertility status of the deeper soil layers on a long term basis in the cropping system should be further investigated.

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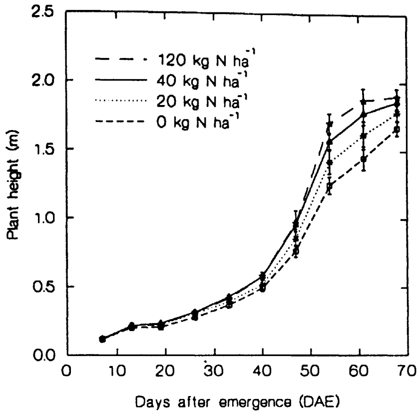
Fig : A 1.2. **Plant height of sorghum as a function of time for the interaction effect of nitrogen * time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

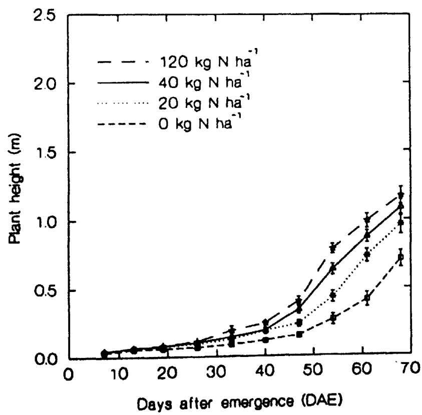
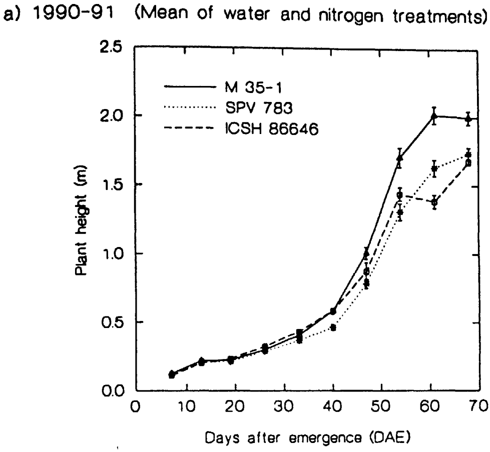


Fig : A 1.3. Plant height of sorghum as a function of time for the interaction effect of genotype * time, during rabi 1990-91 and 1991-92.



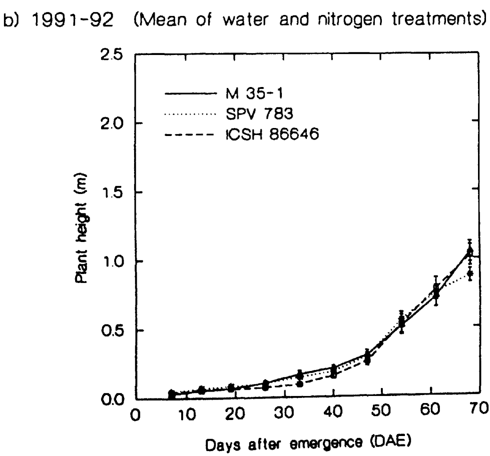
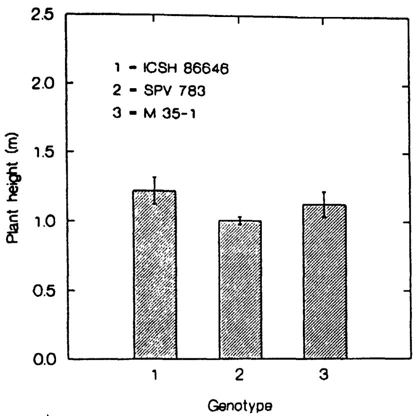


Fig : A 1.4. Plant height of sorghum for the interaction effect of water * genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

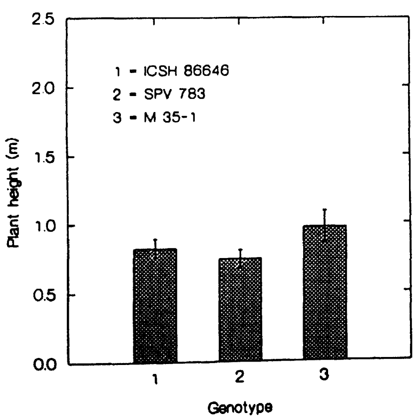
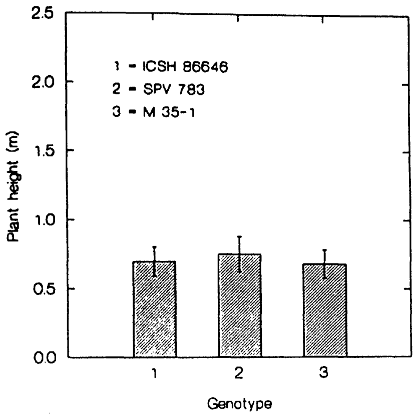


Fig : A 1.5. Plant height of sorghum for the interaction effect of nitrogen * genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} at harvest during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

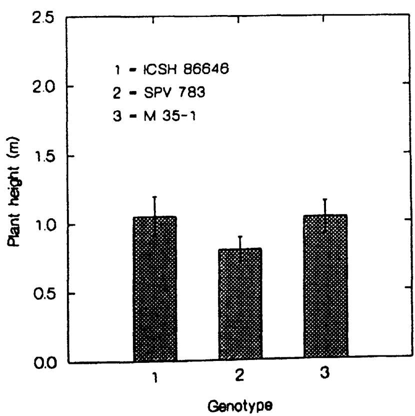
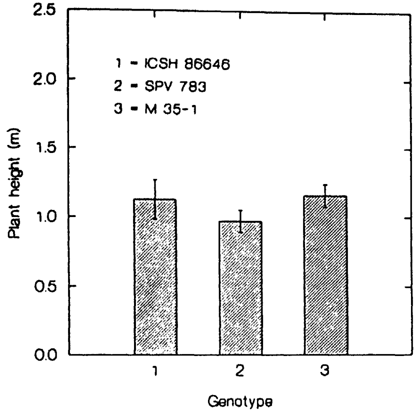


Fig : A 1.6. Plant height of sorghum for the interaction effect of nitrogen * genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} at harvest during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



d) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

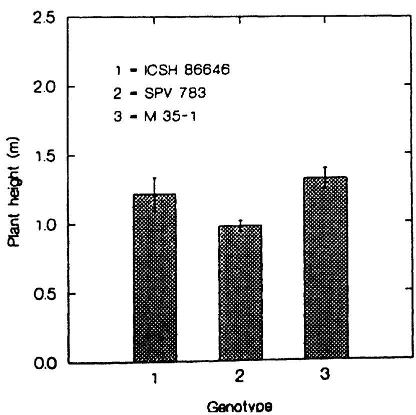
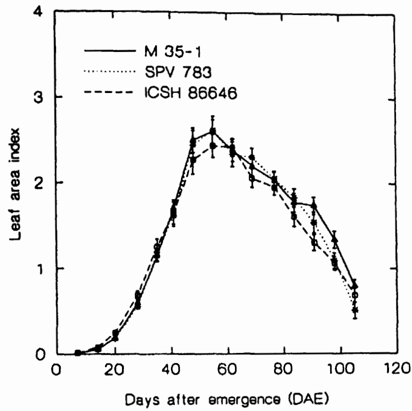


Fig : A 1.9. Leaf area index of sorghum as a function of time for the interaction effect of genotype * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

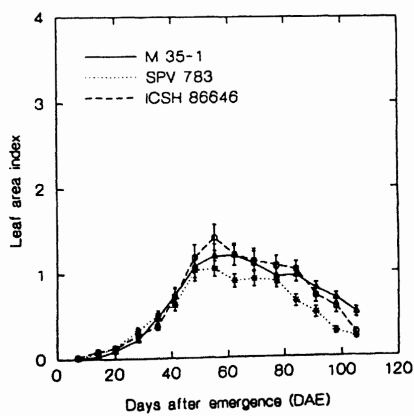
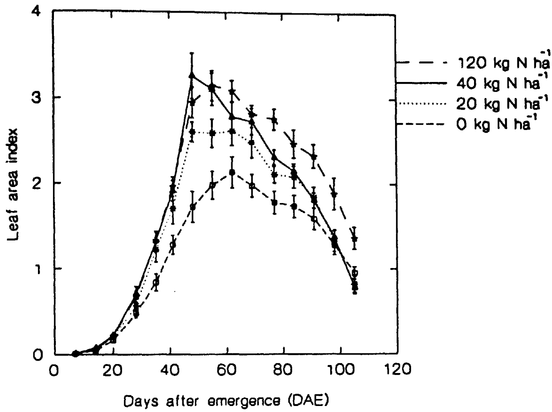


Fig : A 1.10. Leaf area index of sorghum as a function of time for the interaction effect of water * nitrogen * time, in a) Irrigated and b) Dry plots during rabi 1990-91.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

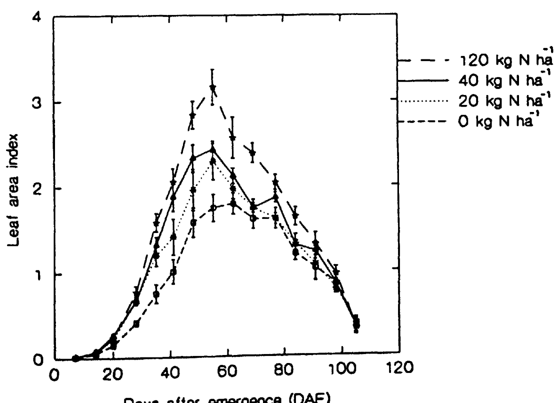
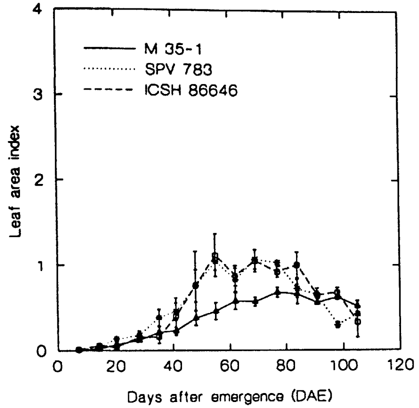


Fig : A 1.13. Leaf area index of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen * genotype * time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

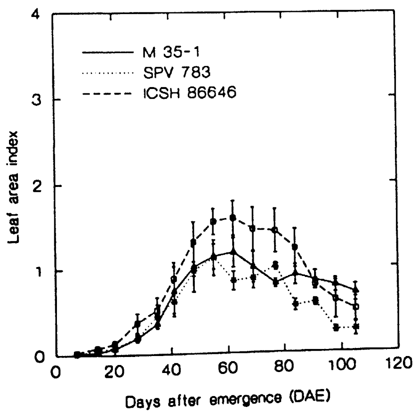
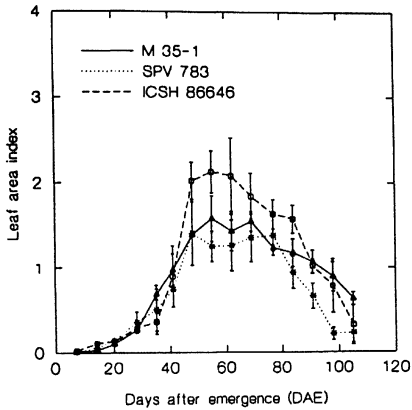


Fig : A 1.14. Leaf area index of sorghum as a function of time in irrigated plots for he interaction effect of water, nitrogen * genotype * time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

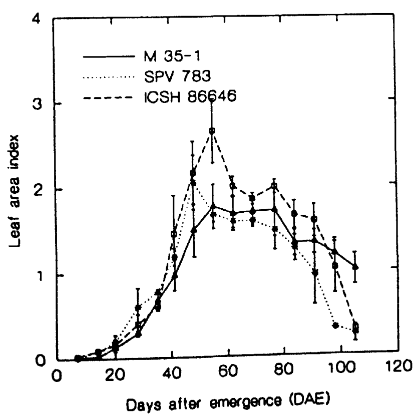
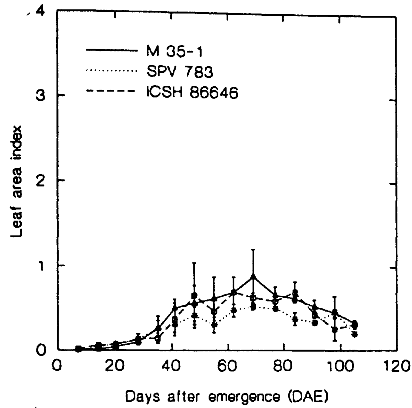


Fig : A 1.15. Leaf area index of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen * genotype * time, a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

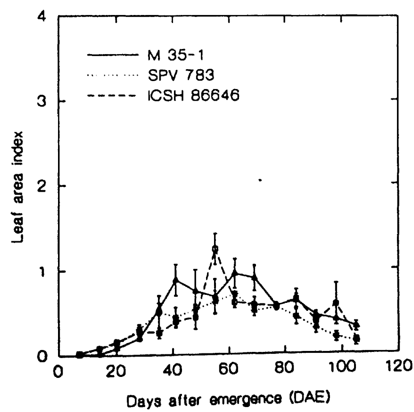
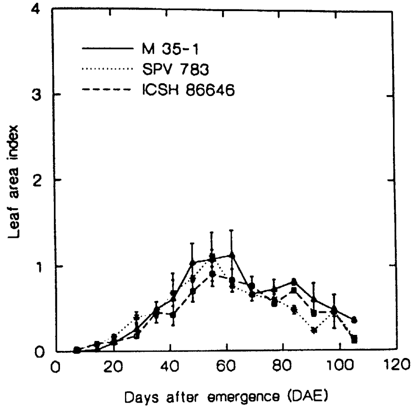


Fig : A 1.16. Leaf area index of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen * genotype * time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

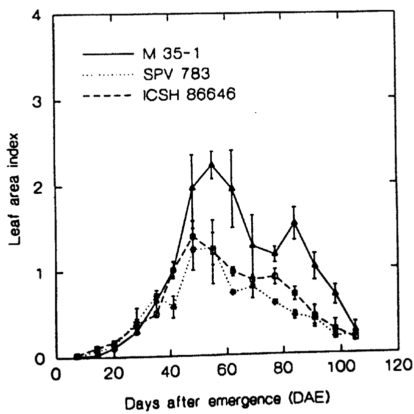
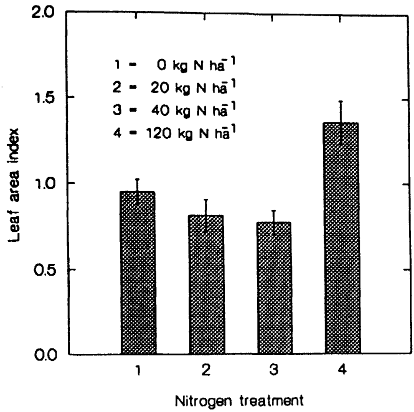


Fig : A 1.17. Leaf area index of sorghum for the interaction effect of water * nitrogen, at harvest in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean genotype treatments in 1991-92)



b) Dry (Mean genotype treatments in 1991-92)

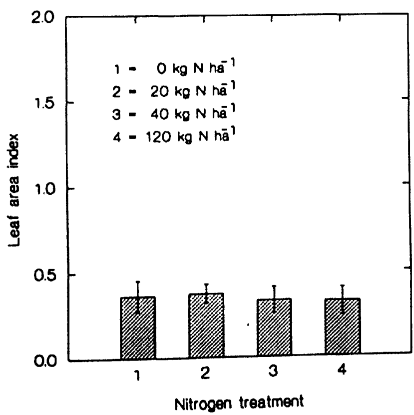
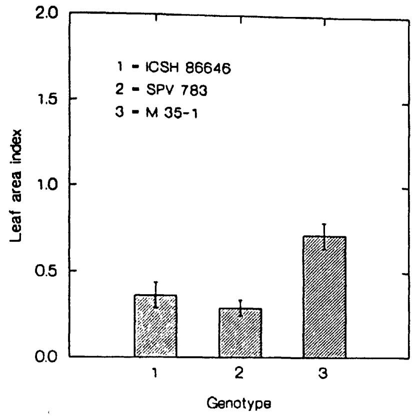


Fig : A 1.18. Leaf area index of sorghum for the interaction effect of water * genotype, at harvest in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

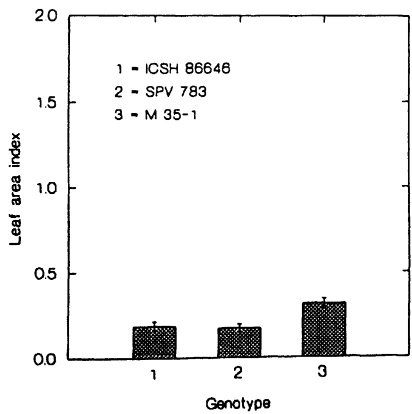
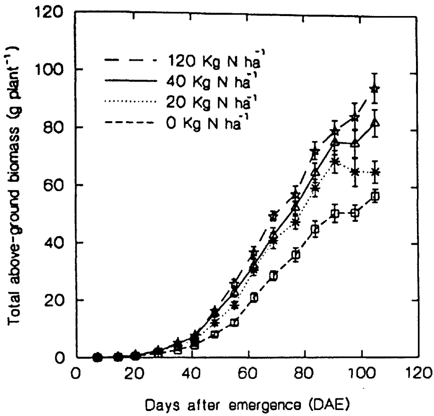


Fig : A 1.20. Total above ground biomass of sorghum as a function of time for the interaction effect of nitrogen * time during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

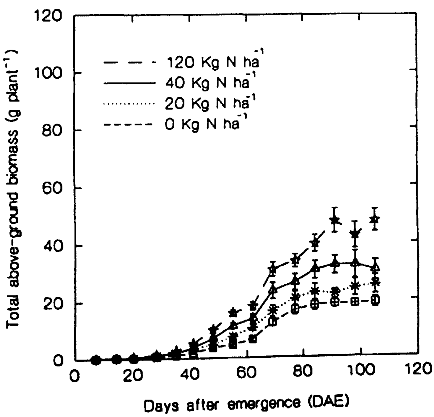
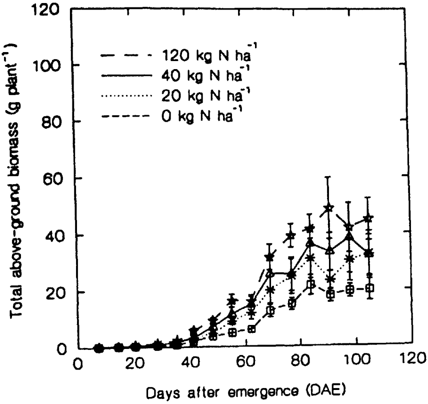


Fig : A 1.24. Total above ground biomass of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of water treatments in 1991-92)



b) SPV 783 (Mean of water treatments in 1991-92)

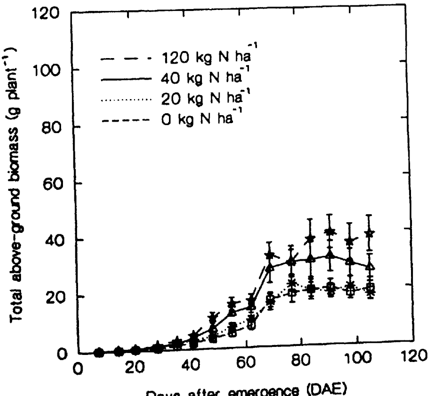


Fig : A 1.25. Total above ground biomass of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

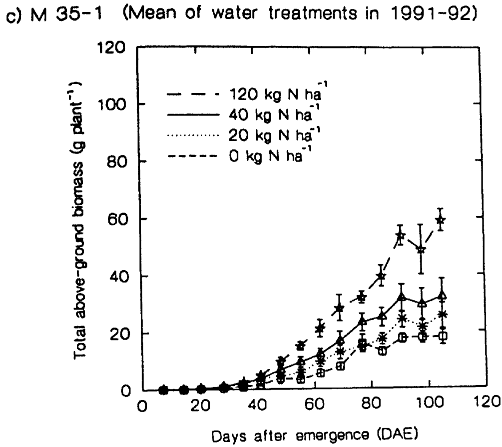
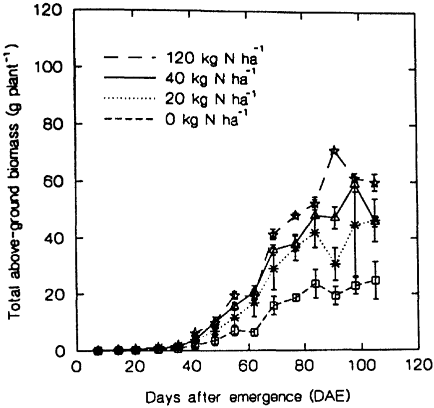


Fig : A 1.26. Total above ground biomass of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for irrigated plots in 1991-92)



b) SPV 783 (Mean of replications for irrigated plots in 1991-92)

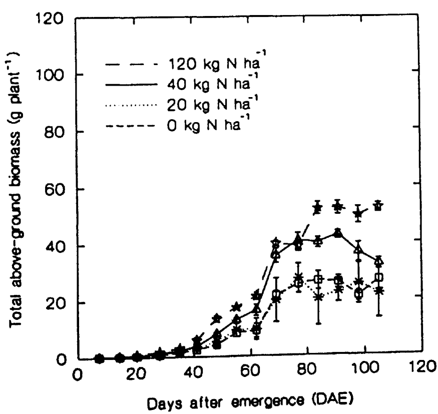


Fig : A 1.27. Total above ground biomass of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype time, in c) M 35-1 genotype during rabi 1991-92.

c) M 35-1 (Mean of replications for irrigated plots in 1991-92)

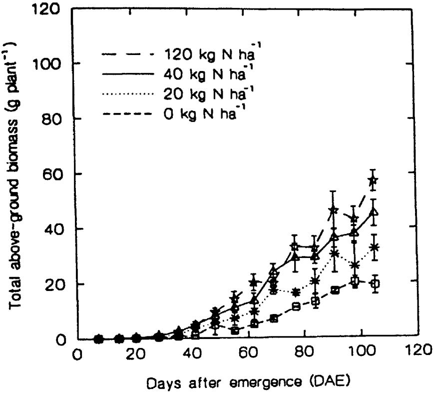
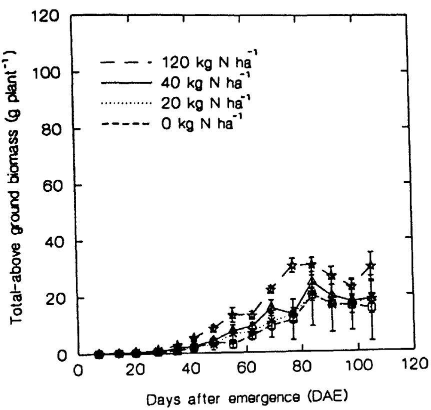


Fig : A 1.28. Total above ground biomass of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for dry plots in 1991-92)



b) SPV 783 (Mean of replications for dry plots in 1991-92)

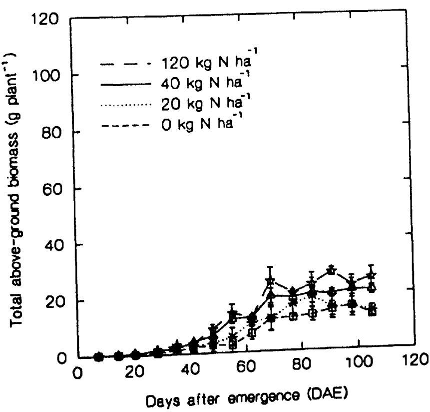


Fig : A 1.29. Total above ground biomass of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

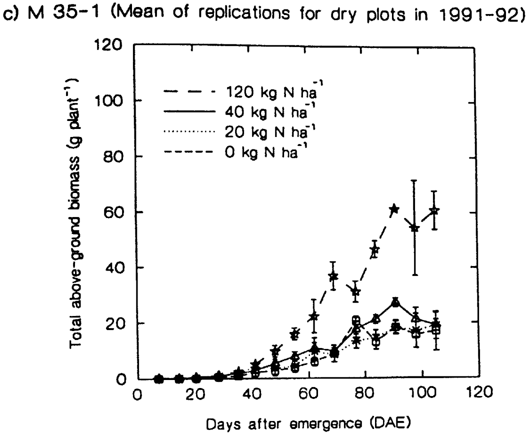
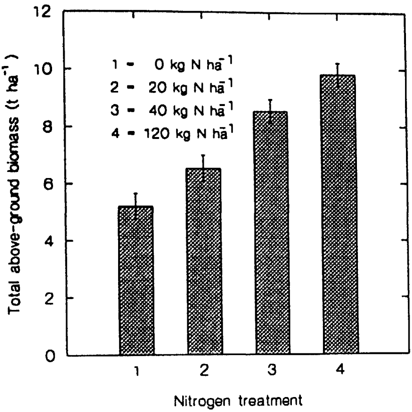


Fig : A 1.30. Total above ground biomass of sorghum for the interaction effect of water * nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

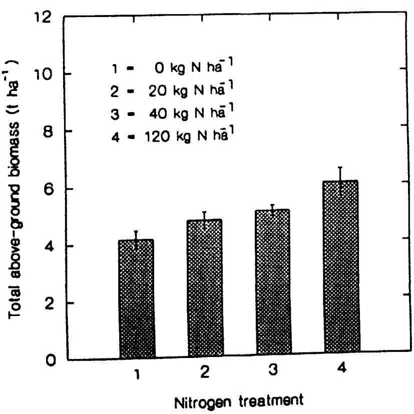
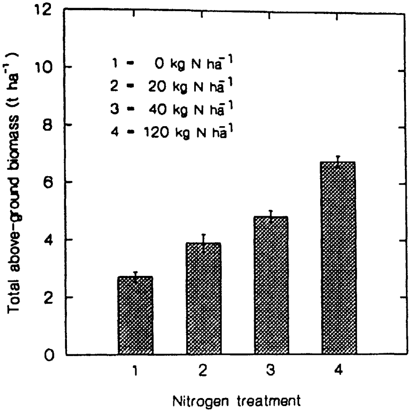


Fig : A 1.31. Total above ground biomass of sorghum for the interaction effect of water * nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

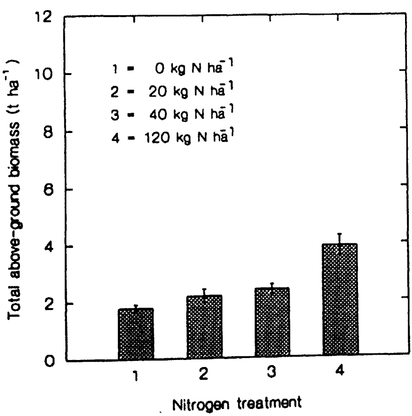
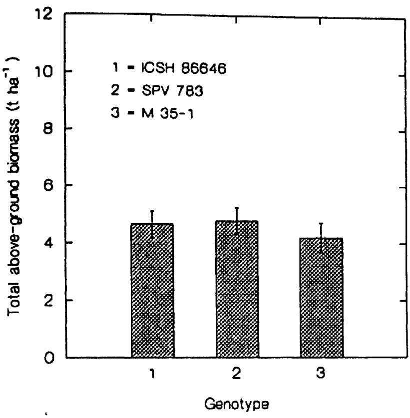


Fig : A 1.32. Total above ground biomass of sorghum for the interaction effect of water * genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

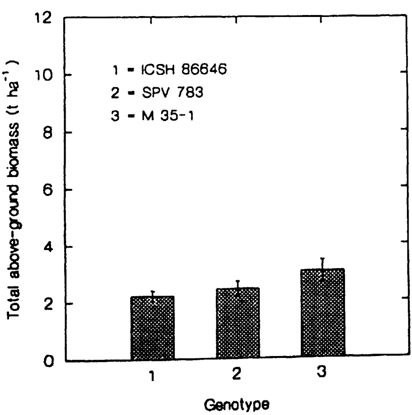
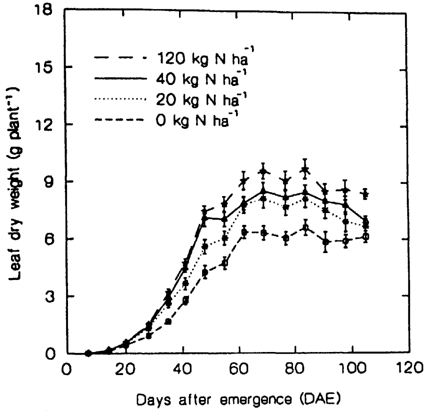


Fig : A 1.36. Leaf dry weight of sorghum as a function of time for the interaction effect of nitrogen * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

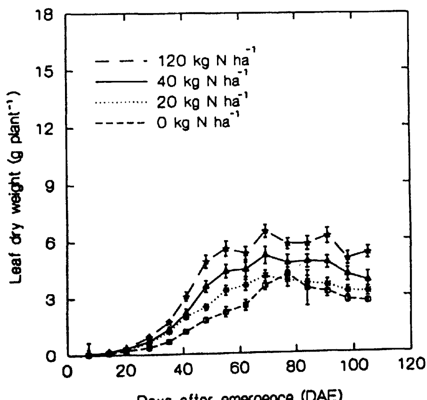
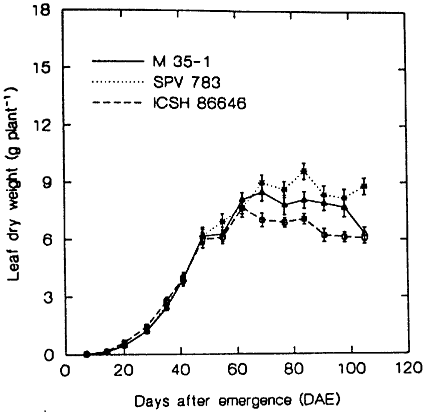


Fig : A 1.37. Leaf dry weight of sorghum as a function of time for the interaction effect of genotype * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

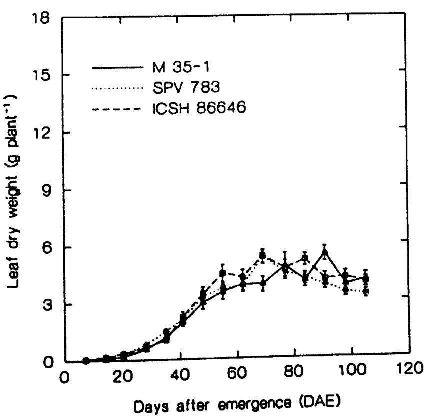
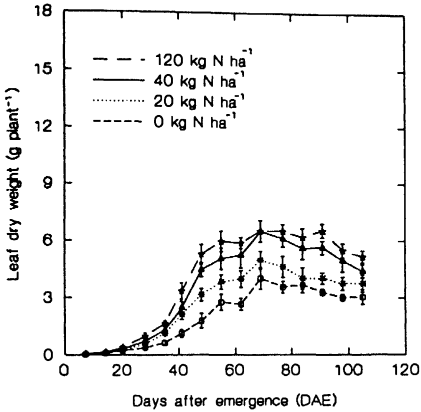


Fig : A 1.38. Leaf dry weight of sorghum as a function of time for the interaction effect of water * nitrogen * time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

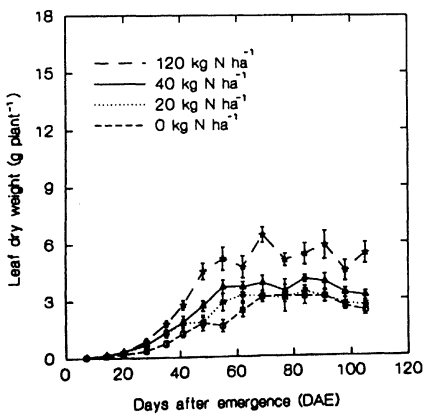
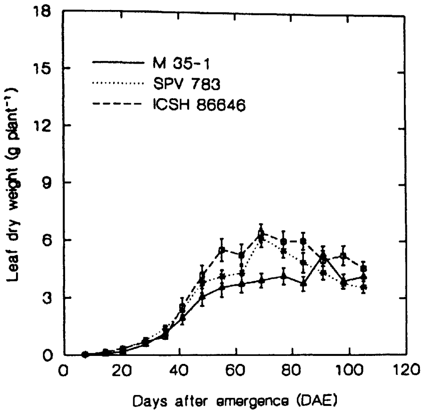


Fig : A 1.39. Leaf dry weight of sorghum as a function of time for the interaction effect of water * genotype * time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

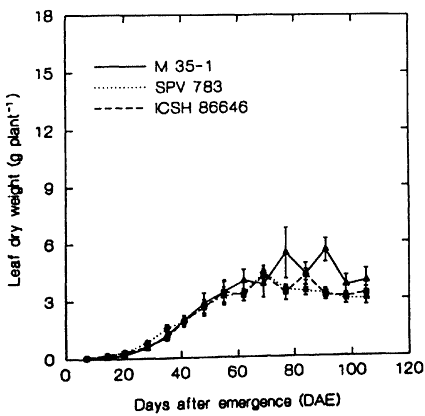
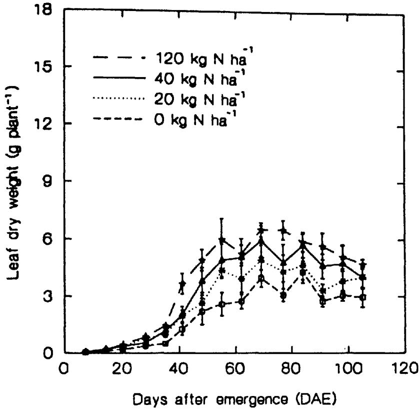


Fig : A 1.40. Leaf dry weight of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of water treatments in 1991-92)



b) SPV 783 (Mean of water treatments in 1991-92)

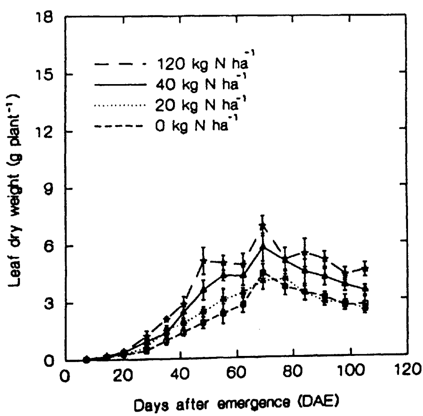


Fig : A 1.41. Leaf dry weight of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

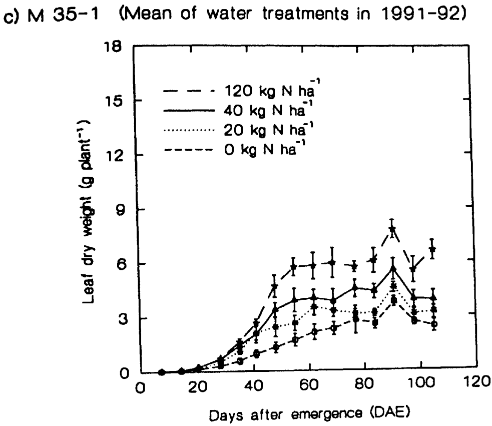
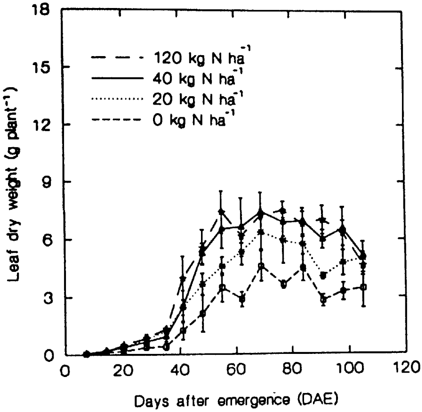


Fig : A 1.42. Leaf dry weight of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for irrigated plots in 1991-92)



b) SPV 783 (Mean of replications for irrigated plots in 1991-92)

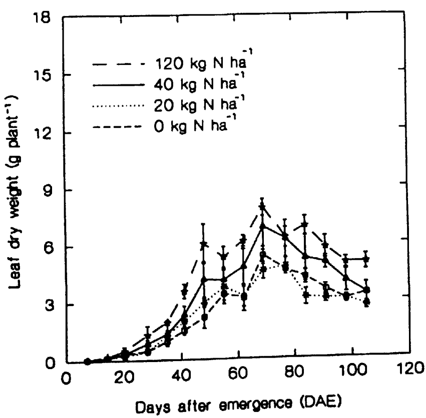


Fig : A 1.43. Leaf dry weight of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

c) M 35-1 (Mean of replications for irrigated plots in 1991-92)

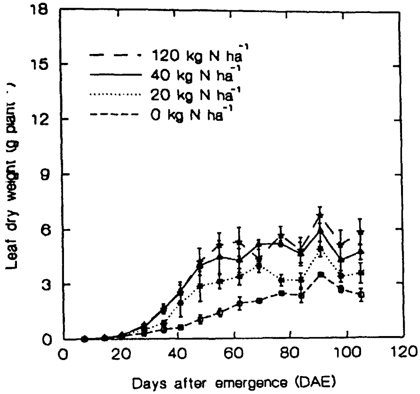
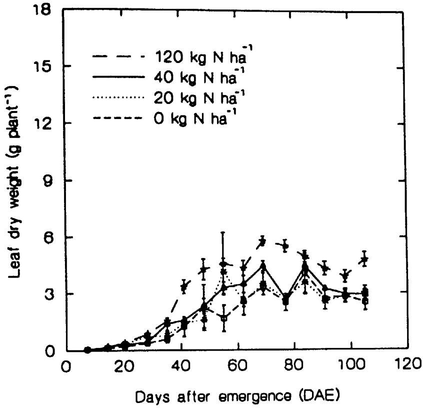


Fig : A 1.44. Leaf dry weight of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for dry plots in 1991-92)



b) SPV 783 (Mean of replications for dry plots in 1991-92)

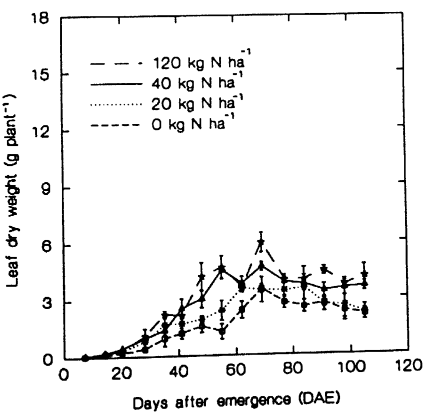


Fig : A 1.45. Leaf dry weight of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

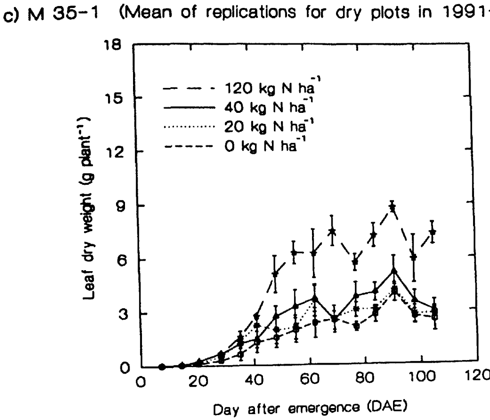


Fig : A 1.46. Leaf dry weight of sorghum for the interaction effect of nitrogen * genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest during rabi 1991-92.

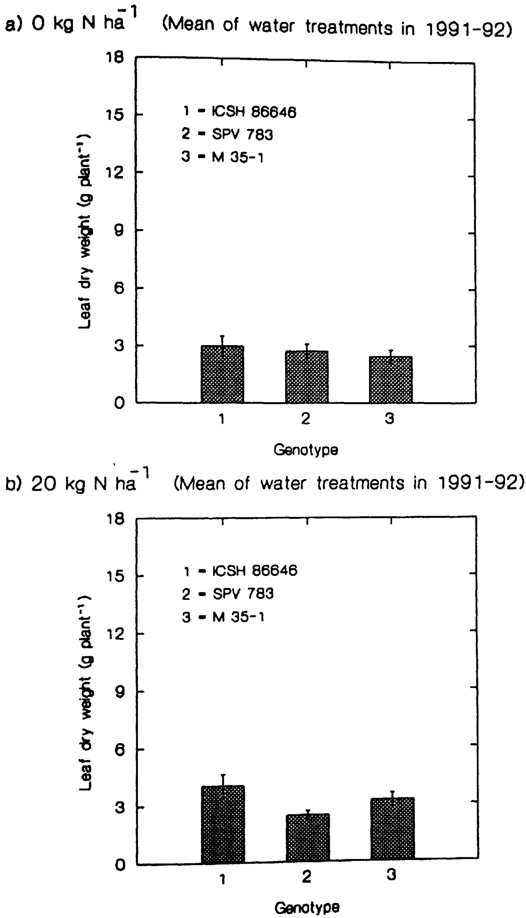
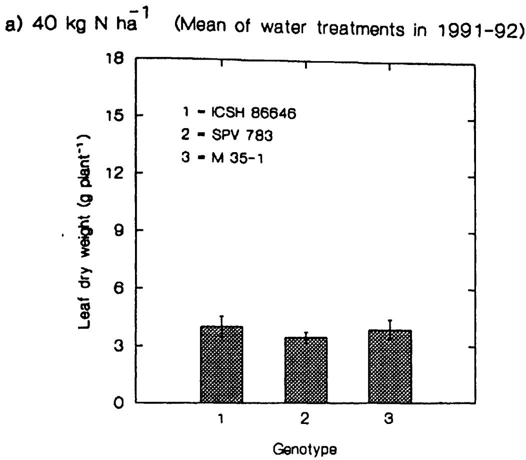


Fig : A 1.47. Leaf dry weight of sorghum for the interaction effect of nitrogen * genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest during rabi 1991-92.



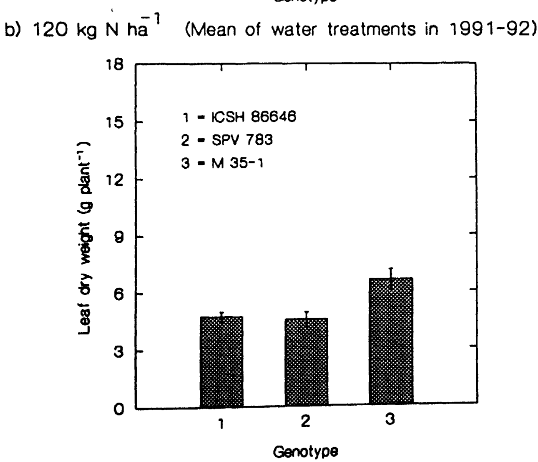
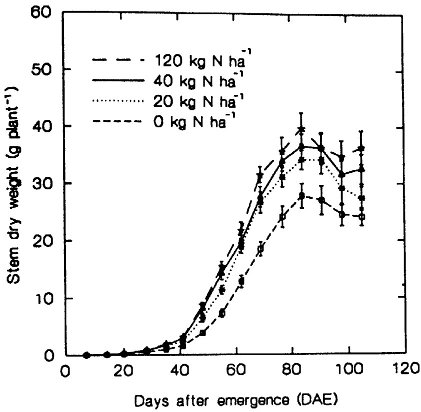


Fig : A 1.49. Stem dry weight of sorghum as a function of time for the interaction effect of nitrogen * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

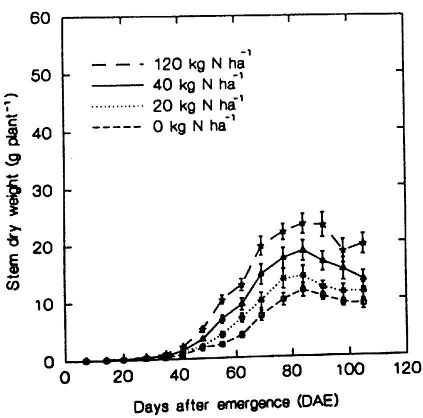
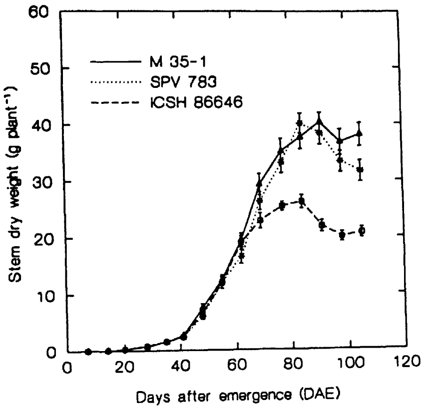


Fig : A 1.50. Stem dry weight of sorghum as a function of time for the interaction effect of genotype * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

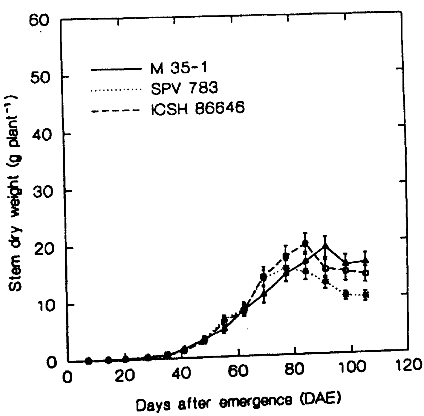
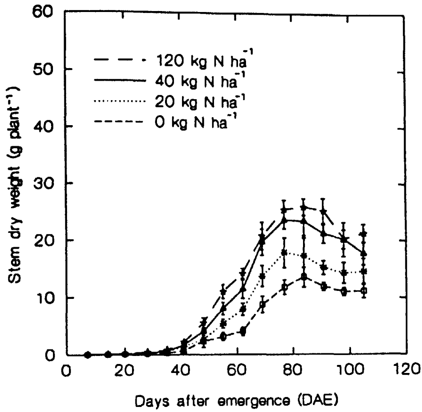


Fig : A 1.51. Stem dry weight of sorghum as a function of time for the interaction effect of water * nitrogen * time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

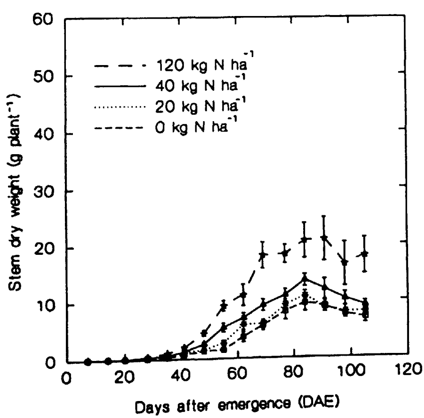
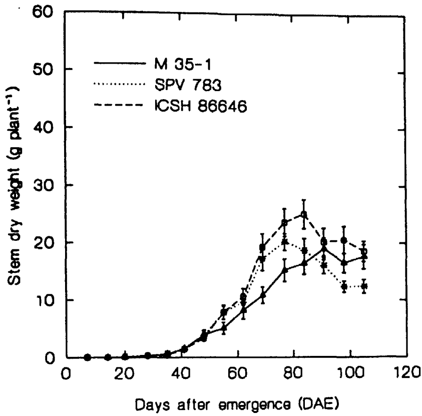


Fig : A 1.52. Stem dry weight of sorghum as a function of time for the interaction effect of water * genotype * time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

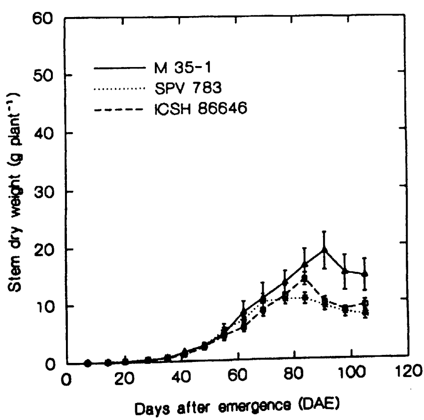
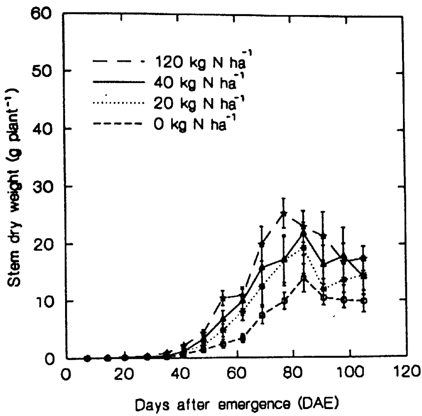


Fig : A 1.53. Stem dry weight of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of water treatments in 1991-92)



b) SPV 783 (Mean of water treatments in 1991-92)

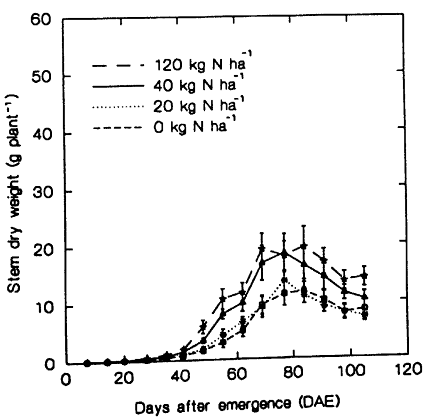


Fig : A 1.54. Stem dry weight of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

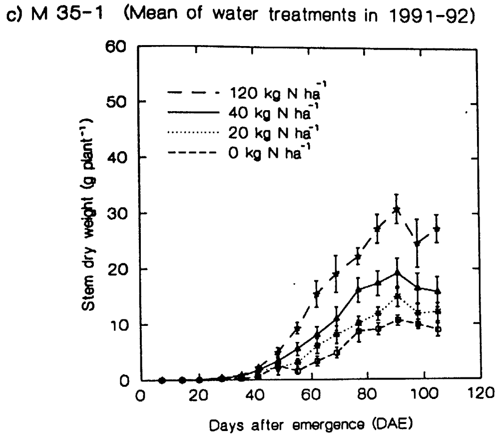
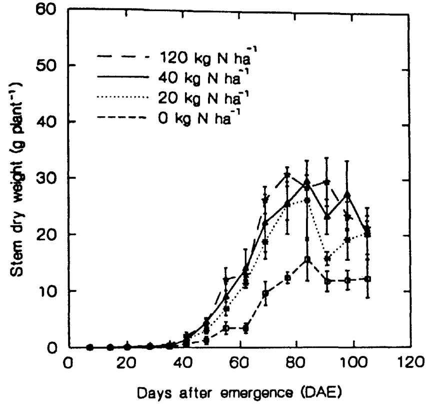


Fig : A 1.55. Stem dry weight of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for irrigated plots in 1991-92)



b) SPV 783 (Mean of replications for irrigated plots in 1991-92)

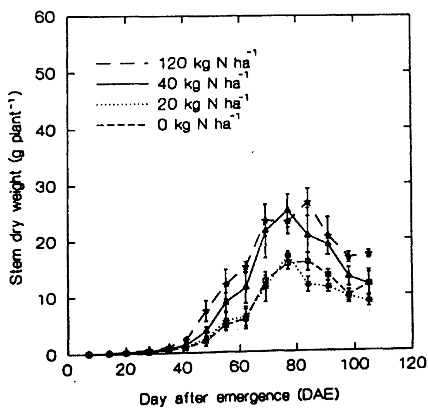


Fig : A 1.56. Stem dry weight of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

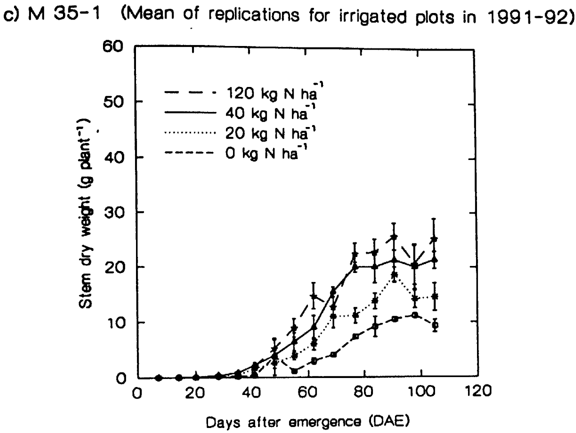
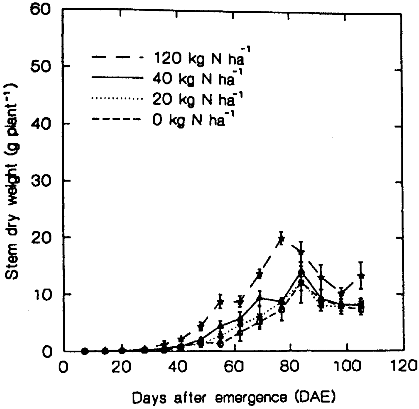


Fig : A 1.57. Stem dry weight of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for dry plots in 1991-92)



b) SPV 783 (Mean of replications for dry plots in 1991-92)

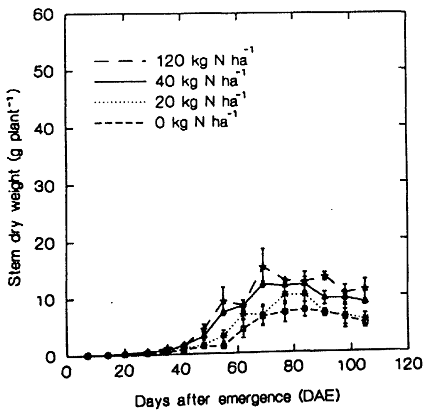


Fig : A 1.58. Stem dry weight in sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

c) M 35-1 (Mean of replications for dry plots in 1991-92)

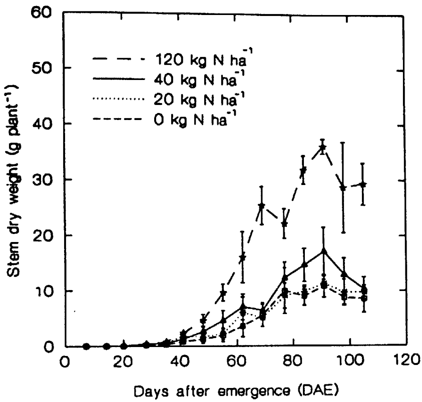
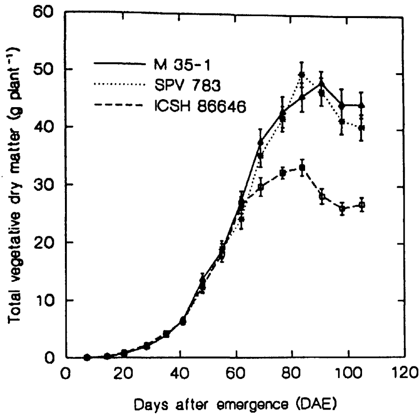


Fig : A 1.62. Total above ground vegetative dry matter of sorghum as a function of time for the interaction effect of genotype * time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

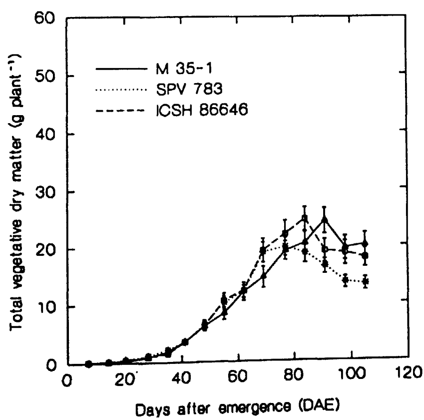
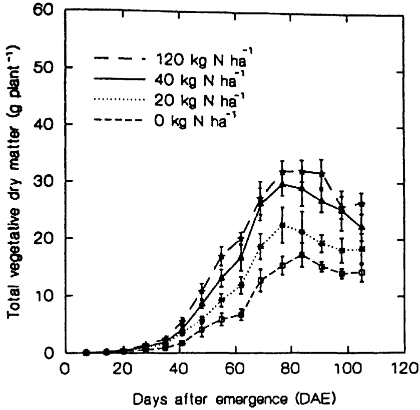


Fig : A 1.63. Total above ground vegetative dry matter of sorghum as a function of time for the interaction effect of water * nitrogen * time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

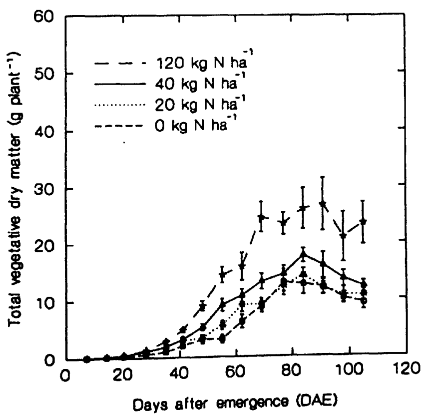
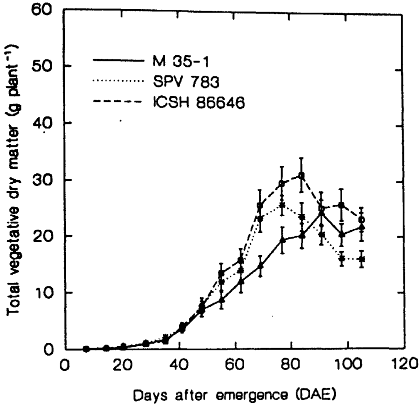


Fig : A 1.64. Total above ground vegetative dry matter of sorghum as a function of time for the interaction effect of water * genotype * time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

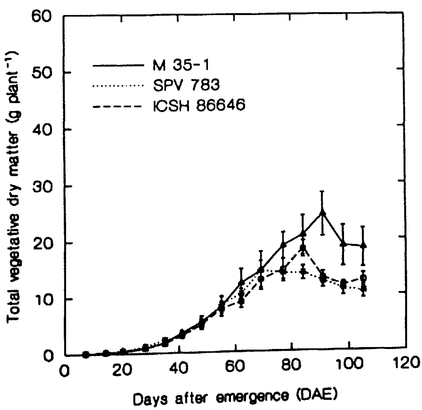
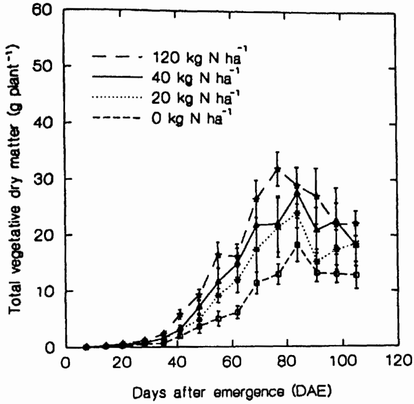


Fig : A 1.65. Total above ground vegetative dry matter of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of water treatments in 1991-92)



b) SPV 783 (Mean of water treatments in 1991-92)

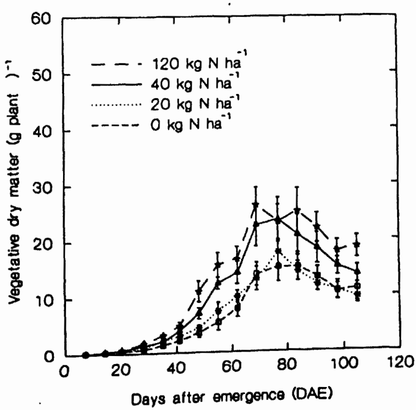


Fig : A 1.66. Total above ground vegetative dry matter of sorghum as a function of time for the interaction effect of nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

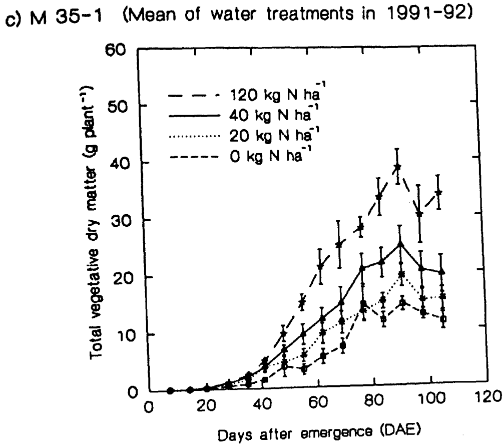
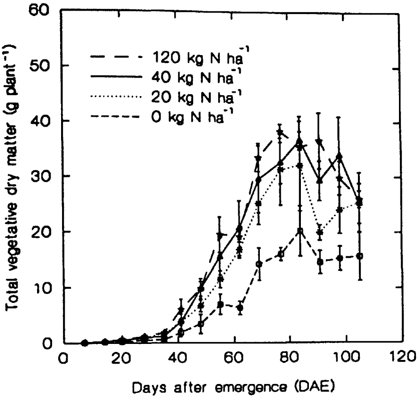


Fig : A 1.67. Total above ground vegetative dry matter of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for irrigated plots in 1991-92)



b) SPV 783 (Mean of replications for irrigated plots in 1991-92)

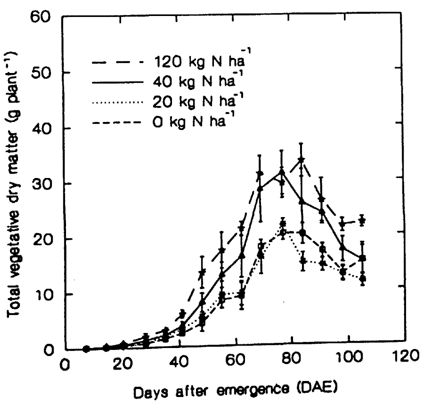


Fig : A 1.68. Total above ground vegetative dry matter of sorghum as a function of time in irrigated plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

c) M 35-1 (Mean of replications for irrigated plots in 1991-92)

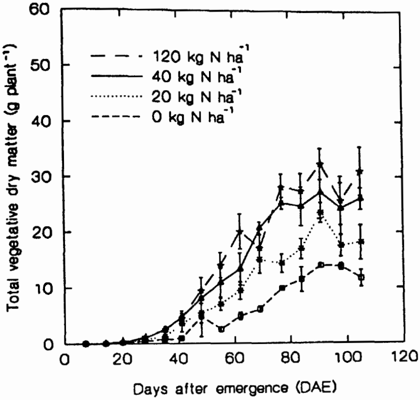
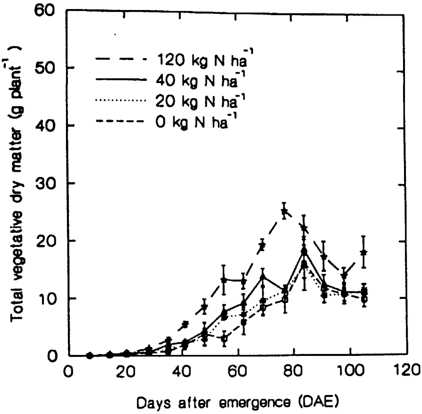


Fig : A 1.69. Total above ground vegetative dry matter of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in a) ICSH 86646 and b) SPV 783 genotypes during rabi 1991-92.

a) ICSH 86646 (Mean of replications for dry plots in 1991-92)



b) SPV 783 (Mean of replications for dry plots in 1991-92)

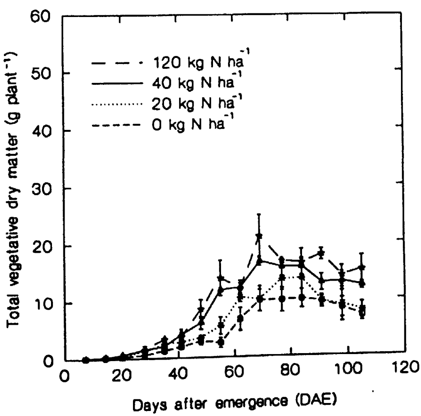


Fig : A 1.70. Total above ground vegetative dry matter of sorghum as a function of time in dry plots for the interaction effect of water * nitrogen * genotype * time, in c) M 35-1 genotype during rabi 1991-92.

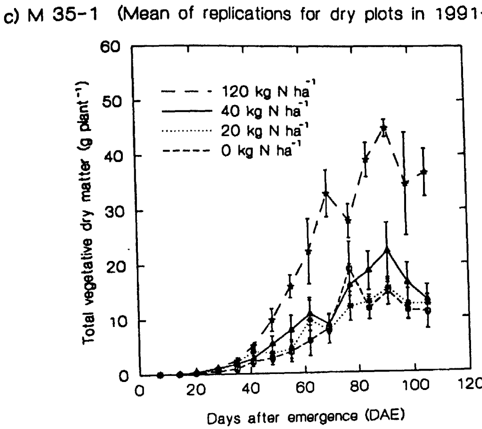
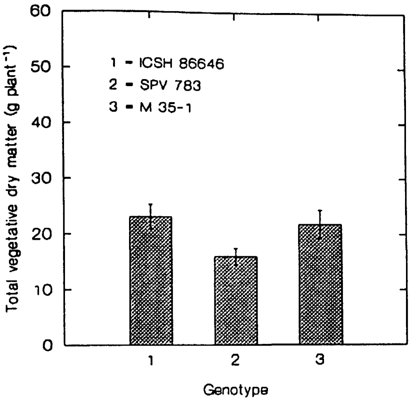


Fig : A 1.71. Total above ground vegetative dry matter of sorghum for the interaction effect of water * genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

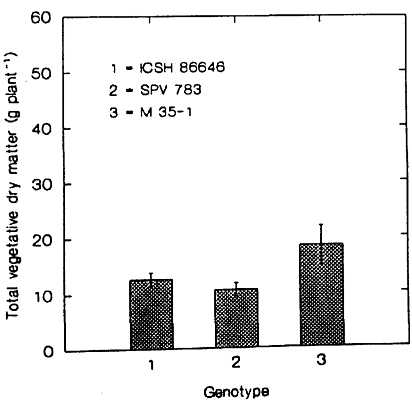
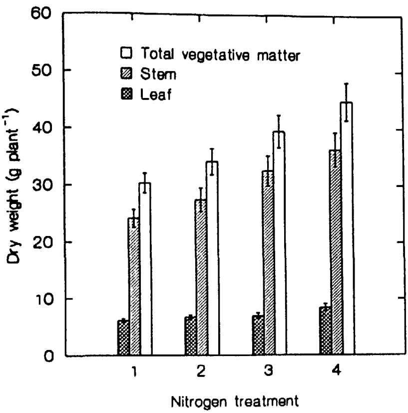


Fig : A 1.75. Dry matter distribution of sorghum in different nitrogen treatments at harvest during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

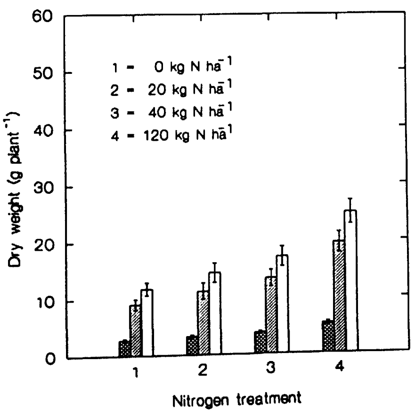
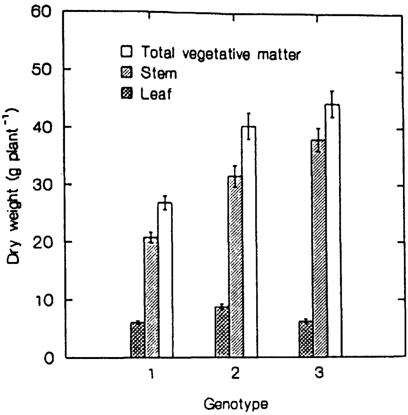


Fig : A 1.76. Dry matter distribution of sorghum genotypes ICSH 86646, SPV 783 and M 35-1 at harvest during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

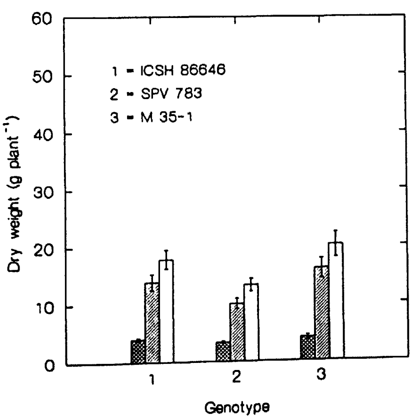
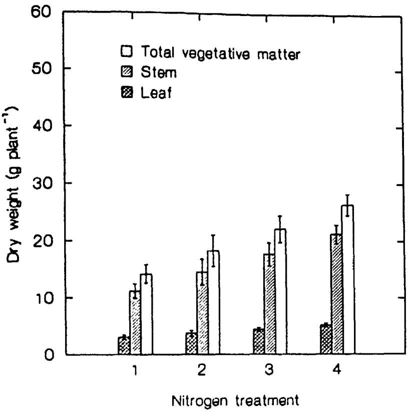


Fig : A 1.77. Dry matter distribution in sorghum for the interaction effect of water * nitrogen at harvest in a) irrigated and b) dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

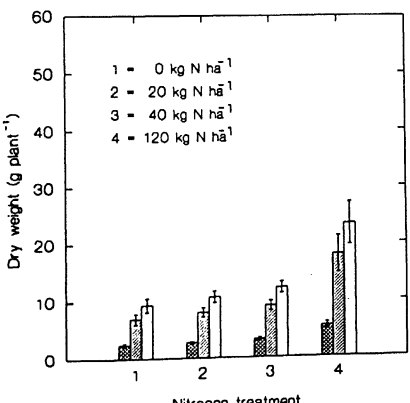
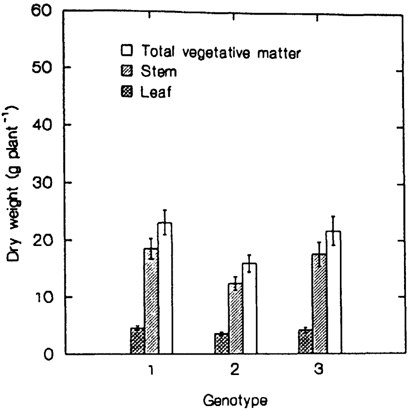


Fig : A 1.78. Dry matter distribution in sorghum for the interaction effect of water * genotype at harvest in a) irrigated and b) dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

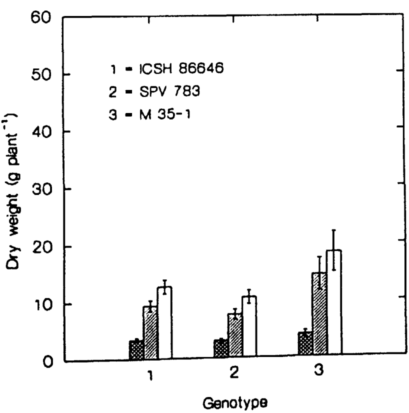
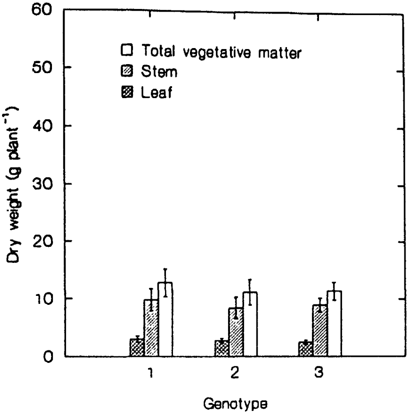


Fig : A 1.79. Dry matter distribution in sorghum for the interaction effect of nitrogen * genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

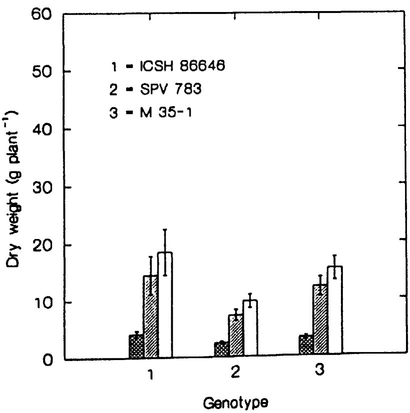
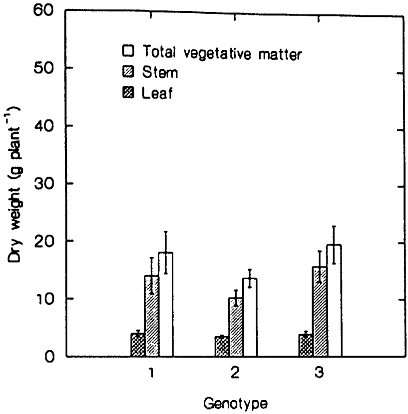


Fig : A 1.80. Dry matter distribution in sorghum for the interaction effect of nitrogen * genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



d) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

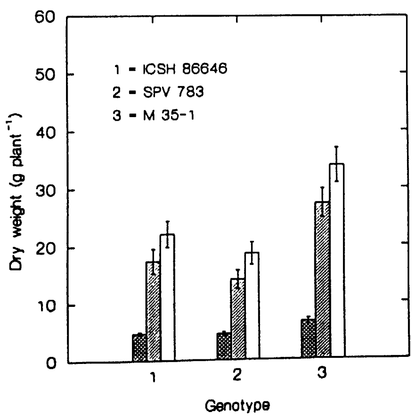
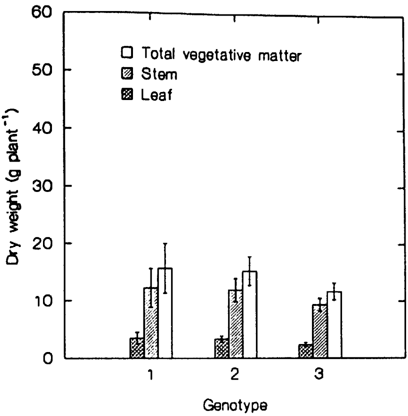


Fig : A 1.81. Dry matter distribution in sorghum in irrigated plots for the interaction effect of water * nitrogen * genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

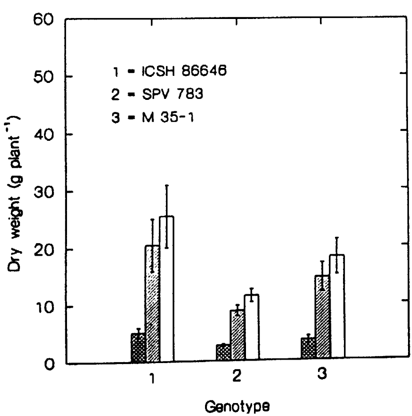
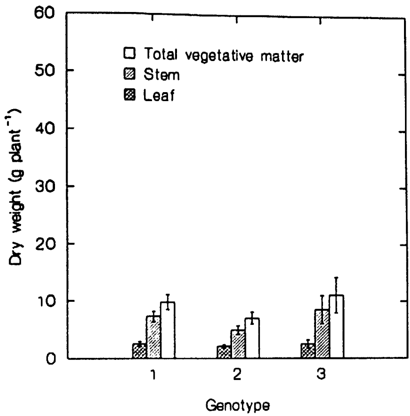


Fig : A 1.82. Dry matter distribution in sorghum in irrigated plots for the interaction effect of water * nitrogen * genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

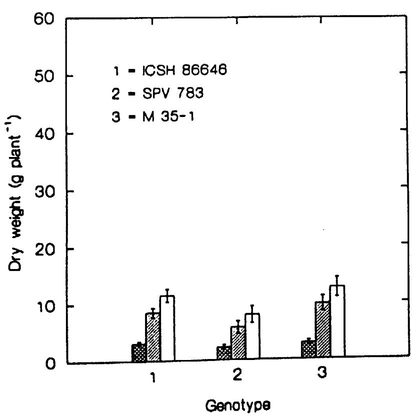


Fig : A 1.83. Dry matter distribution in sorghum in dry plots for the interaction effect of water * nitrogen * genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} in 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

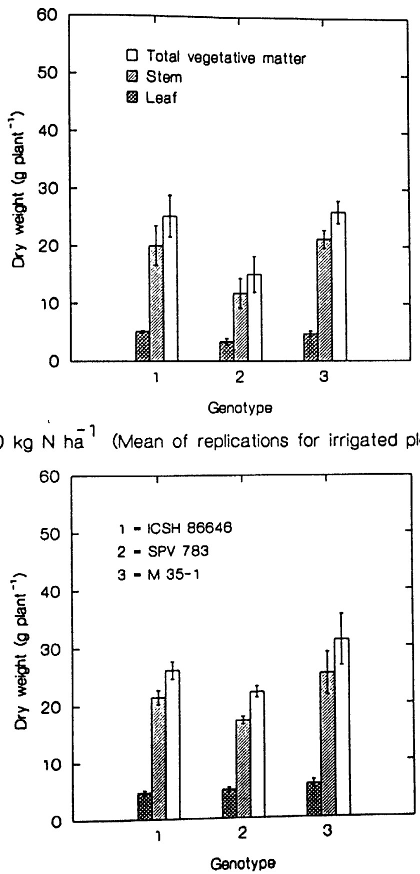
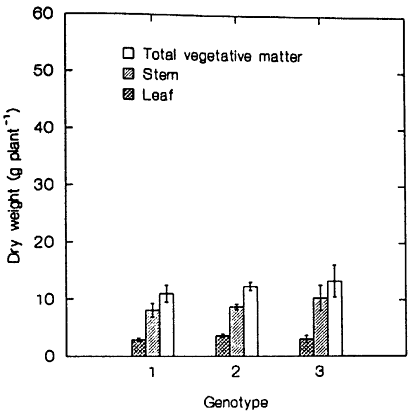


Fig : A 1.84. Dry matter distribution in sorghum in dry plots for the interaction effect of water * nitrogen * genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

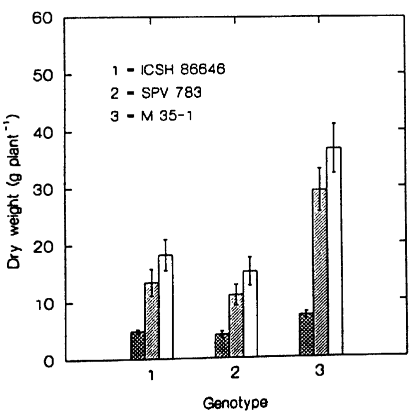
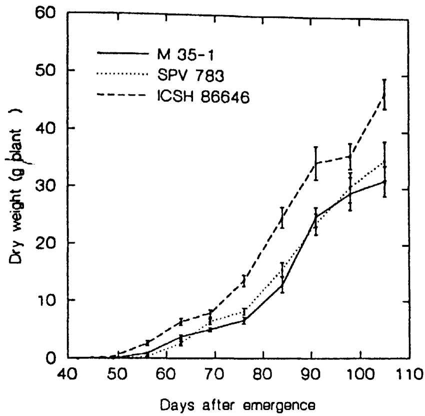


Fig : A 1.87. Total dry earhead and grain weight of sorghum as a function of time for the interaction effect of genotype * time, during rabi 1990-91.

a) Earhead



b) Grain

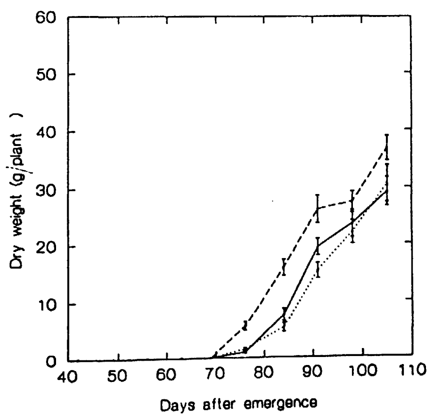
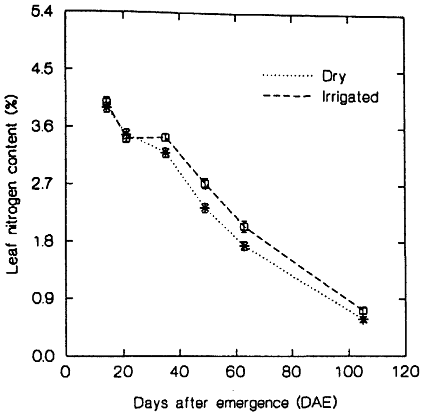


Fig : A 2.1. **Leaf nitrogen content of sorghum as a function of time for the interaction effect of water and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)

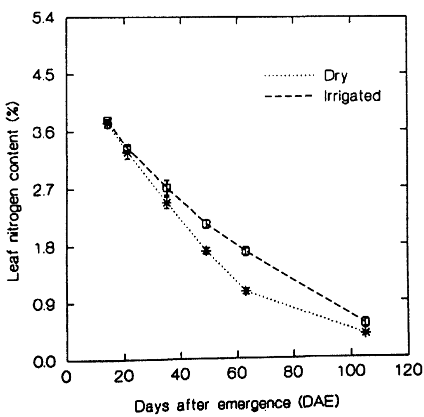
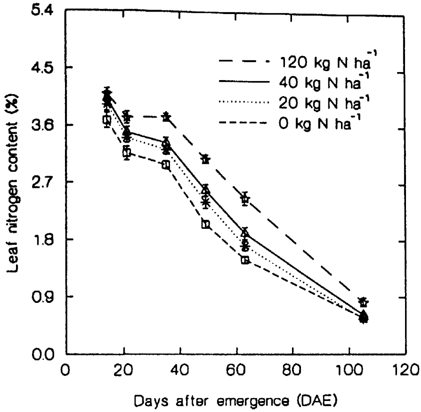


Fig : A 2.2. **Leaf nitrogen content of sorghum as a function of time for the interaction effect of nitrogen and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

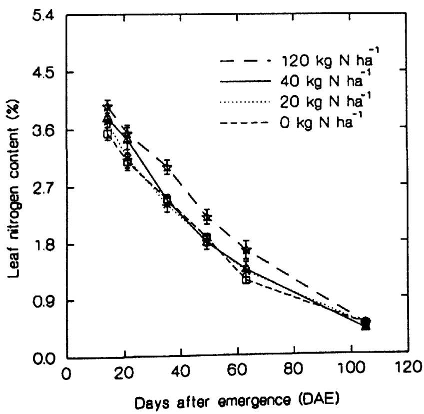
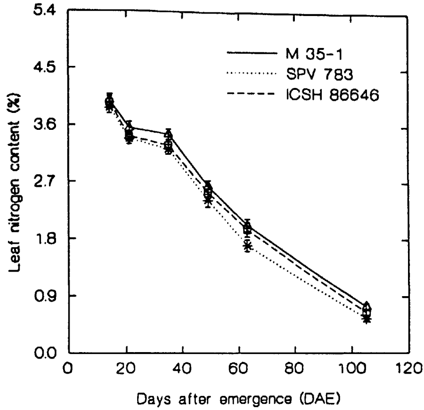


Fig : A 2.3. **Leaf nitrogen content of sorghum as a function of time for the interaction effect of genotype and time, during rabi 1990-91 and 1991-92.**

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

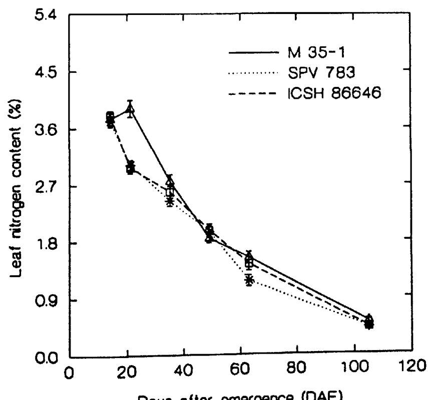
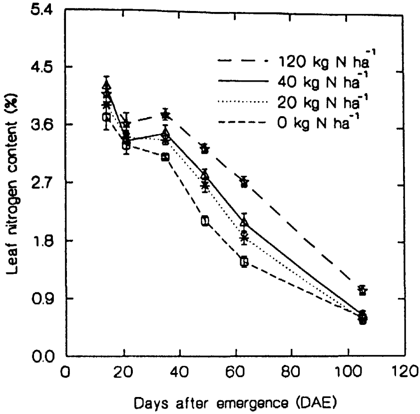


Fig : A 2.4. Leaf nitrogen content of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1990-91.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

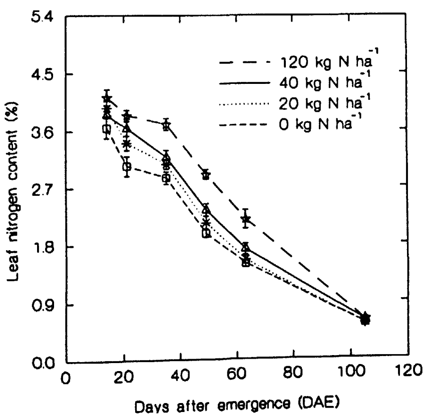
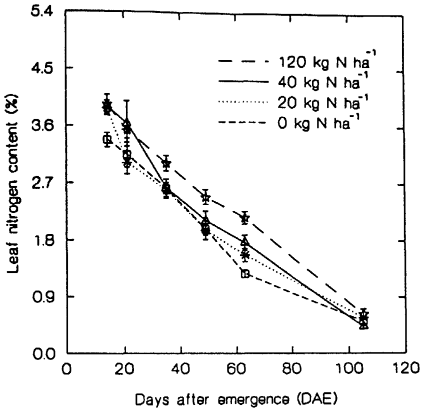


Fig : A 2.5. Leaf nitrogen content of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

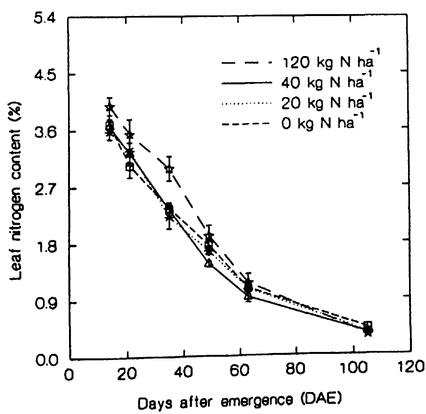
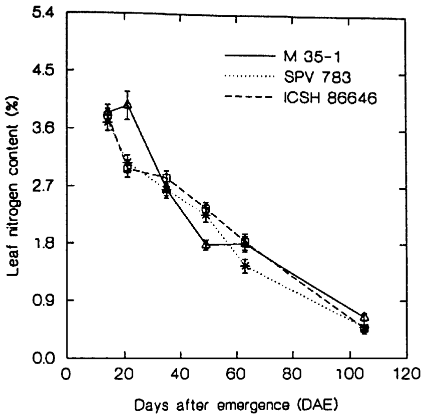


Fig : A 2.6 **Leaf nitrogen content of sorghum as a function of time for the interaction effect of water, genotype and time, in a) Irrigated and b) Dry plots during rabi 1991-92.**

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

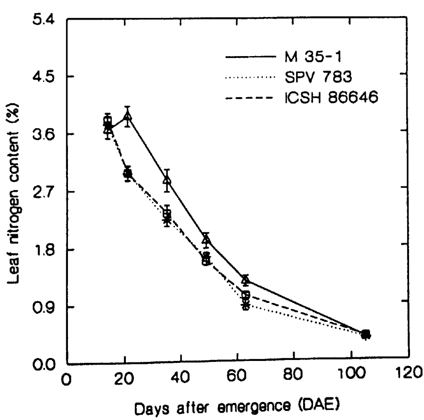
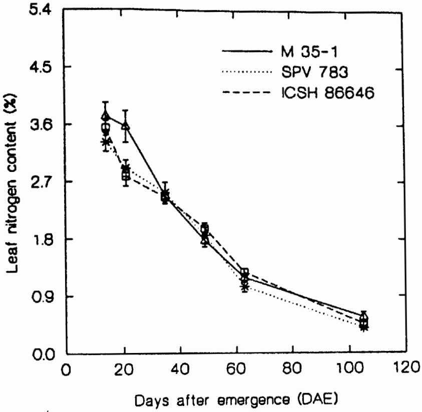


Fig : A 2.7. **Leaf nitrogen content of sorghum as a function of time for the interaction effect of nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.**

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

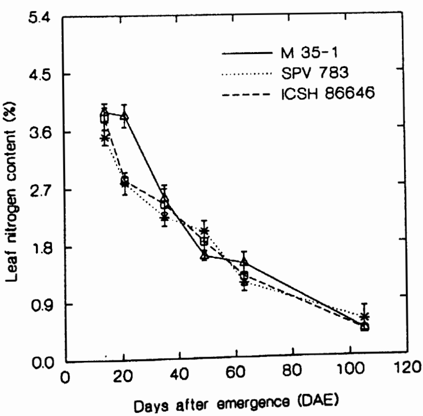
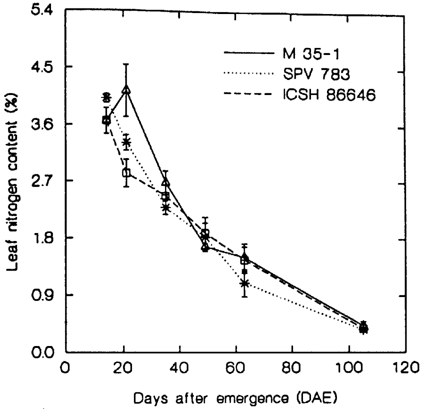


Fig : A 2.8. **Leaf nitrogen content of sorghum as a function of time for the interaction effect of nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.**

c) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



d) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

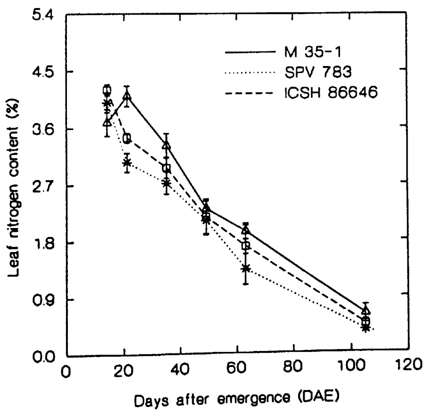
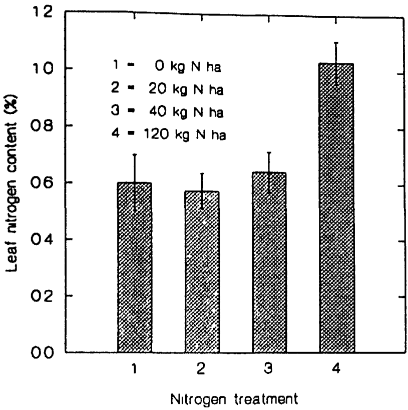


Fig : A 2.9. Leaf nitrogen content of sorghum for the interaction effect of water and nitrogen in a) irrigated and b) dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

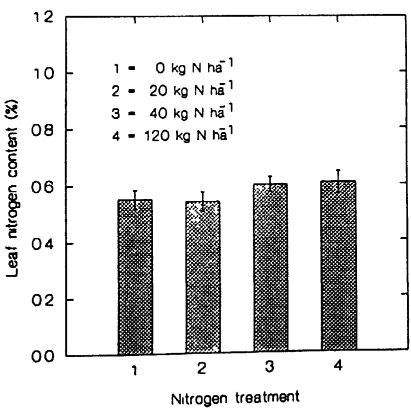
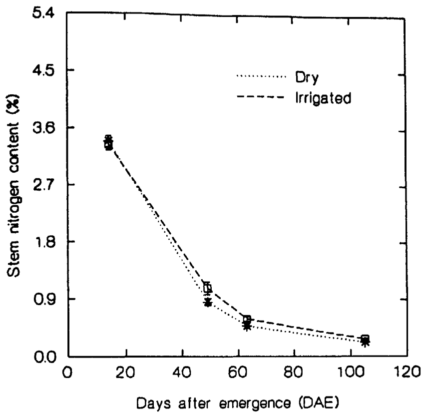


Fig : A 2.10. Stem nitrogen content of sorghum as a function of time for the interaction effect of water and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of nitrogen and genotype treatments)



b) 1991-92 (Mean of nitrogen and genotype treatments)

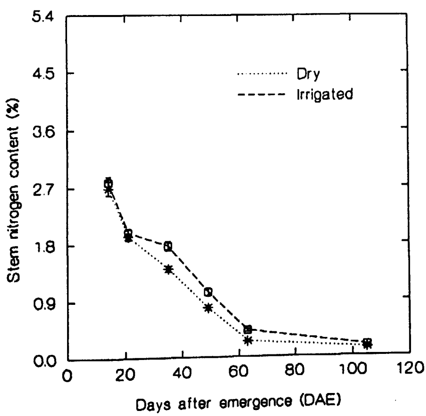
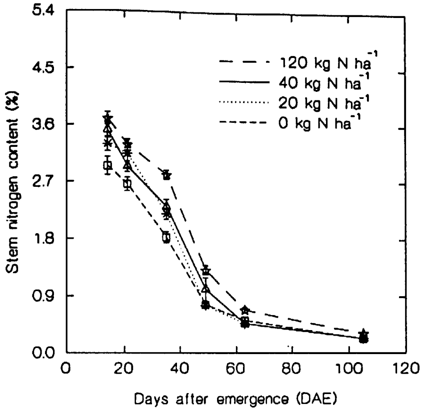


Fig : A 2.11. Stem nitrogen content of sorghum as a function of time for the interaction effect of nitrogen and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatment)



b) 1991-92 (Mean of water and genotype treatment)

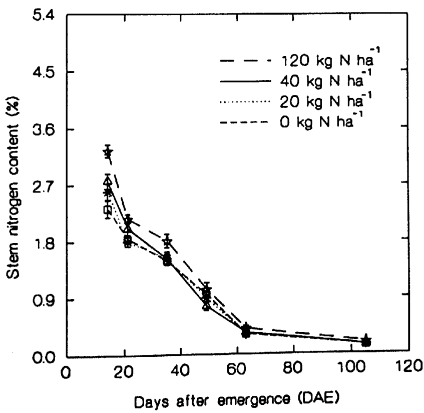
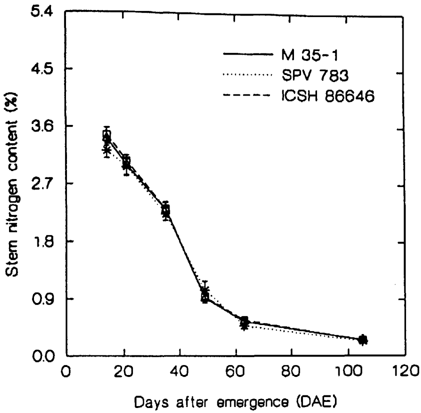


Fig : A 2.12. Stem nitrogen content of sorghum as a function of time for the interaction effect of genotype and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

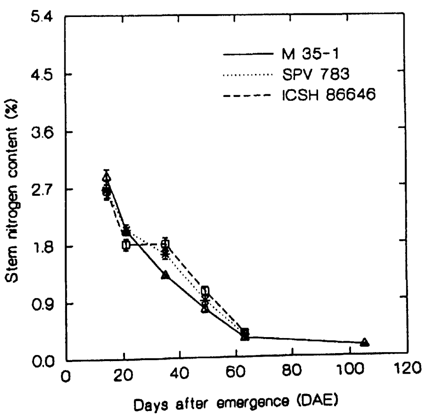
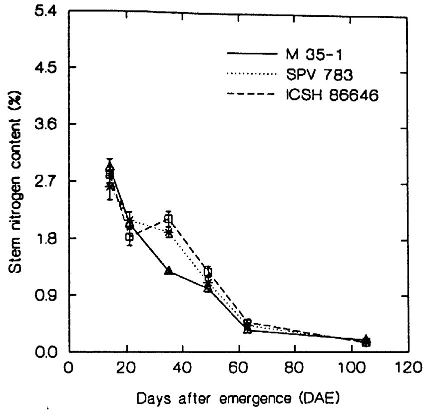


Fig : A 2.13. Stem nitrogen content of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1990-91.

a) Irrigated (Mean of nitrogen treatments in 1990-91)



b) Dry (Mean of nitrogen treatments in 1990-91)

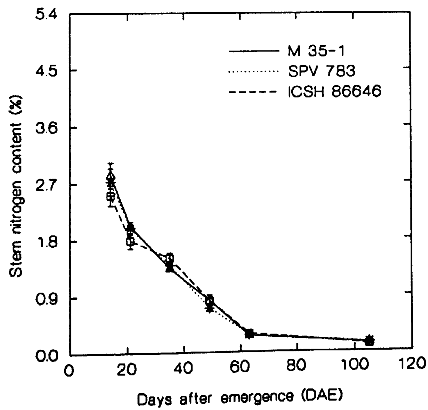
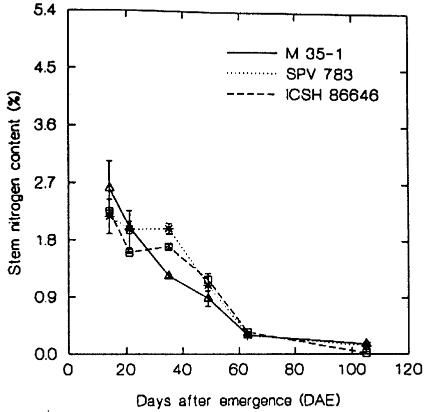


Fig : A 2.14. Stem nitrogen content of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

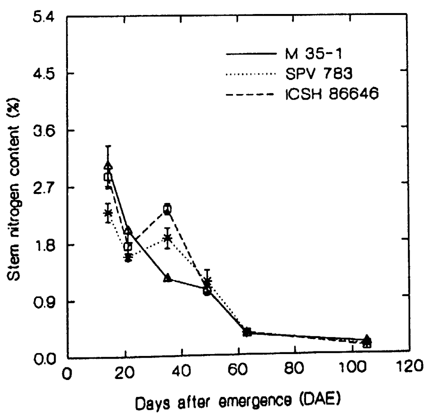
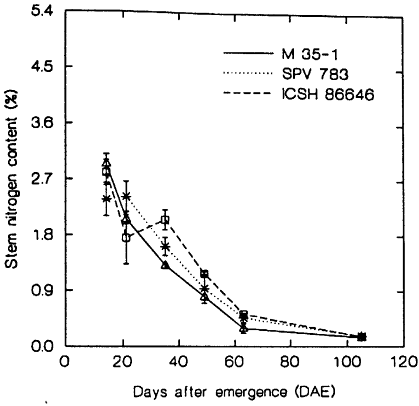


Fig : A 2.15. Stem nitrogen content of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

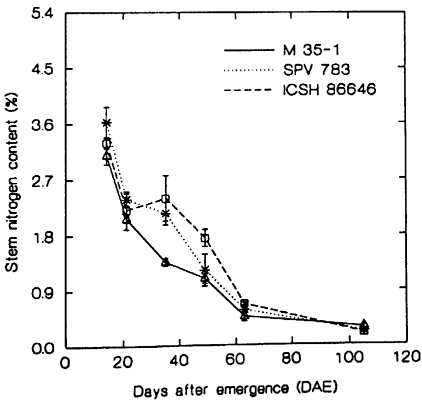
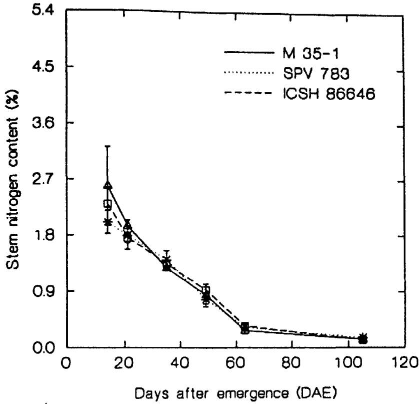


Fig : A 2.16 Stem nitrogen content of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

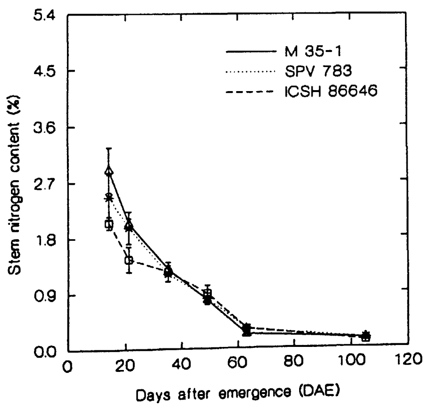
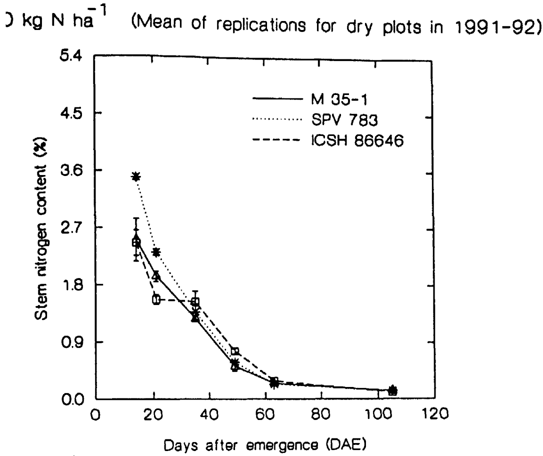


Fig : A 2.17. Stem nitrogen content of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.



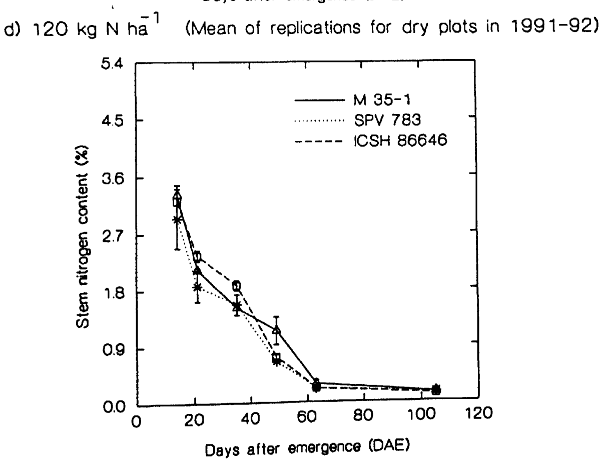
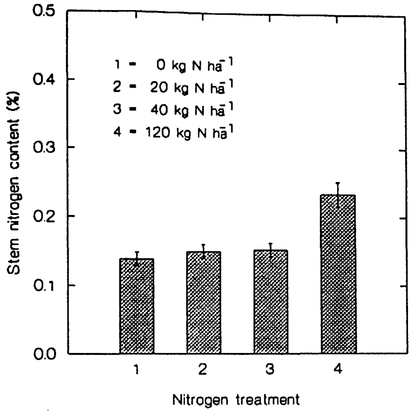


Fig : A 2.18. Stem nitrogen content of sorghum as a function of nitrogen treatments for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

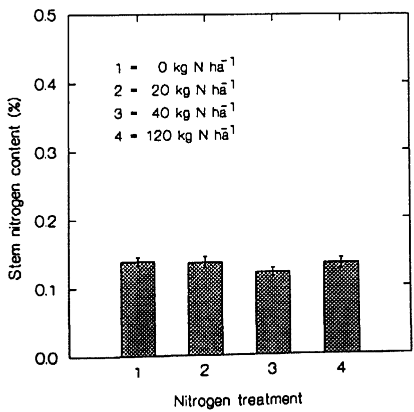
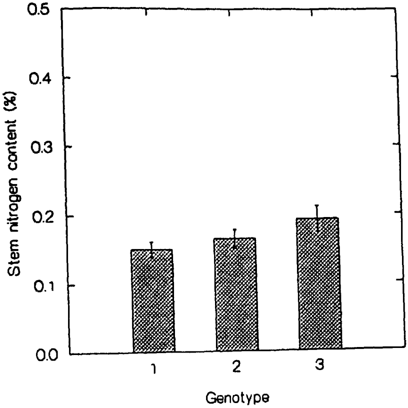


Fig : A 2.19. Stem nitrogen content of sorghum as a function of genotypes for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated



b) Dry

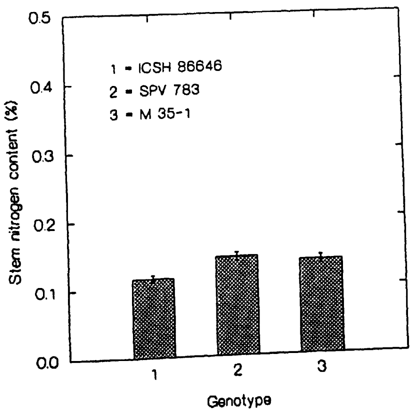
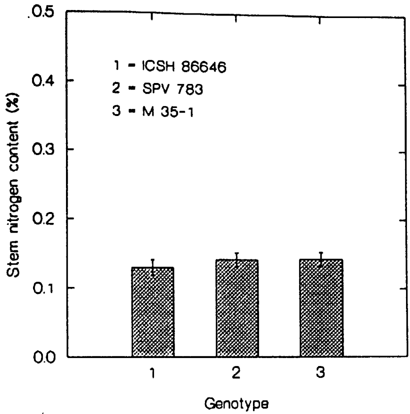


Fig : A 2.20. Stem nitrogen content of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

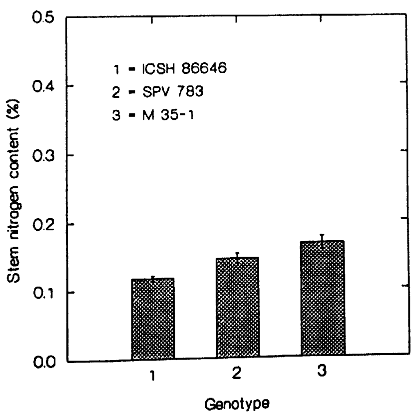
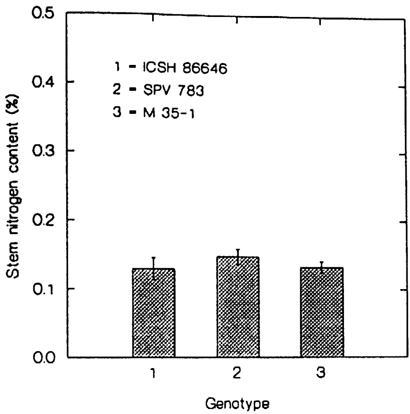


Fig : A 2.21. Stem nitrogen content of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} during rabi 1991-92.

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

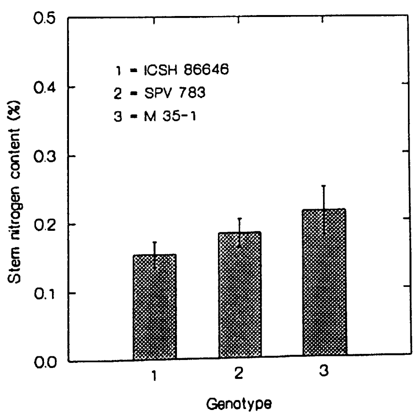


Fig : A 2.22. **Stem nitrogen content of sorghum genotypes in irrigated and dry plots for the interaction effect of water, nitrogen and genotype, at harvest during rabi 1991-92.**

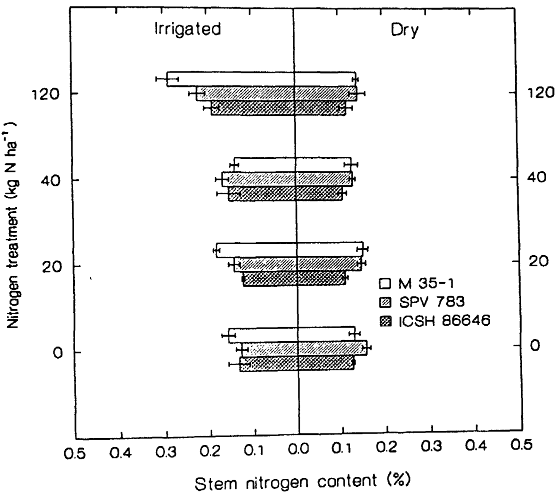
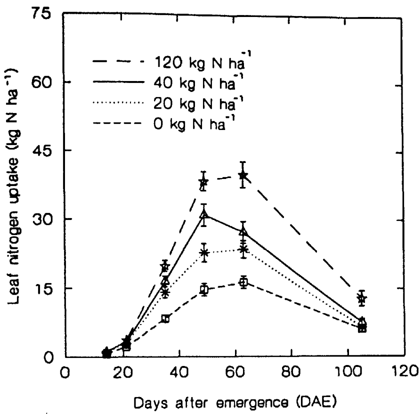


Fig : A 2.28. Total leaf nitrogen uptake of sorghum as a function of time for the interaction effect of nitrogen and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

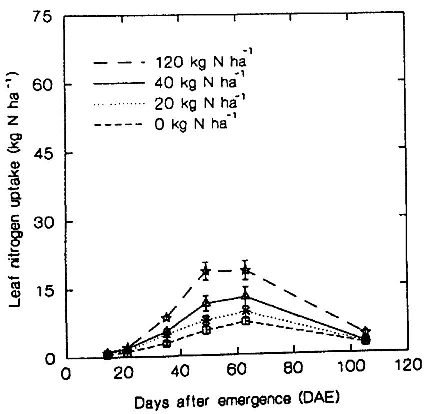
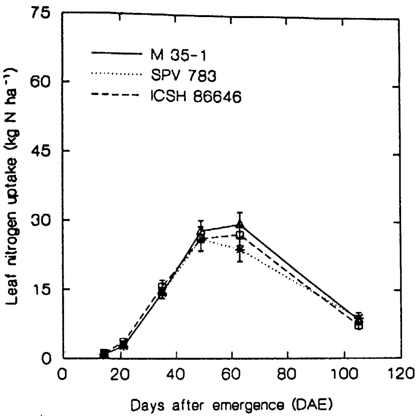


Fig : A 2.29. Total leaf nitrogen uptake of sorghum as a function of time for the interaction effect of genotype and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

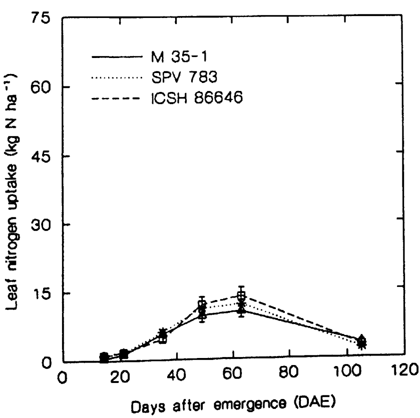


Fig : A 2.30. Total leaf nitrogen uptake of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1990-91.

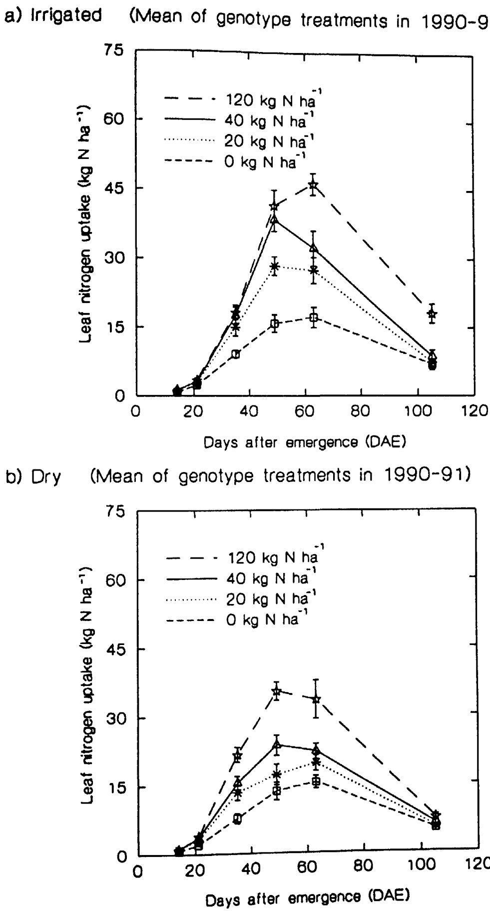
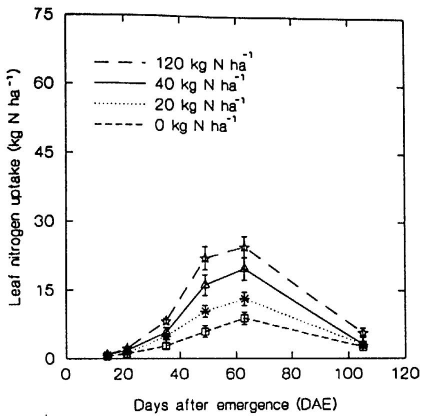


Fig : A 2.31. Total leaf nitrogen uptake of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

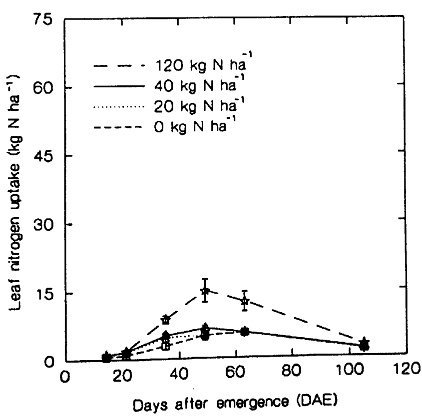
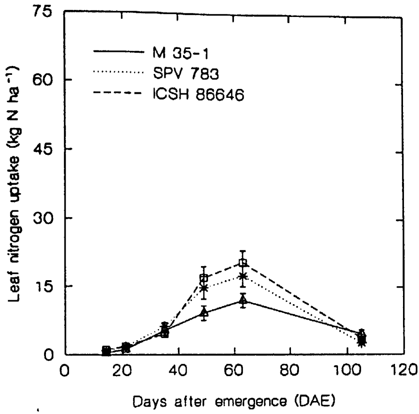


Fig : A 2.32. Total leaf nitrogen uptake of sorghum as a function of time for the interaction effect of water, genotype and time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

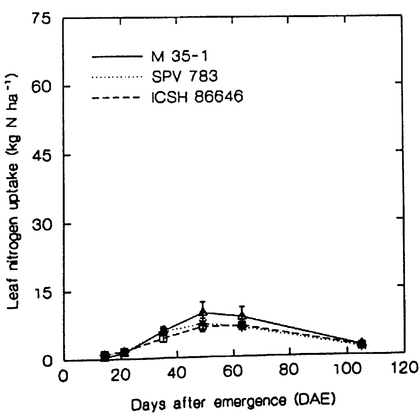
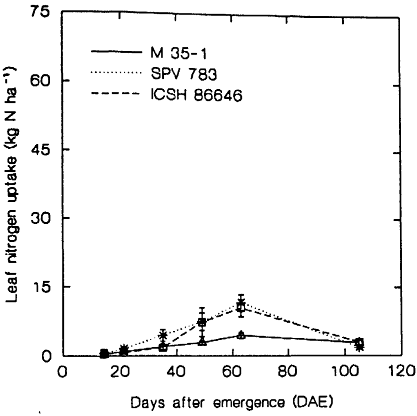


Fig : A 2.33. Total leaf nitrogen uptake of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

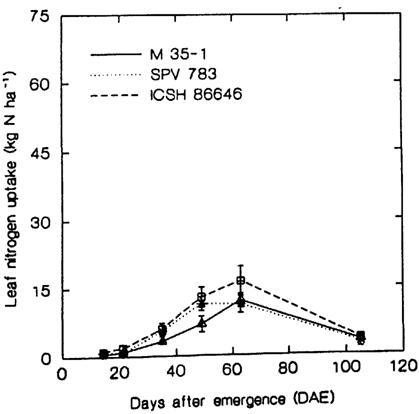
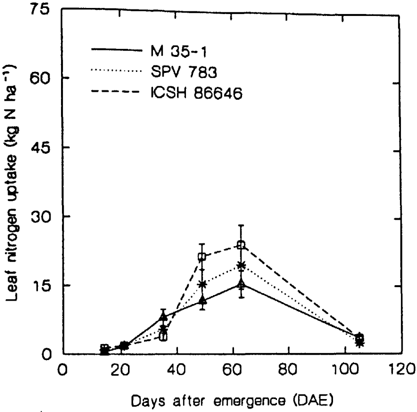


Fig : A 2.34. Total leaf nitrogen uptake of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

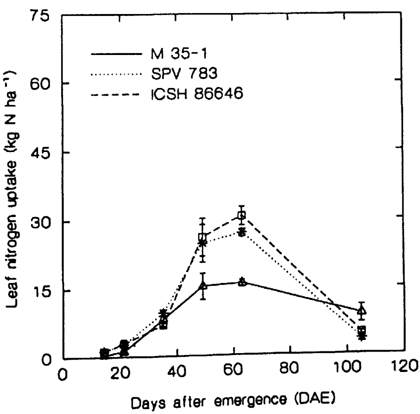
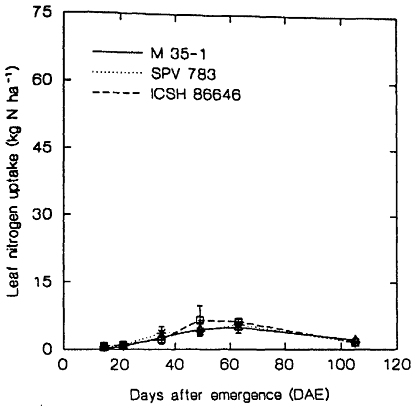


Fig : A 2.35. Total leaf nitrogen uptake of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

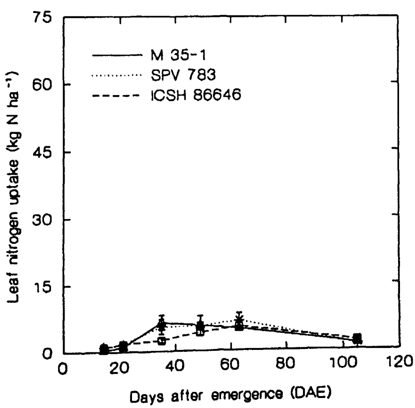
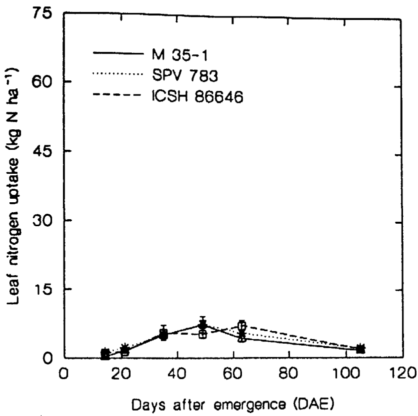


Fig : A 2.36. Total leaf nitrogen uptake of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

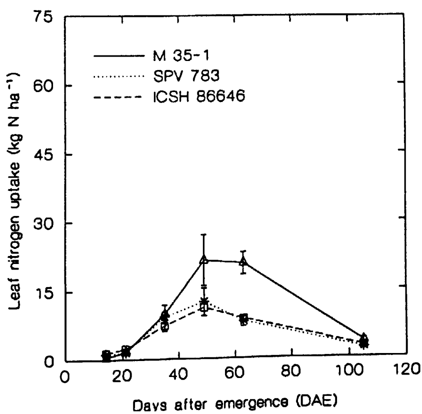
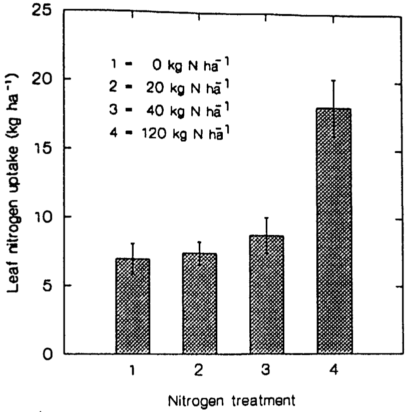


Fig : A 2.37. Total leaf nitrogen uptake of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

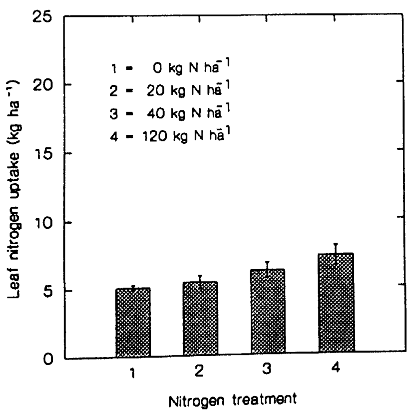
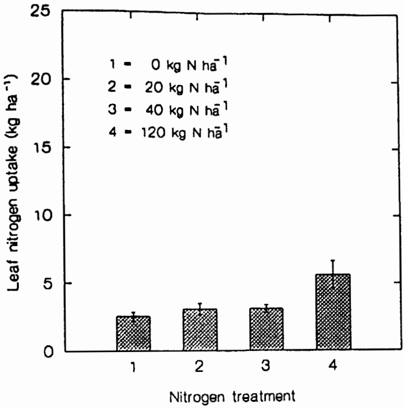


Fig : A 2.38. Total leaf nitrogen uptake of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

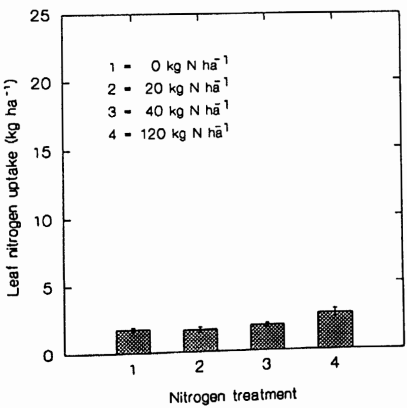
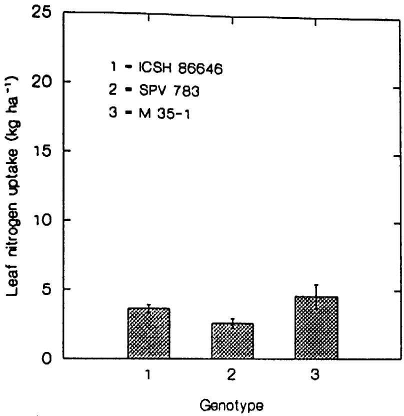


Fig : A 2.39. Total leaf nitrogen uptake of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

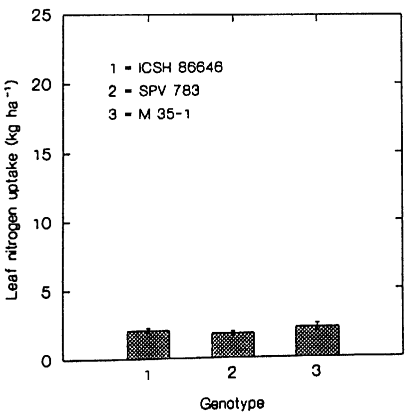
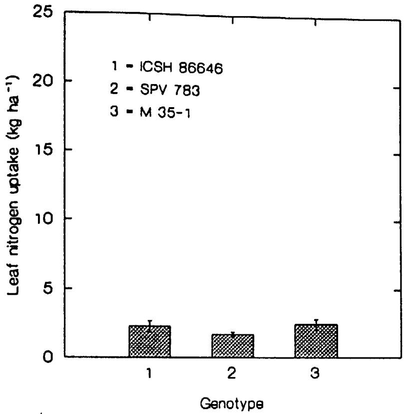


Fig : A 2.40. Total leaf nitrogen uptake of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

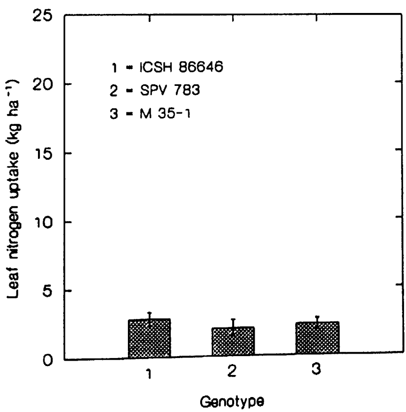
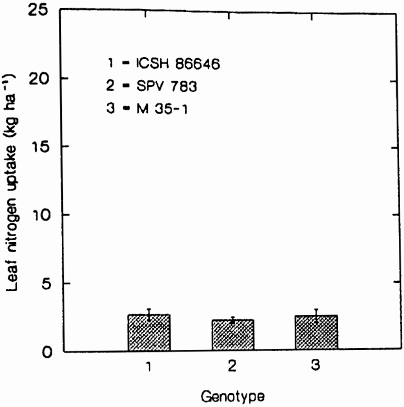


Fig : A 2.41. Total leaf nitrogen uptake of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} during rabi 1991-92.

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

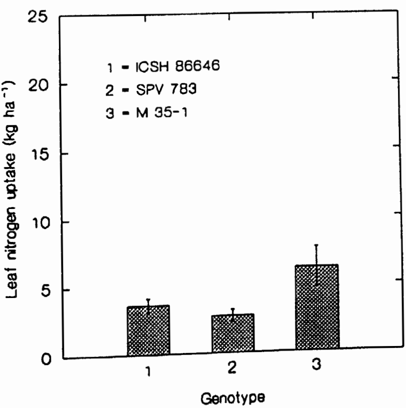
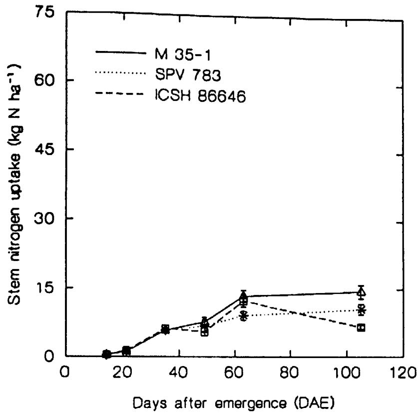


Fig : A 2.44. Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of genotype and time, during rabi 1990-91 and 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

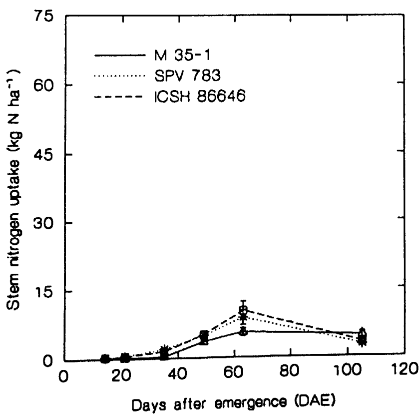
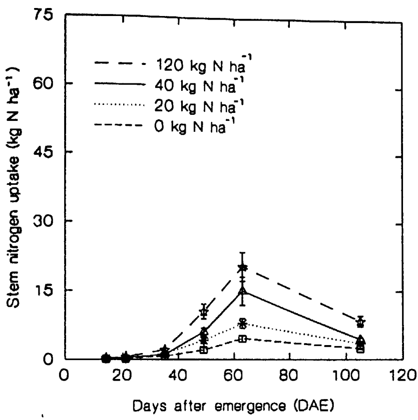


Fig : A 2.45. Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

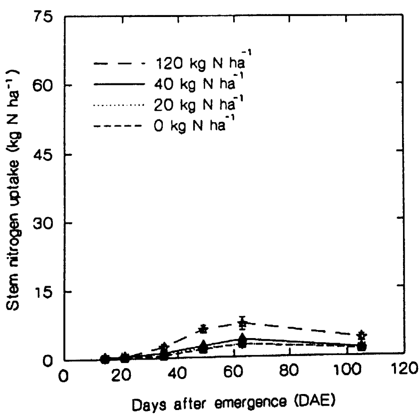
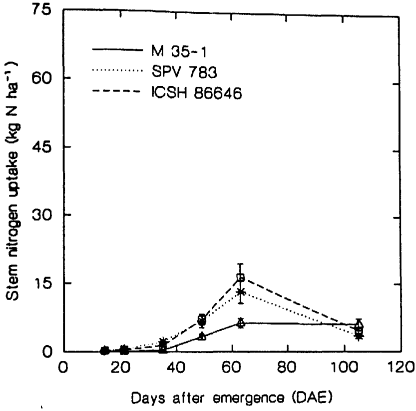


Fig : A 2.46. Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of water, genotype and time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

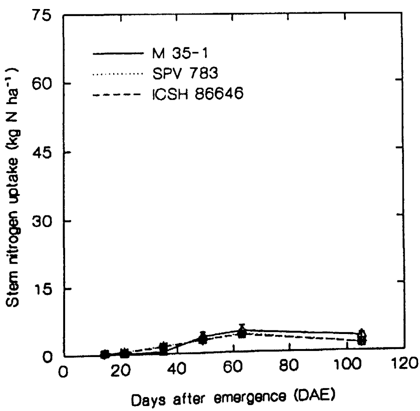
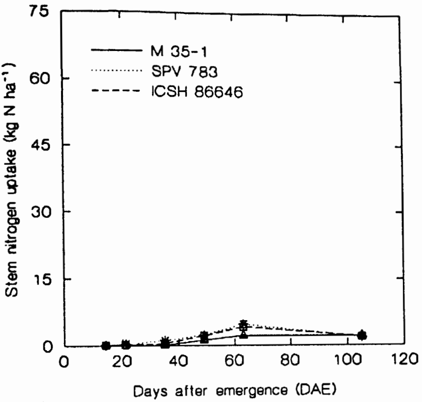


Fig : A 2.47. Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

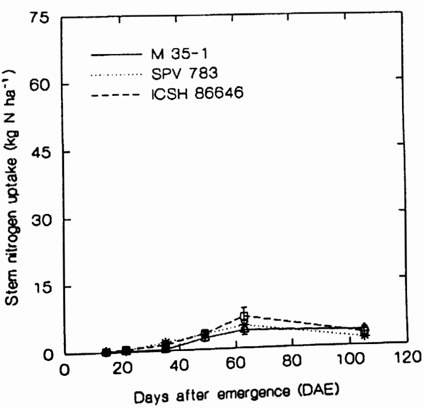
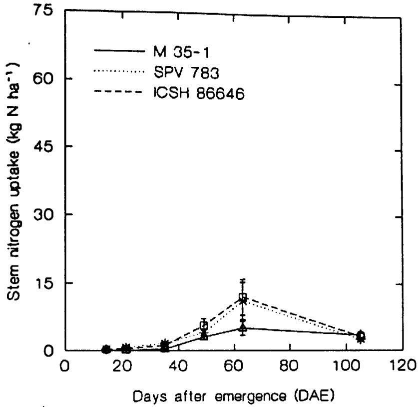


Fig : A 2.48. Total stem nitrogen uptake of sorghum as a function of time for the interaction effect of nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



d) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

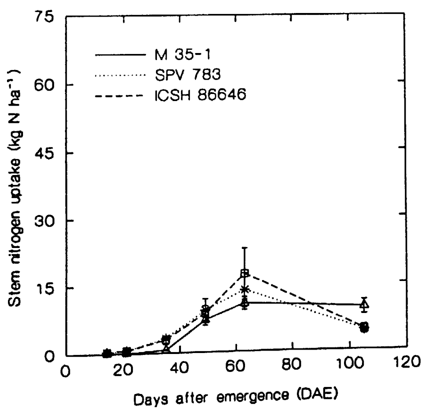
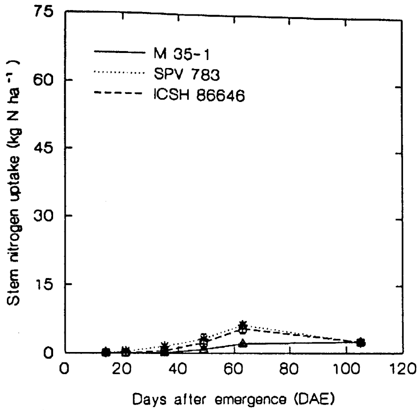


Fig : A 2.49. Total stem nitrogen uptake of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

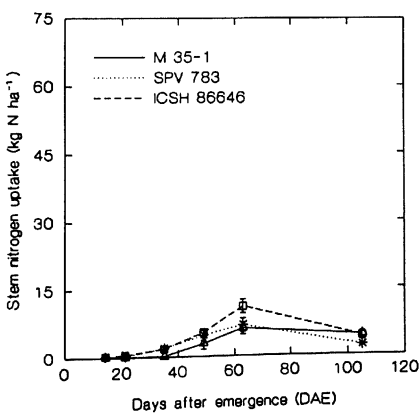
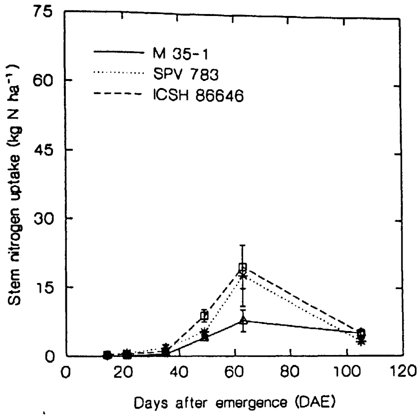


Fig : A 2.50. Total stem nitrogen uptake of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

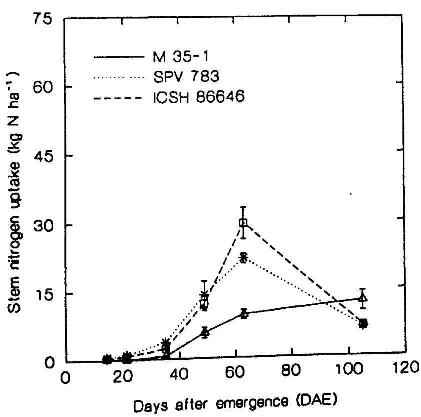
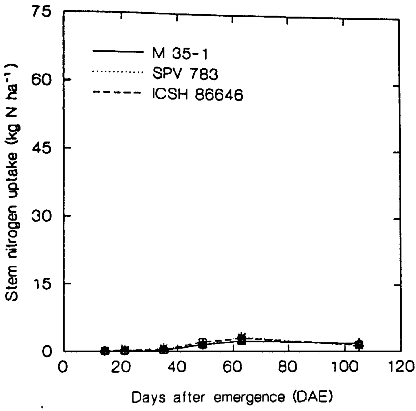


Fig : A 2.51. Total stem nitrogen uptake of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

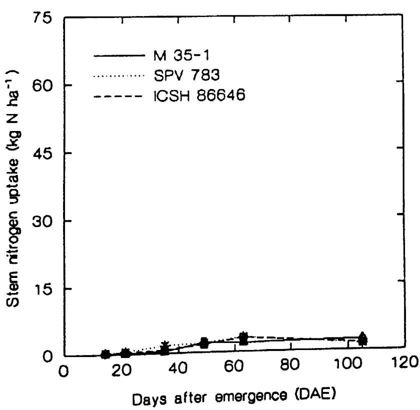
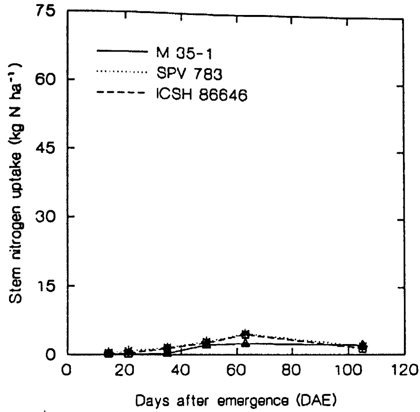


Fig : A 2.52. Total stem nitrogen uptake of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

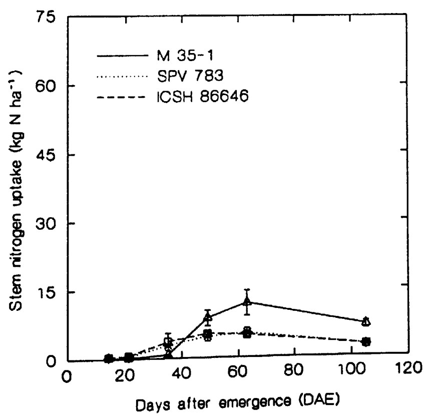
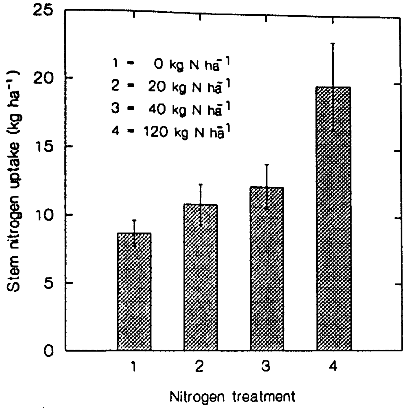


Fig : A 2.53. Total stem nitrogen uptake of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

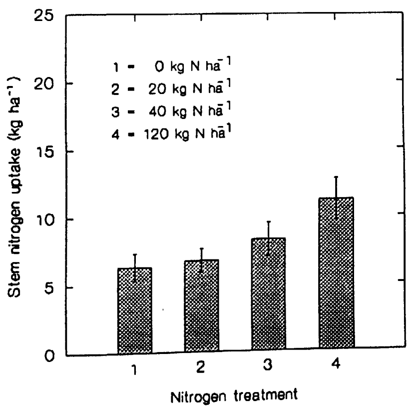
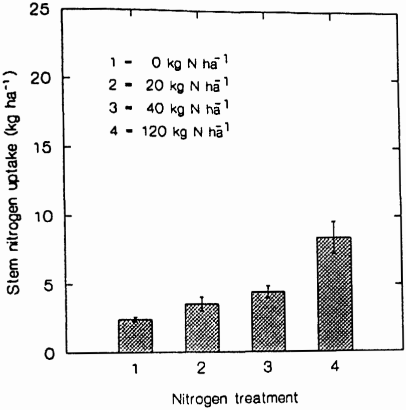


Fig : A 2.54. Total stem nitrogen uptake of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

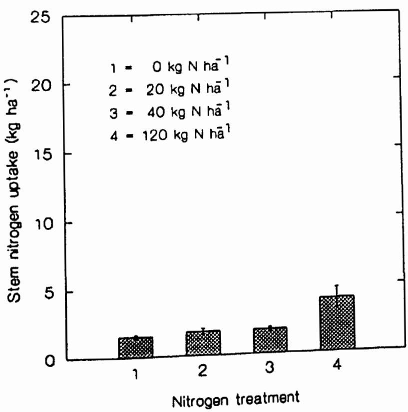
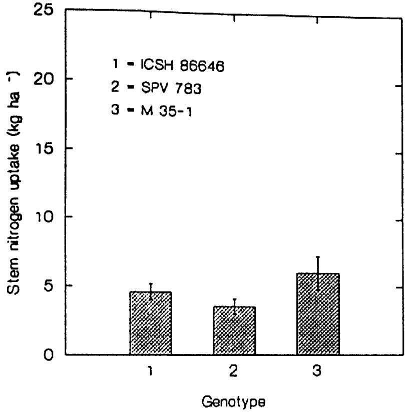


Fig : A 2.55. Total stem nitrogen uptake of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

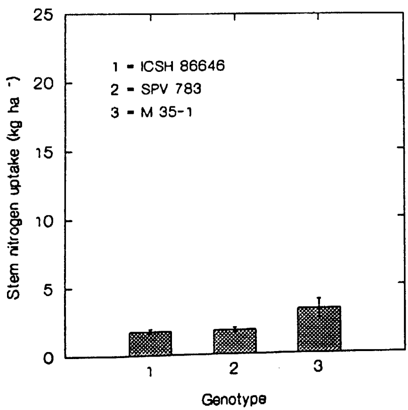
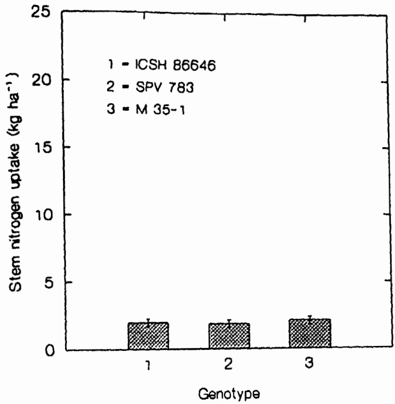


Fig : A 2.56. Total stem nitrogen uptake of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

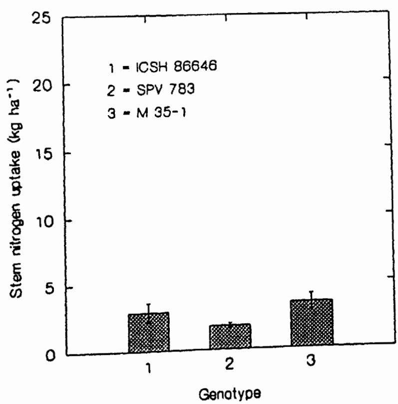


Fig : A 2.57. Total stem nitrogen uptake of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} during rabi 1991-92.

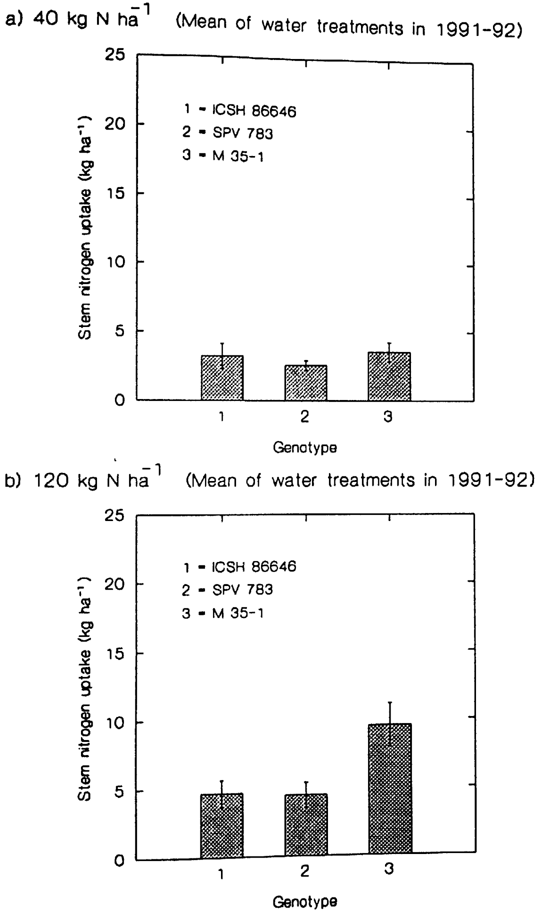
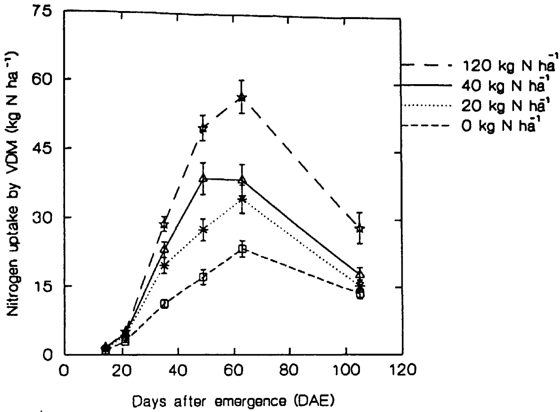


Fig : A 2.59. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of nitrogen and time, in a) 1990-91 and b) 1991-92.

a) 1990-91 (Mean of water and genotype treatments)



b) 1991-92 (Mean of water and genotype treatments)

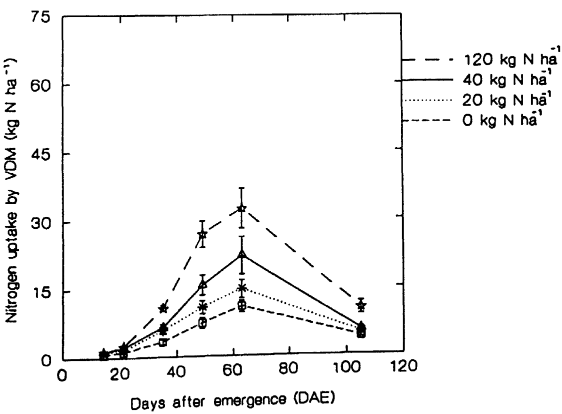
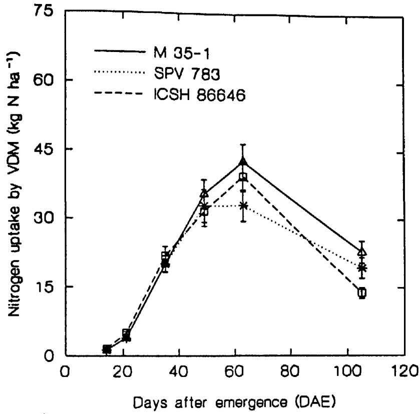


Fig : A 2.60. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of genotype and time, in a) 1990-91 and b) 1991-92.

a) 1990-91 (Mean of water and nitrogen treatments)



b) 1991-92 (Mean of water and nitrogen treatments)

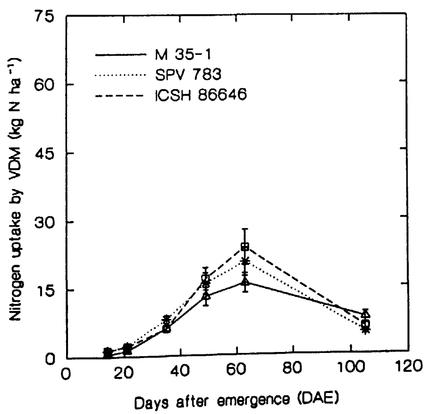
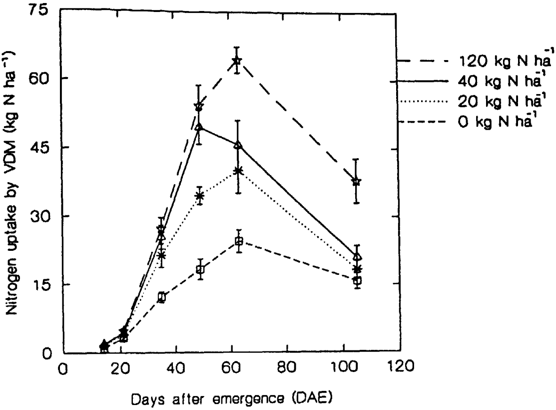


Fig : A 2.61. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1990-91 season.

a) Irrigated (Mean of genotpye treatments in 1990-91)



b) Dry (Mean of genotpye treatments in 1990-91)

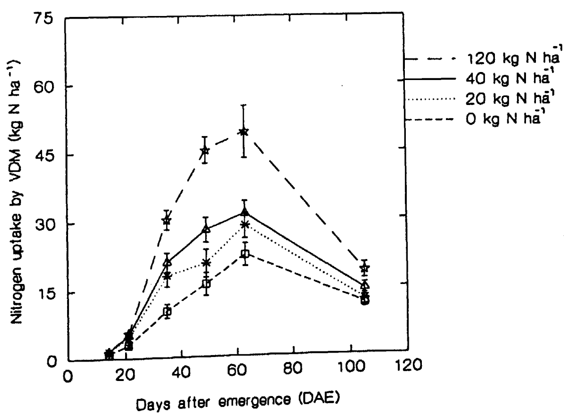
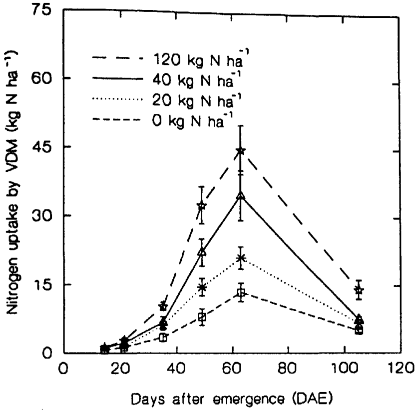


Fig : A 2.62. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of water, nitrogen and time, in a) Irrigated and b) Dry plots during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

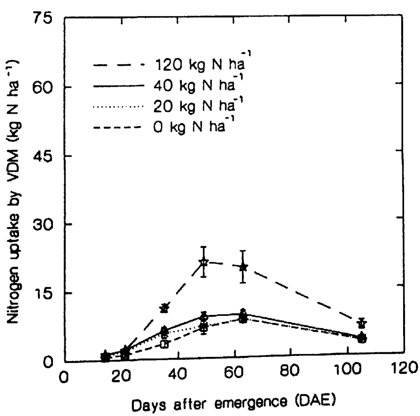
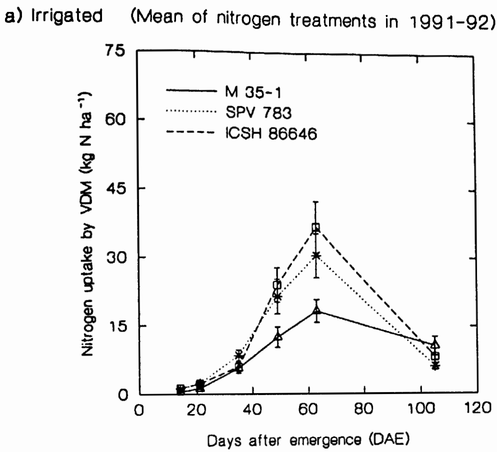


Fig : A 2.63. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of water, genotype and time, in a) Irrigated and b) Dry plots during rabi 1991-92.



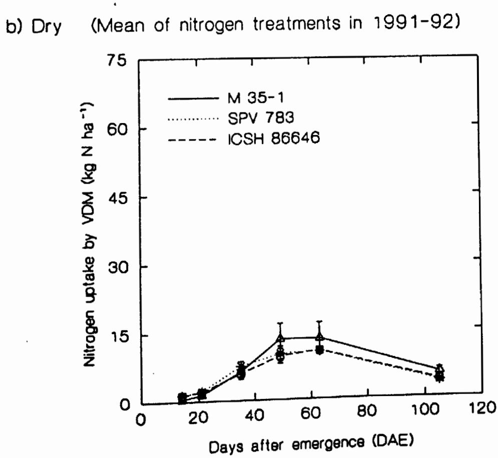
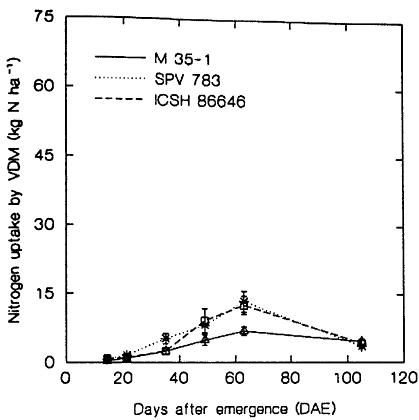


Fig : A 2.64. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

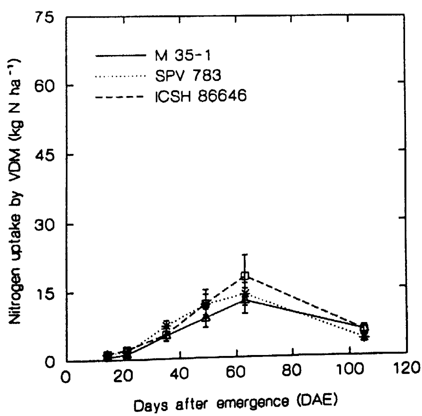
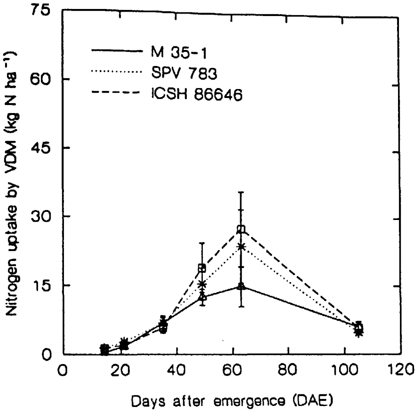


Fig : A 2.65. Total nitrogen uptake by vegetative matter of sorghum as a function of time for the interaction effect of nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



d) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

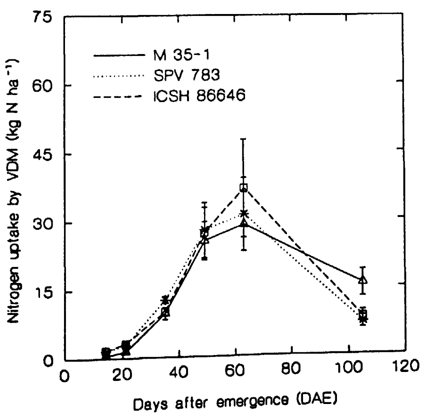
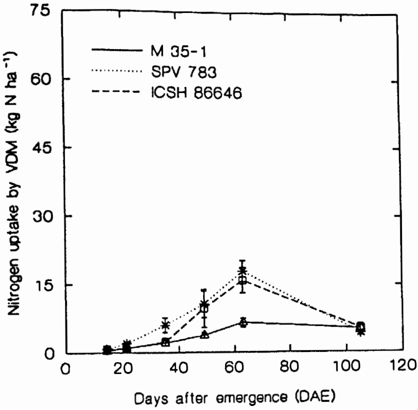


Fig : A 2.66. Total nitrogen uptake by vegetative matter of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

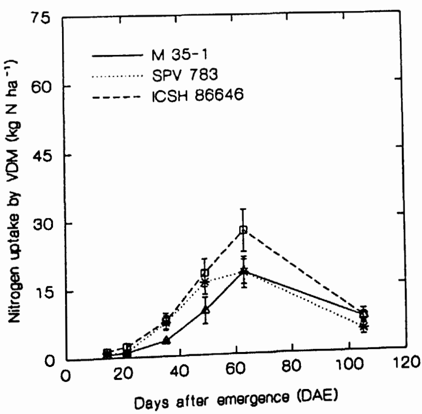
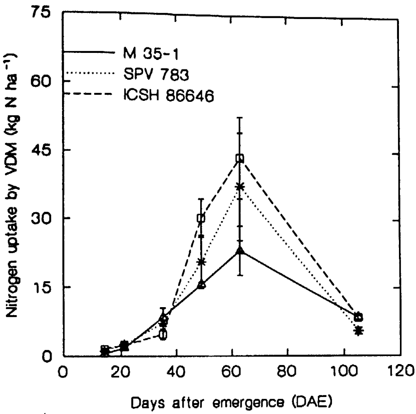


Fig : A 2.67. Total nitrogen uptake by vegetative matter of sorghum as a function of time in irrigated plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

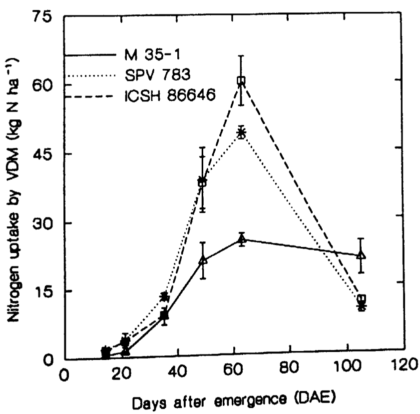
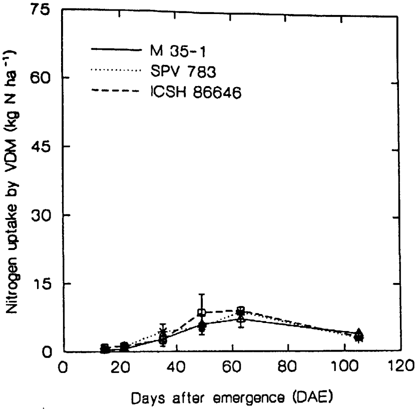


Fig : A 2.68. Total nitrogen uptake by vegetative matter of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for dry plots in 1991-92)

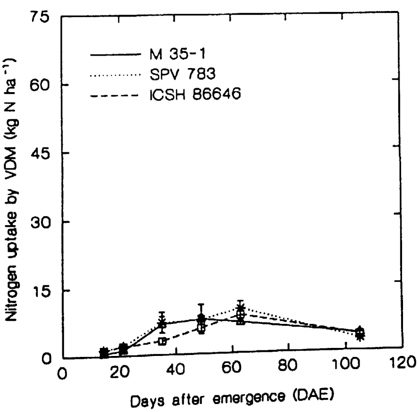
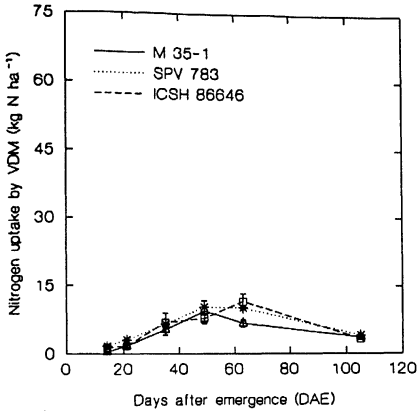


Fig : A 2.69. Total nitrogen uptake by vegetative matter of sorghum as a function of time in dry plots for the interaction effect of water, nitrogen, genotype and time, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for dry plots in 1991-92



d) 120 kg N ha^{-1} (Mean of replications for dry plots in 1991-92

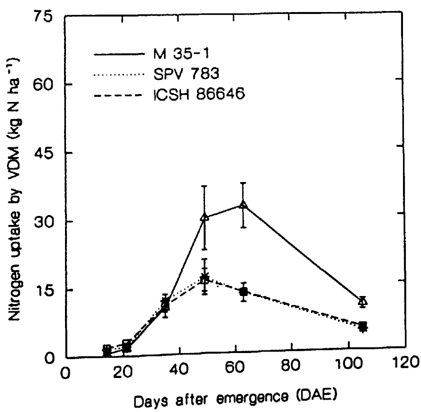
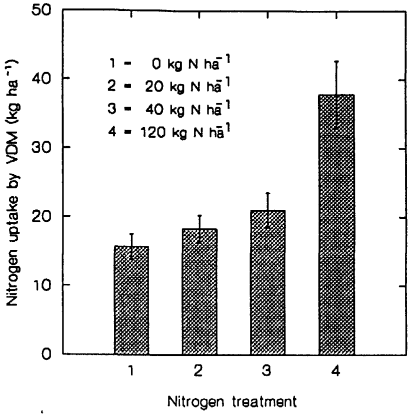


Fig : A 2.70. Total nitrogen uptake by vegetative matter of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.

a) Irrigated (Mean of genotype treatments in 1990-91)



b) Dry (Mean of genotype treatments in 1990-91)

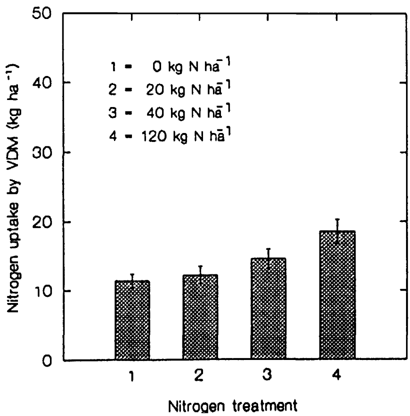
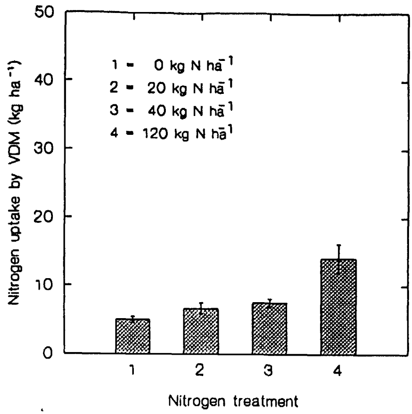


Fig : A 2.71. Total nitrogen uptake by vegetative matter of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of genotype treatments in 1991-92)



b) Dry (Mean of genotype treatments in 1991-92)

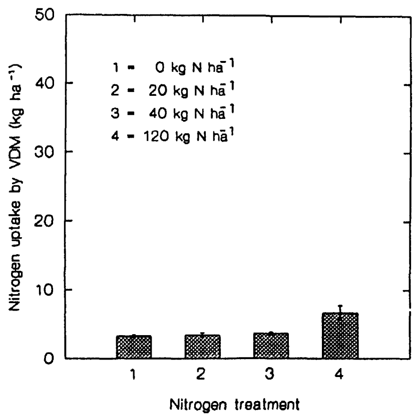
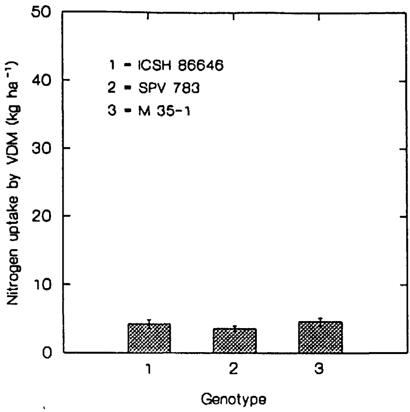


Fig : A 2.72. **Total nitrogen uptake by vegetative matter of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} in 1991-92.**

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

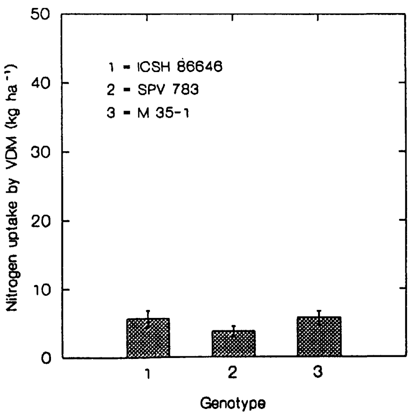
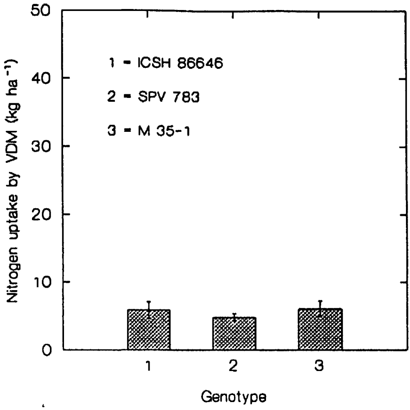


Fig : A 2.73. Total nitrogen uptake by vegetative matter of sorghum for the interaction effect of nitrogen and genotype at harvest in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} in 1991-92.

a) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

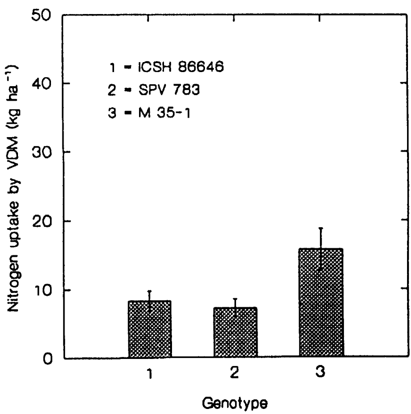
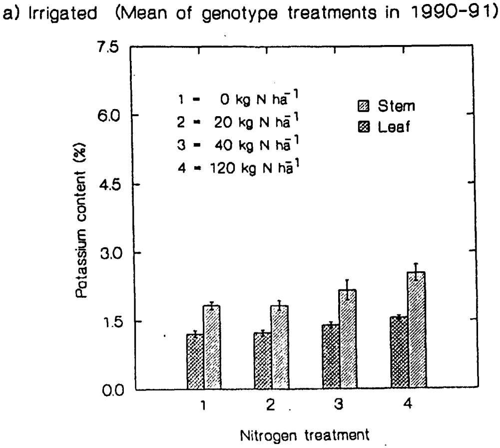


Fig : A 3.1. Leaf and stem potassium content of sorghum for the interaction effect of water and nitrogen, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.



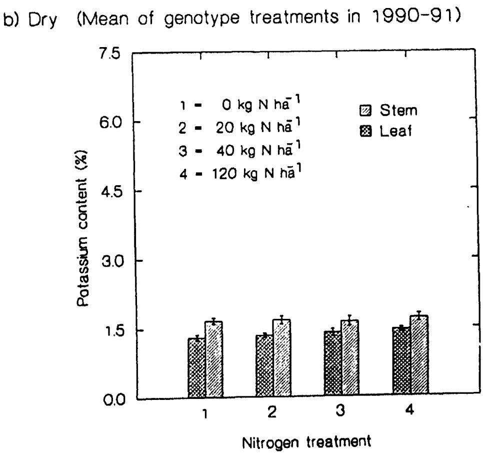
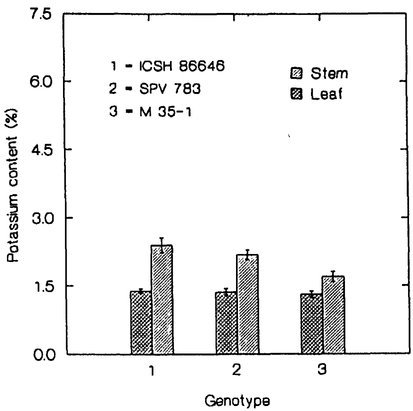


Fig : A 3.2. Leaf and stem potassium content of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.

a) Irrigated. (Mean of nitrogen treatments in 1990-91)



b) Dry (Mean of nitrogen treatments in 1990-91)

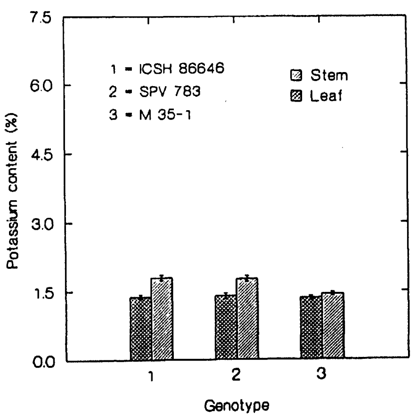
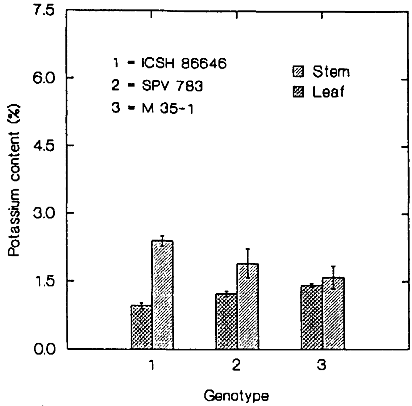


Fig : A 3.3. Leaf and stem potassium content of sorghum for the interaction effect of nitrogen and genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest during rabi 1990-91.

a) 0 kg N ha^{-1} (Mean of water treatments in 1990-91)



b) 20 kg N ha^{-1} (Mean of water treatments in 1990-91)

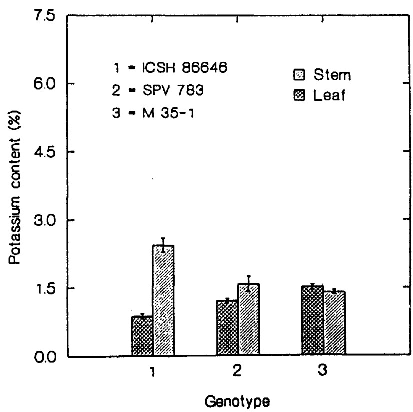
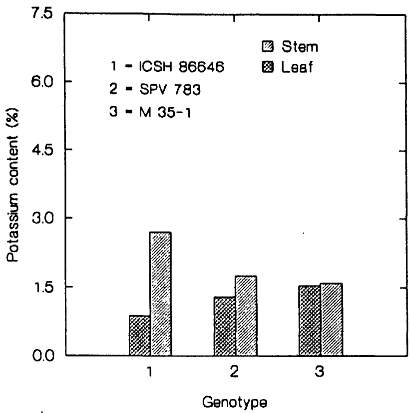


Fig : A 3.4. Leaf and stem potassium content of sorghum for the interaction effect of nitrogen and genotype,in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest in 1990-91.

c) 40 kg N ha^{-1} (Mean of water treatments in 1990-91)



d) 120 kg N ha^{-1} (Mean of water treatments in 1990-91)

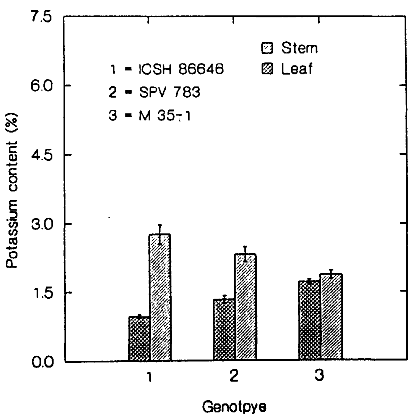
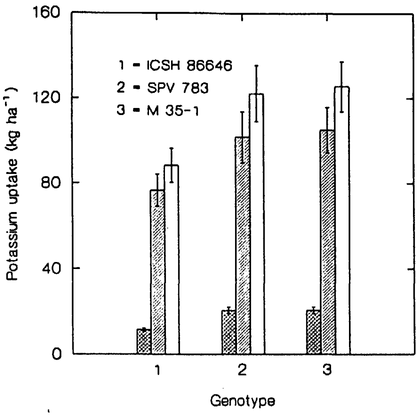


Fig : A 3.9. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1990-91.

a) Irrigated (Mean of nitrogen treatments in 1990-91)



b) Dry (Mean of nitrogen treatments in 1990-91)

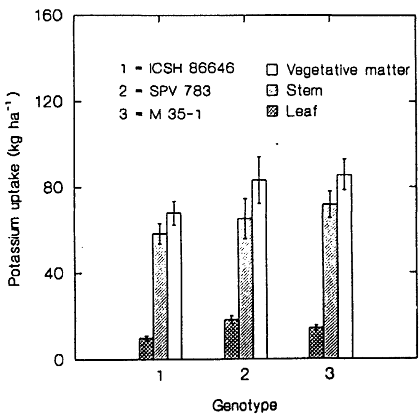
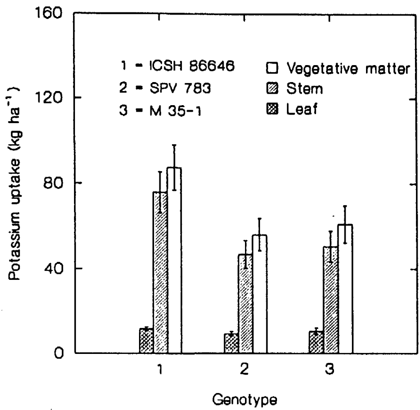


Fig : A 3.10. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of water and genotype, in a) Irrigated and b) Dry plots at harvest during rabi 1991-92.

a) Irrigated (Mean of nitrogen treatments in 1991-92)



b) Dry (Mean of nitrogen treatments in 1991-92)

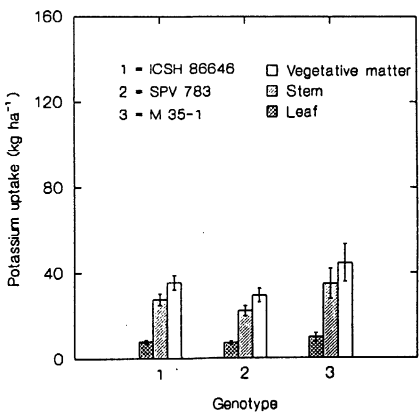
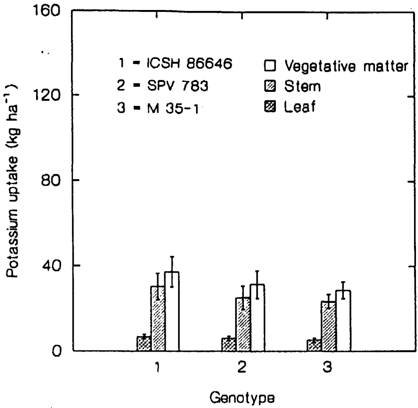


Fig : A 3.11. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of nitrogen and genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments at harvest during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of water treatments in 1991-92)



b) 20 kg N ha^{-1} (Mean of water treatments in 1991-92)

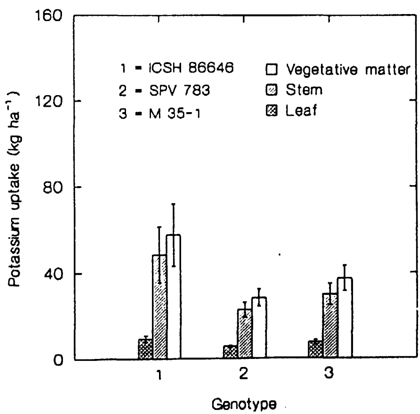
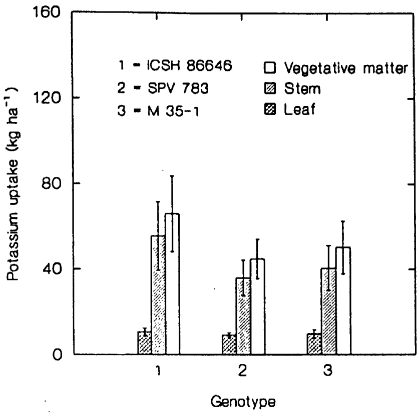


Fig : A 3.12. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of nitrogen and genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments at harvest during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of water treatments in 1991-92)



d) 120 kg N ha^{-1} (Mean of water treatments in 1991-92)

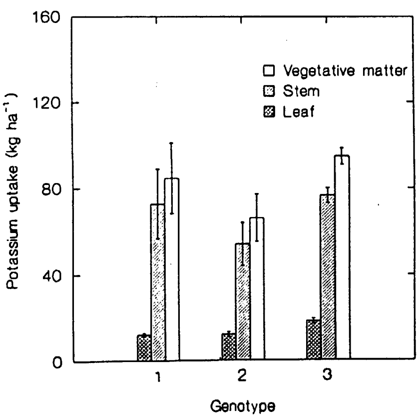
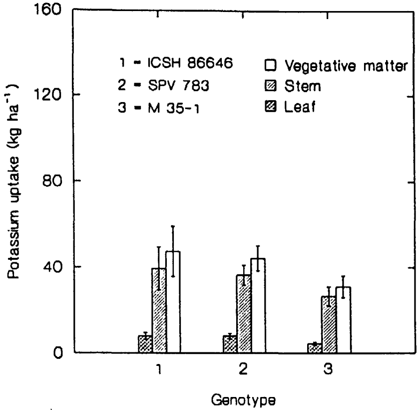


Fig : A 3.13. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of water, nitrogen and genotype, in a) 0 kg N ha^{-1} and b) 20 kg N ha^{-1} treatments in irrigated plots at harvest during rabi 1991-92.

a) 0 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



b) 20 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

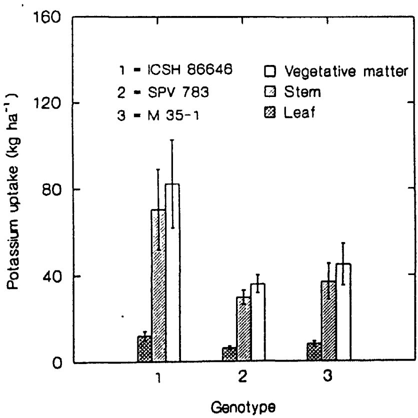
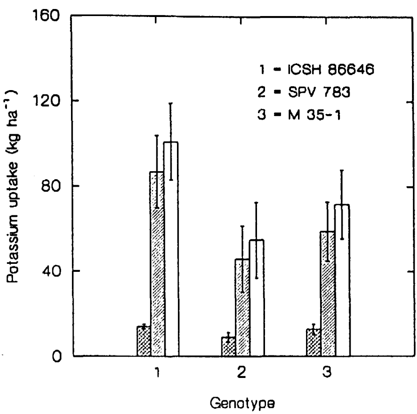


Fig : A 3.14. Total potassium uptake of leaf, stem and vegetative dry matter of sorghum for the interaction effect of water, nitrogen and genotype, in a) 40 kg N ha^{-1} and b) 120 kg N ha^{-1} treatments in irrigated plots at harvest during rabi 1991-92.

c) 40 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)



d) 120 kg N ha^{-1} (Mean of replications for irrigated plots in 1991-92)

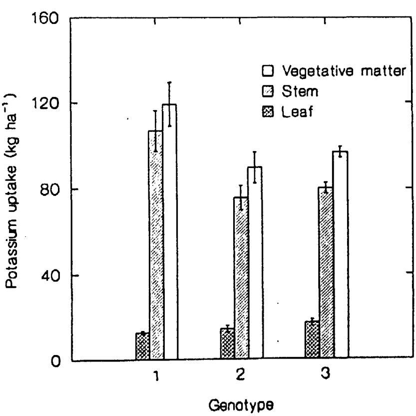
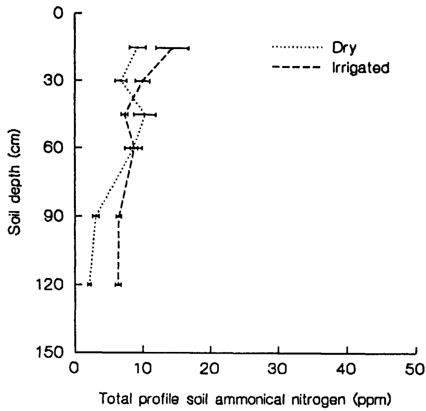


Fig : A 4.1. **a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of water and soil depth, at sowing in 1991-92.**

a) Soil ammonical nitrogen (Mean of nitrogen and genotype treatments at sowing in 1990-91)



b) Soil nitrate nitrogen (Mean of nitrogen and genotype treatments at sowing in 1990-91)

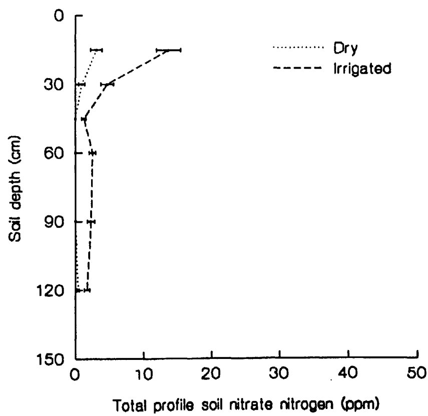
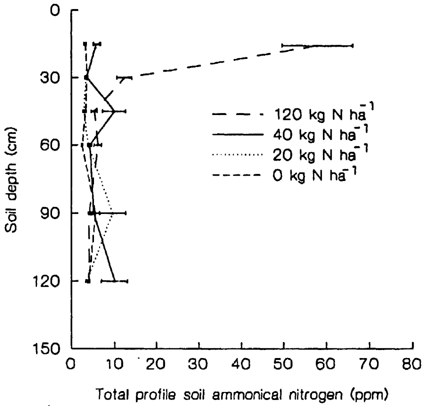


Fig : A 4.2. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of nitrogen and soil depth, at sowing during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of water and genotype treatments at sowing in 1990-91)



b) Soil nitrate nitrogen (Mean of water and genotype treatments at sowing in 1990-91)

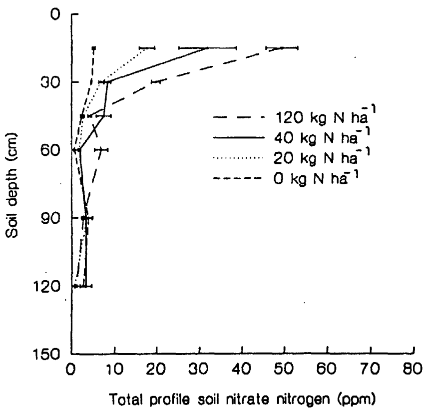
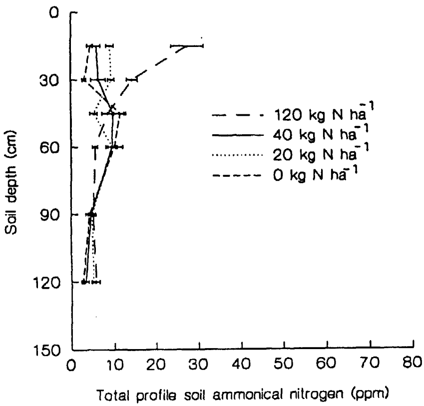


Fig : A 4.3. **a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of nitrogen and soil depth, at sowing during rabi 1991-92.**

a) Soil ammonical nitrogen (Mean of water and genotype treatments at sowing in 1991-92)



b) Soil nitrate nitrogen (Mean of water and genotype treatments at sowing in 1991-92)

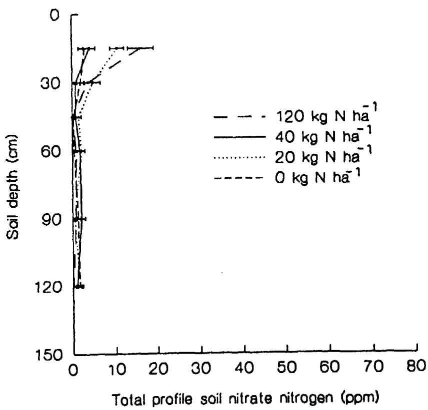
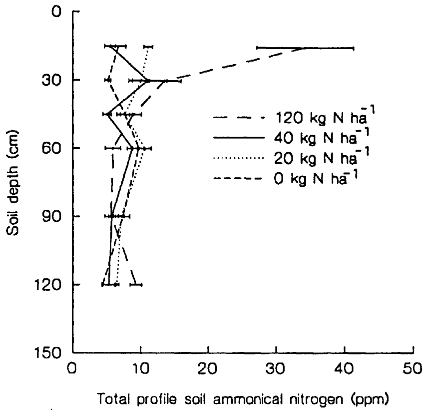


Fig : A 4.4. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, nitrogen and soil depth, at sowing during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of genotypes in irrigated plots at sowing in 1991-92)



b) Soil nitrate nitrogen (Mean of genotypes in irrigated plots at sowing in 1991-92)

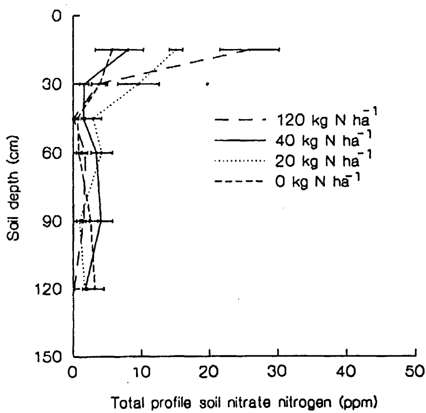
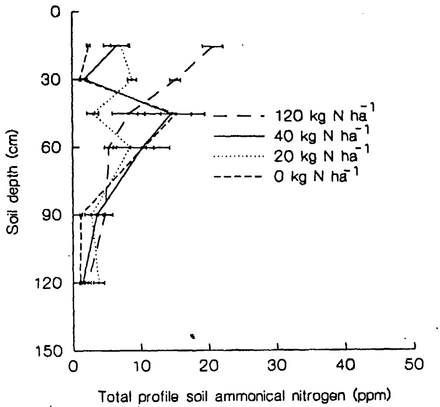


Fig : A 4.5. **a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, nitrogen and soil depth, at sowing during rabi 1991-92.**

a) Soil ammonical nitrogen (Mean of genotypes in dry plots at sowing in 1991-92)



b) Soil nitrate nitrogen (Mean of genotypes in dry plots at sowing in 1991-92)

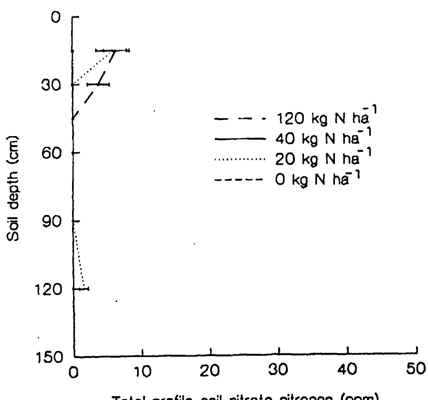
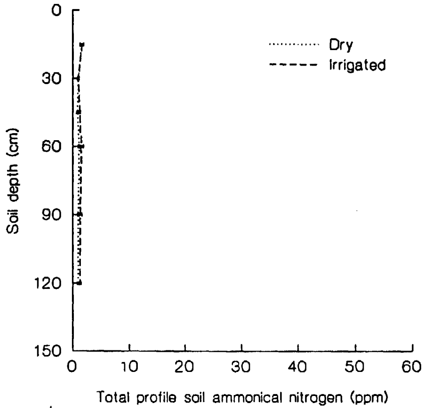


Fig : A 4.6. **a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of water and soil depth, at anthesis during rabi 1990-91.**

a) Soil ammonical nitrogen (Mean of nitrogen and genotype treatments at anthesis in 1990-91)



b) Soil nitrate nitrogen (Mean of nitrogen and genotype treatments at anthesis in 1990-91)

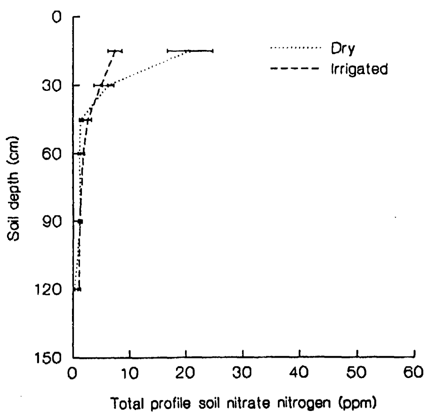
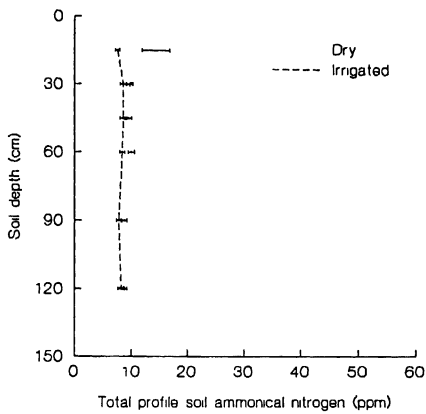


Fig : A 4.7. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of water and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of nitrogen and genotype treatments at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of nitrogen and genotype treatments at anthesis in 1991-92)

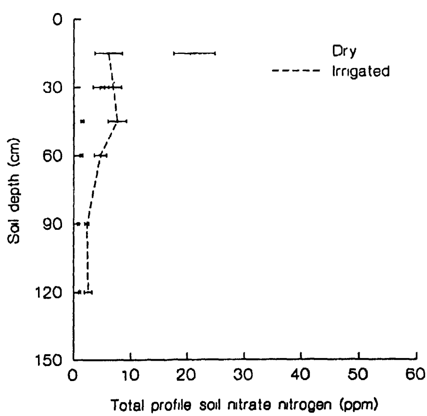
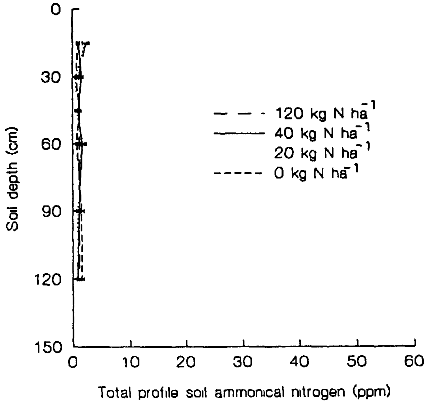


Fig : A 4.8. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of nitrogen and soil depth, at anthesis during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of water and genotype treatments at anthesis in 1990-91)



b) Soil nitrate nitrogen (Mean of water and genotype treatments at anthesis in 1990-91)

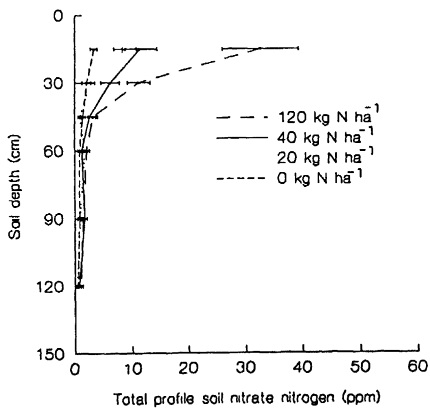
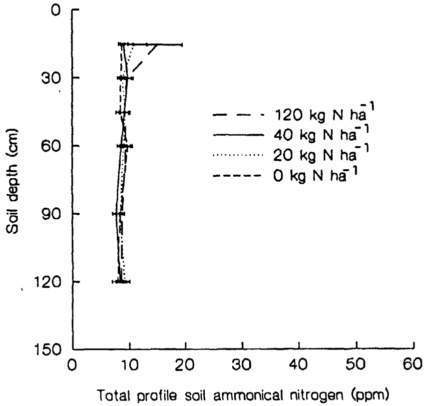


Fig : A 4.9. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of nitrogen and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of water and genotype treatments at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of water and genotype treatments at anthesis in 1991-92)

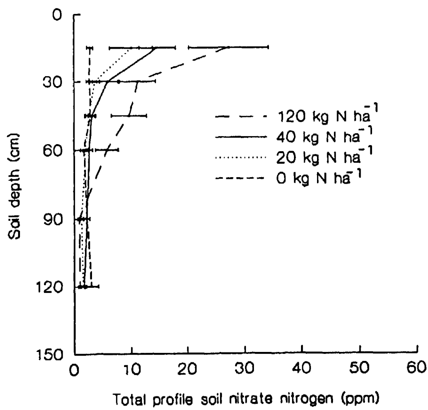
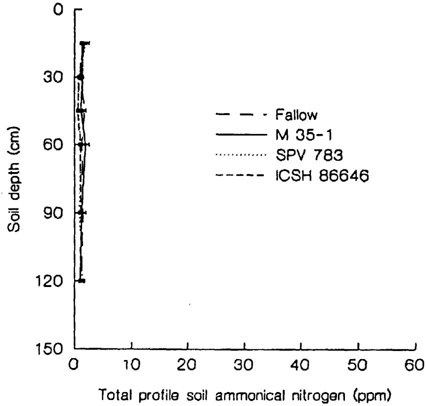


Fig : A 4.10. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of genotype and soil depth, at anthesis during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of water and nitrogen treatments at anthesis in 1990-91)



b) Soil nitrate nitrogen (Mean of water and nitrogen treatments at anthesis in 1990-91)

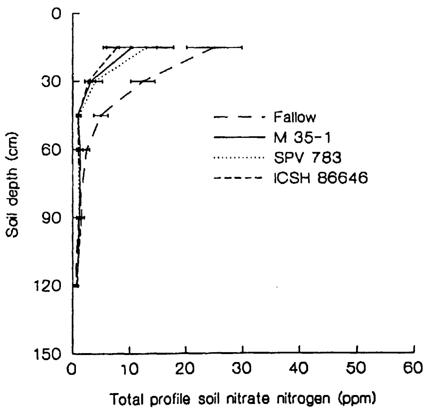
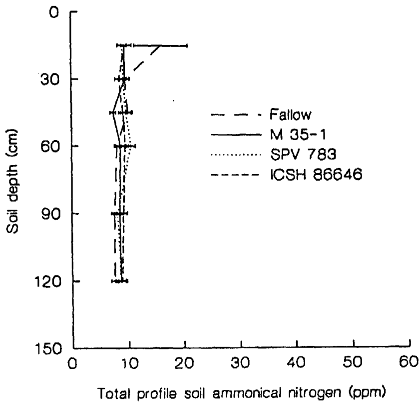


Fig : A 4.11. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of genotype and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of water and nitrogen treatments at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of water and nitrogen treatments at anthesis in 1991-92)

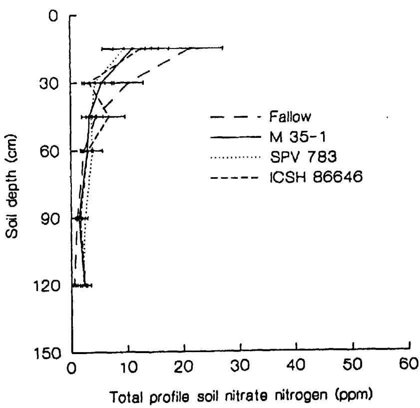
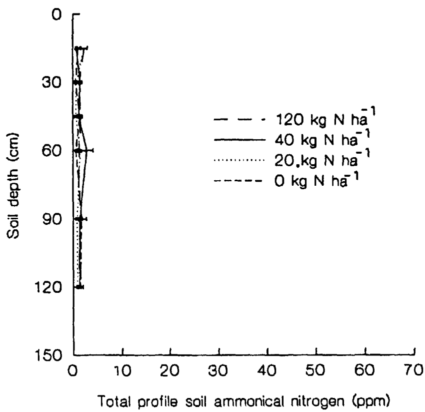


Fig : A 4.12. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, nitrogen and soil depth, at anthesis during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of genotypes in irrigated at anthesis in 1990-91)



b) Soil nitrate nitrogen (Mean of genotypes in irrigated at anthesis in 1990-91)

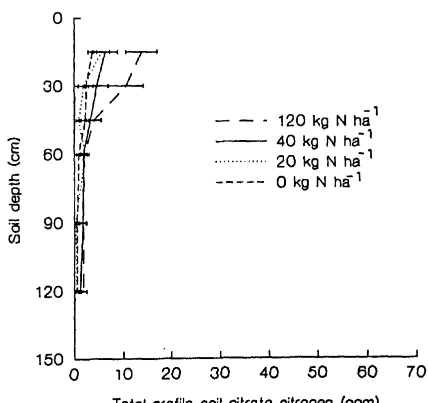
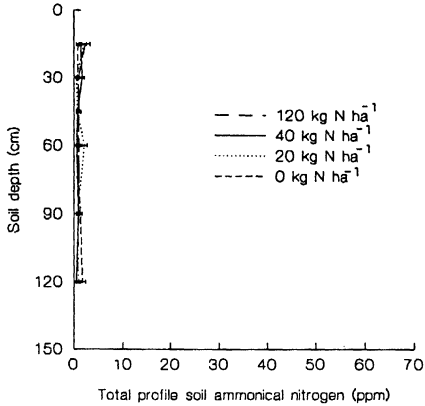


Fig : A 4.13. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, nitrogen and soil depth, at anthesis during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of genotypes in dry plots at anthesis in 1990-91)



b) Soil nitrate nitrogen (Mean of genotypes in dry plots at anthesis in 1990-91)

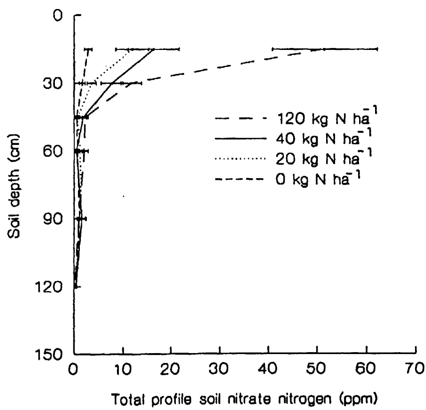
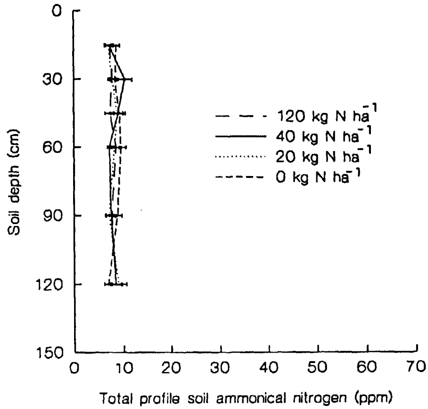


Fig : A 4.14. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, nitrogen and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of genotypes in irrigated plots at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of genotypes in irrigated plots at anthesis in 1991-92)

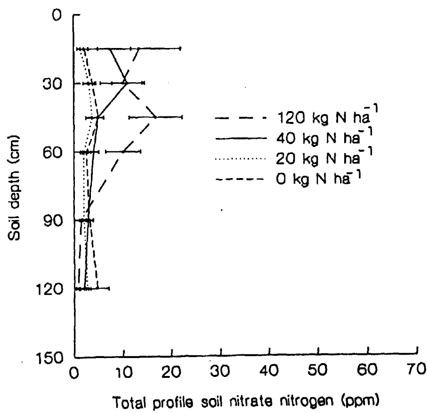
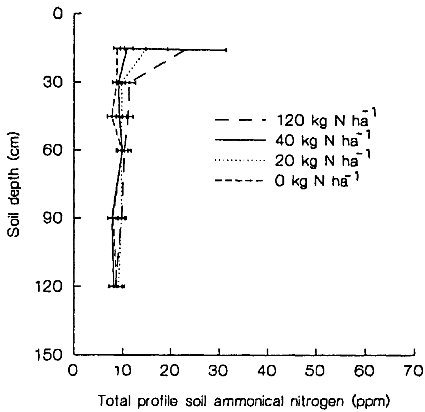


Fig : A 4.15. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, nitrogen and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of genotypes in dry plots at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of genotypes in dry plots at anthesis in 1991-92)

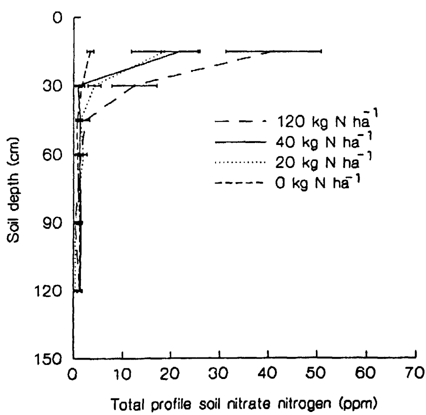
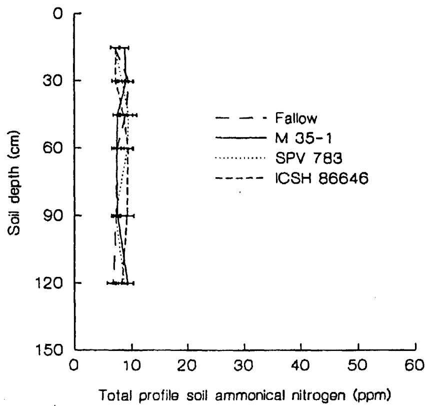


Fig : A 4.16. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, genotype and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of nitrogen treatments in irrigated plots at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of nitrogen treatments in irrigated plots at anthesis in 1991-92)

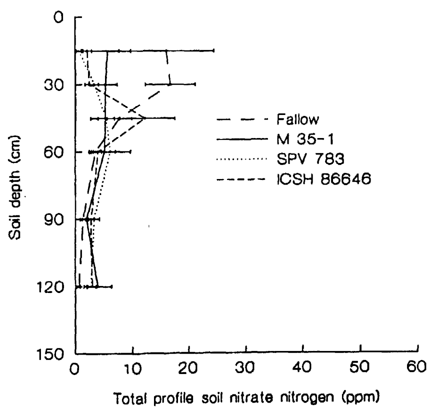
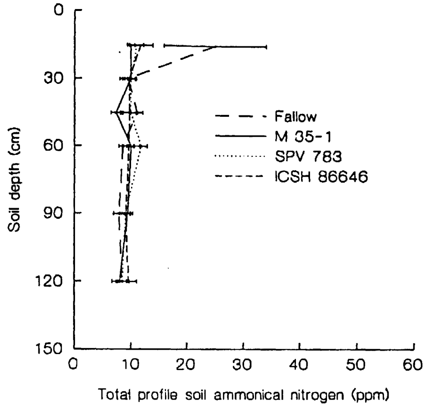


Fig : A 4.17. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, genotype and soil depth, at anthesis during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of nitrogen treatments in dry plots at anthesis in 1991-92)



b) Soil nitrate nitrogen (Mean of nitrogen treatments in dry plots at anthesis in 1991-92)

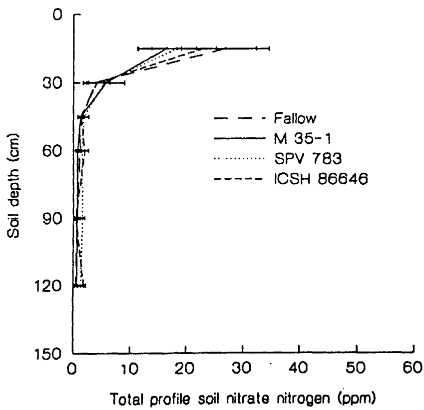
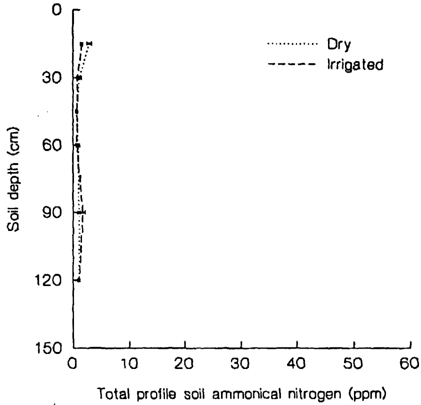


Fig : A 4.18. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of water and soil depth, at harvest during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of nitrogen and genotype treatments at harvest in 1990-91)



b) Soil nitrate nitrogen (Mean of nitrogen and genotype treatments at harvest in 1990-91)

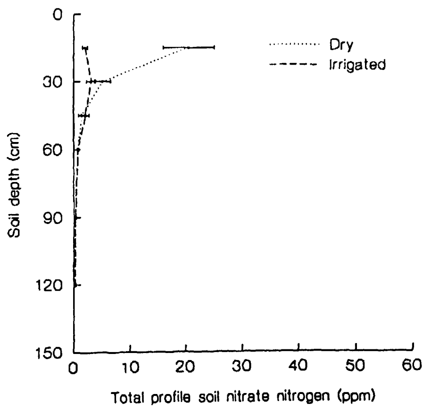
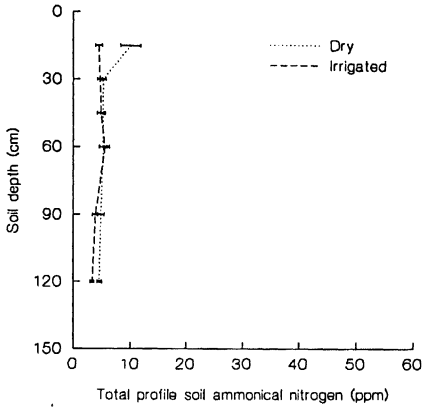


Fig : A 4.19. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of water and soil depth, at harvest during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of nitrogen and genotype treatments at harvest in 1991-92)



b) Soil nitrate nitrogen (Mean of nitrogen and genotype treatments at harvest in 1991-92)

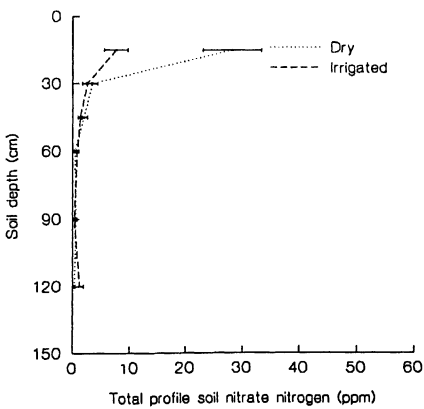
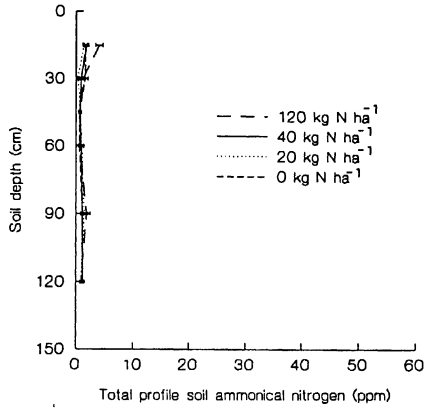


Fig : A 4.20. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of nitrogen and soil depth, at harvest during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of water and genotype treatments at harvest in 1990-91)



b) Soil nitrate nitrogen (Mean of water and genotype treatments at harvest in 1990-91)

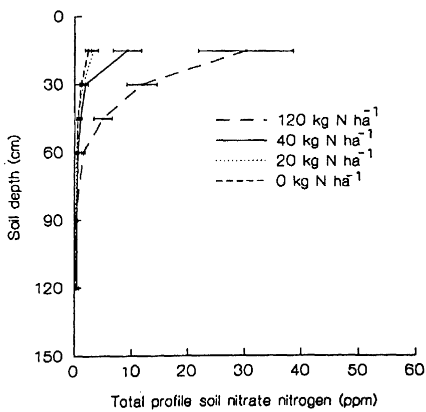
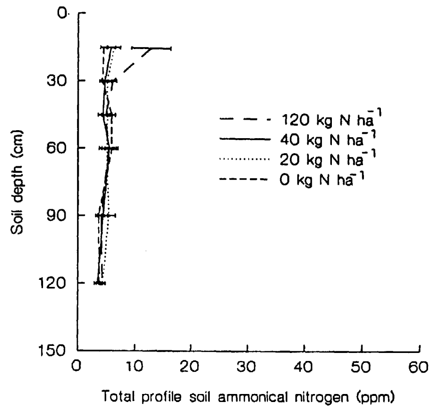


Fig : A 4.21. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m for the interaction effect of nitrogen and soil depth, at harvest during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of water and genotype treatments at harvest in 1991-92)



b) Soil nitrate nitrogen (Mean of water and genotype treatments at harvest in 1991-92)

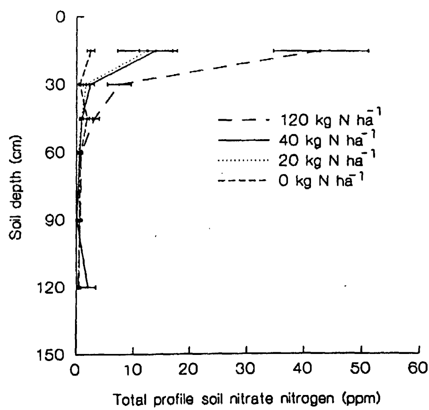
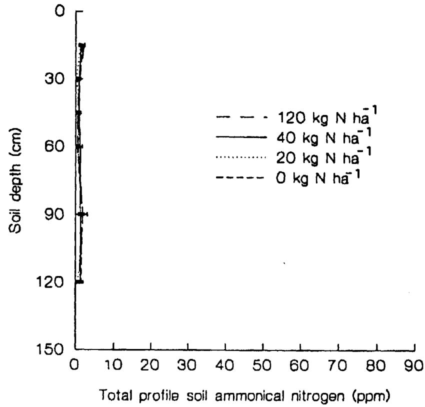


Fig : A 4.22. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, nitrogen and soil depth, at harvest during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of genotypes in irrigated plots at harvest in 1990-91)



b) Soil nitrate nitrogen (Mean of genotypes in irrigated plots at harvest in 1990-91)

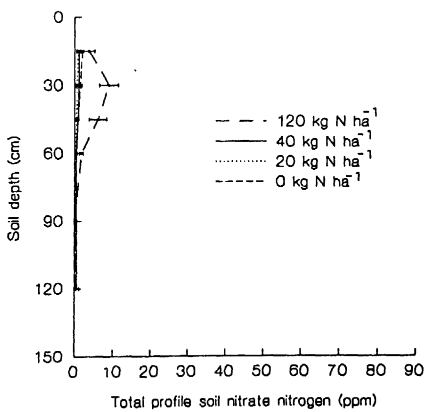
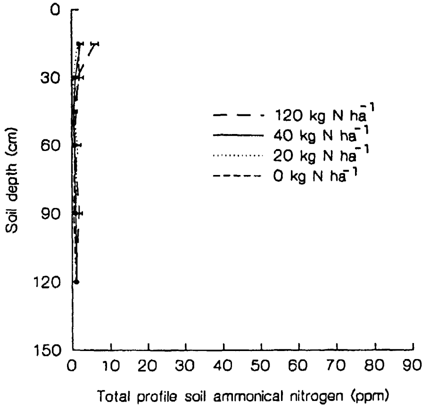


Fig : A 4.23. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, nitrogen and soil depth, at harvest during rabi 1990-91.

a) Soil ammonical nitrogen (Mean of genotypes in dry plots at harvest in 1990-91)



b) Soil nitrate nitrogen (Mean of genotypes in dry plots at harvest in 1990-91)

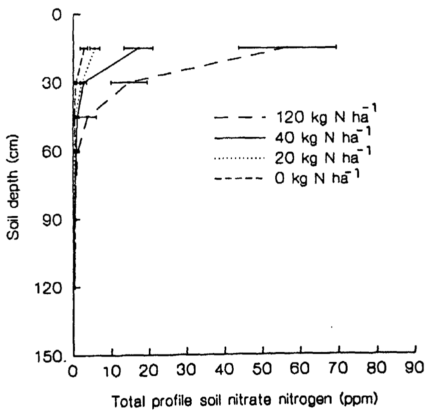
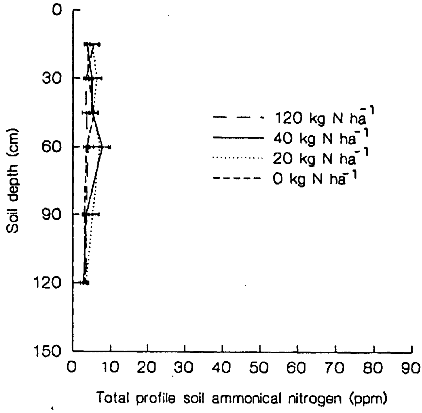


Fig : A 4.24. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, nitrogen and soil depth, at harvest during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of genotypes in irrigated plots at harvest in 1991-92)



b) Soil nitrate nitrogen (Mean of genotypes in irrigated plots at harvest in 1991-92)

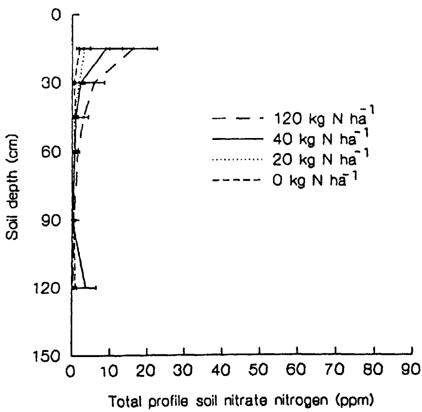
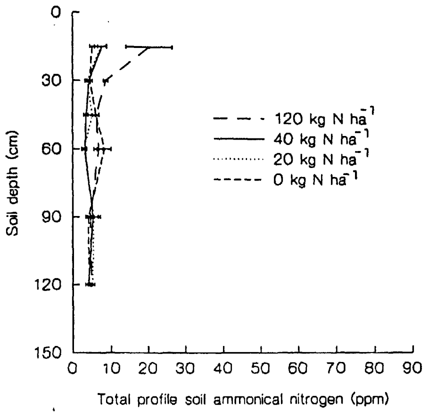


Fig : A 4.25. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, nitrogen and soil depth, at harvest during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of genotypes in dry plots at harvest in 1991-92)



b) Soil nitrate nitrogen (Mean of genotypes in dry plots at harvest in 1991-92)

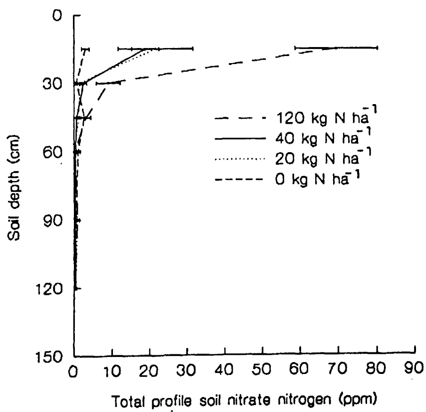


Fig : A 4.26. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in irrigated plots for the interaction effect of water, genotype and soil depth, at harvest during rabi 1991-92.

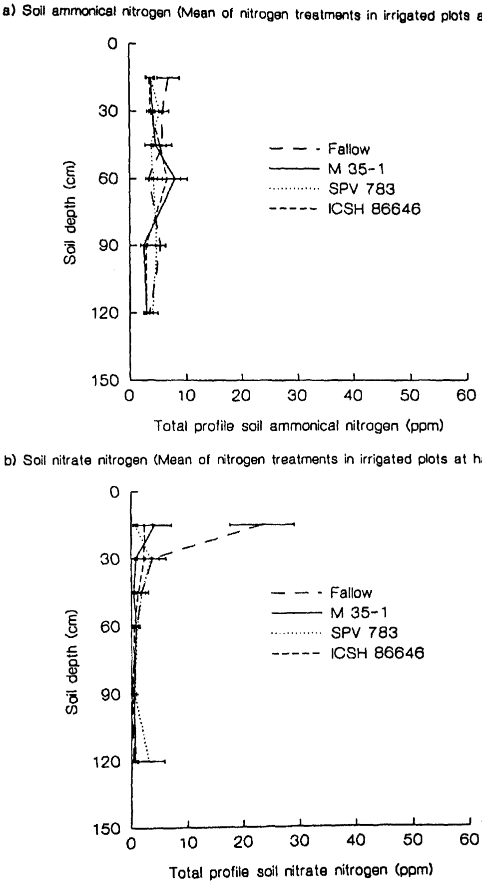
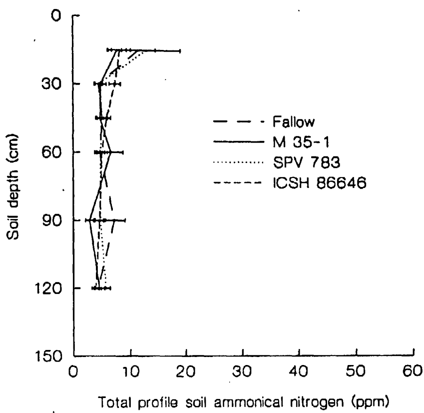


Fig : A 4.27. a) Soil ammonical and b) nitrate nitrogen as a function of soil depth upto 1.2 m in dry plots for the interaction effect of water, genotype and soil depth, at harvest during rabi 1991-92.

a) Soil ammonical nitrogen (Mean of nitrogen treatments in dry plots at harvest in 1991-91)



b) Soil nitrate nitrogen (Mean of nitrogen treatments in dry plots at harvest in 1991-91)

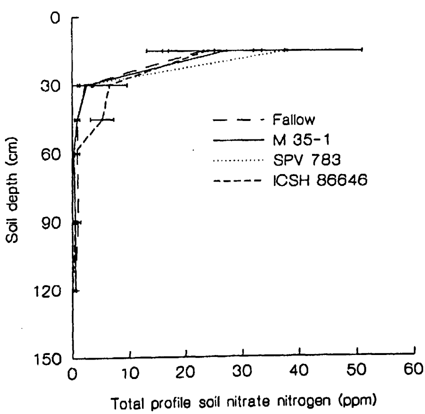


Fig : A 4.51 Cumulative light interception by ICSH 86646 in different nitrogen treatments in irrigated plots in 1990-91.

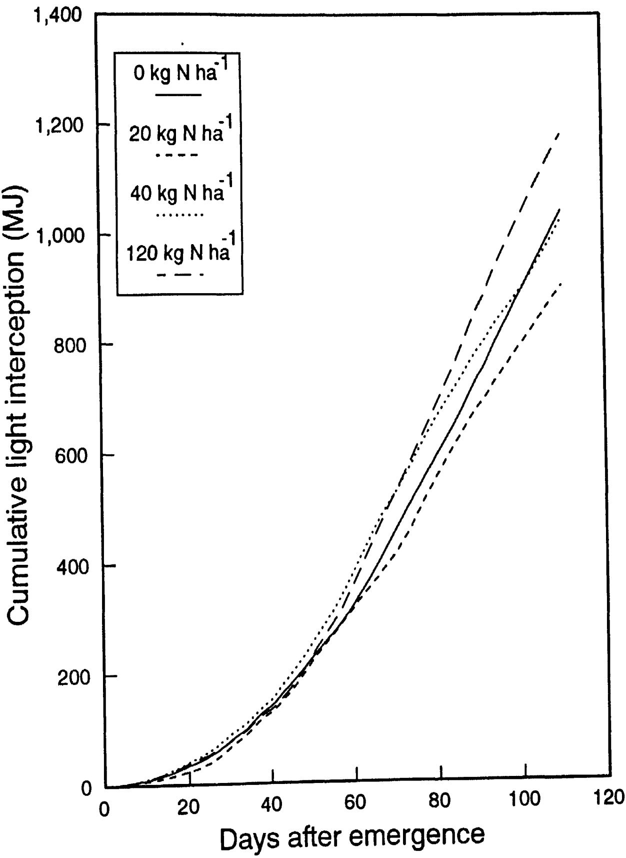


Fig : 4.52 Cumulative light interception by ICSH 86646 in different nitrogen treatments in dry plots in 1990-91.

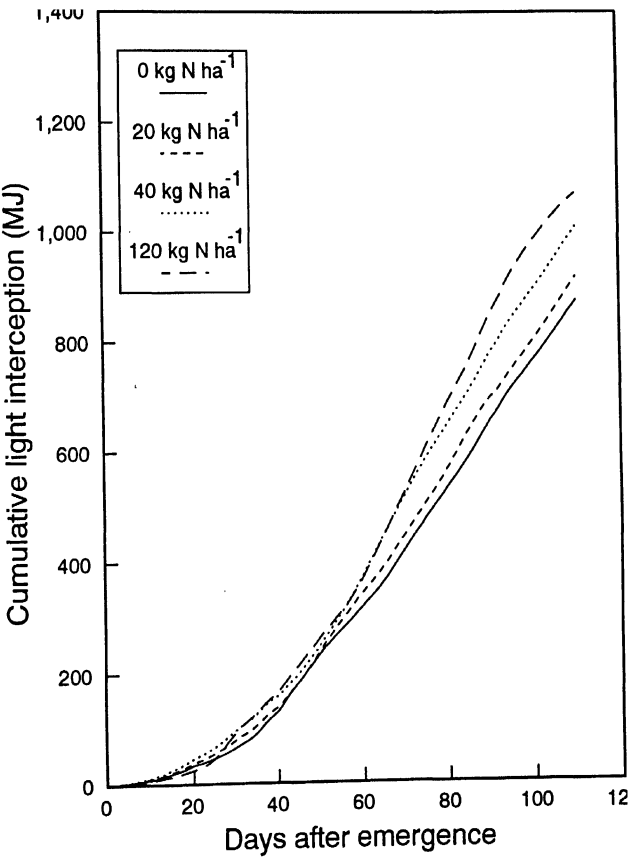


Fig : 4.53 Cumulative light interception by SPV 783 in different nitrogen treatments in irrigated plots in 1990-91.

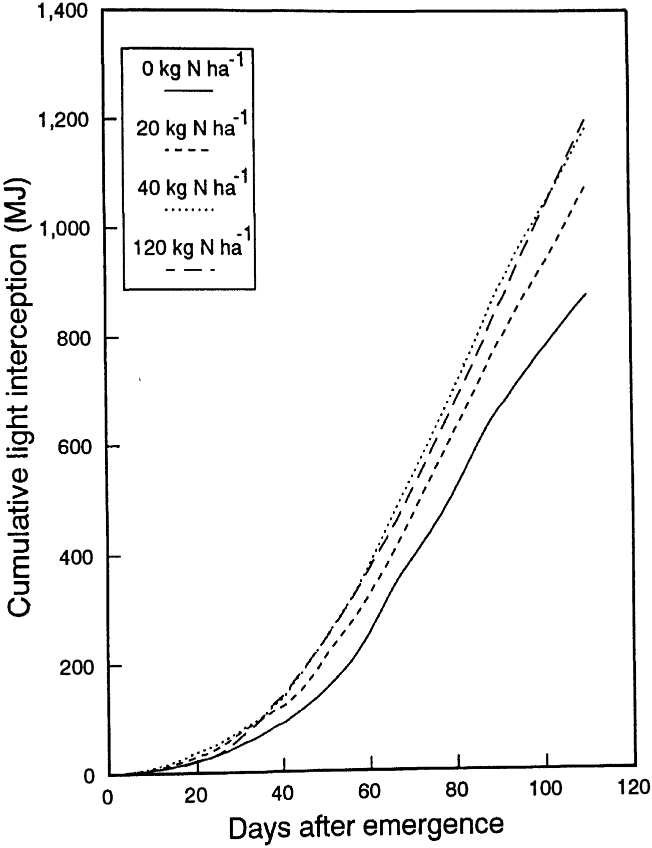


Fig : 4.55 Cumulative light interception by M 35-1 in different nitrogen treatments in irrigated plots in 1990-91.

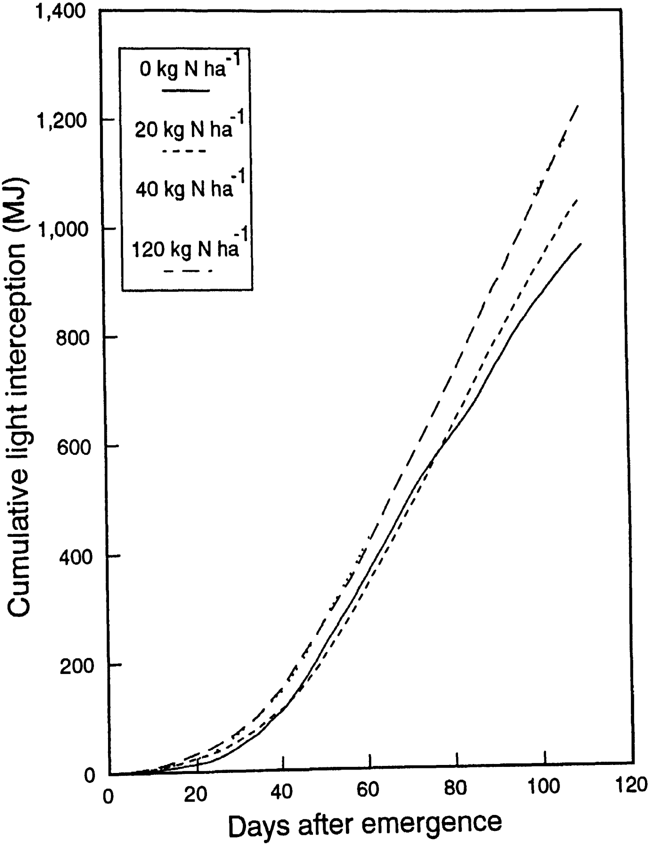


Fig : 4.56 Cumulative light interception by M 35-1 in different nitrogen treatments in dry plots in 1990-91.

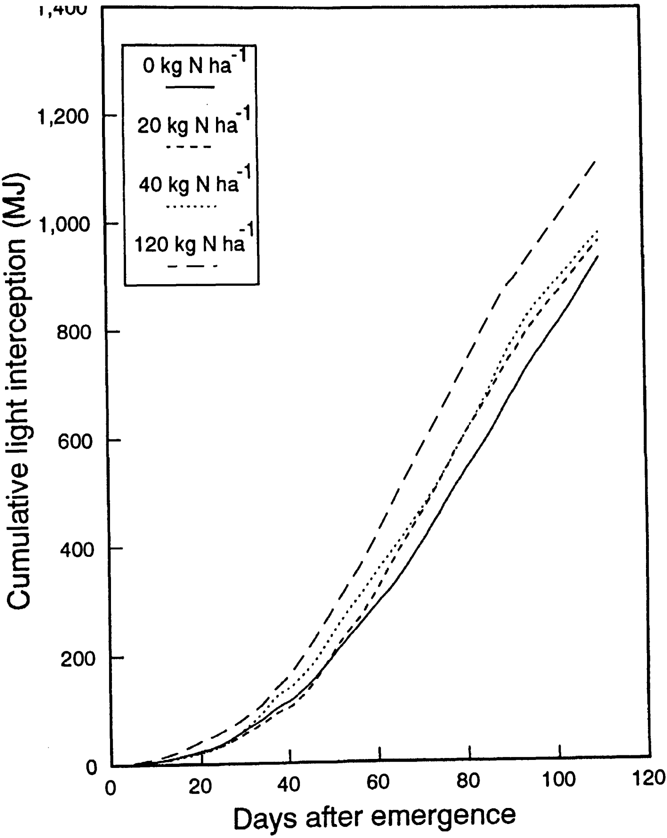


Fig : 4.57 Cumulative light interception by ICSH 86646 in different nitrogen treatments in irrigated plots in 1991-92.

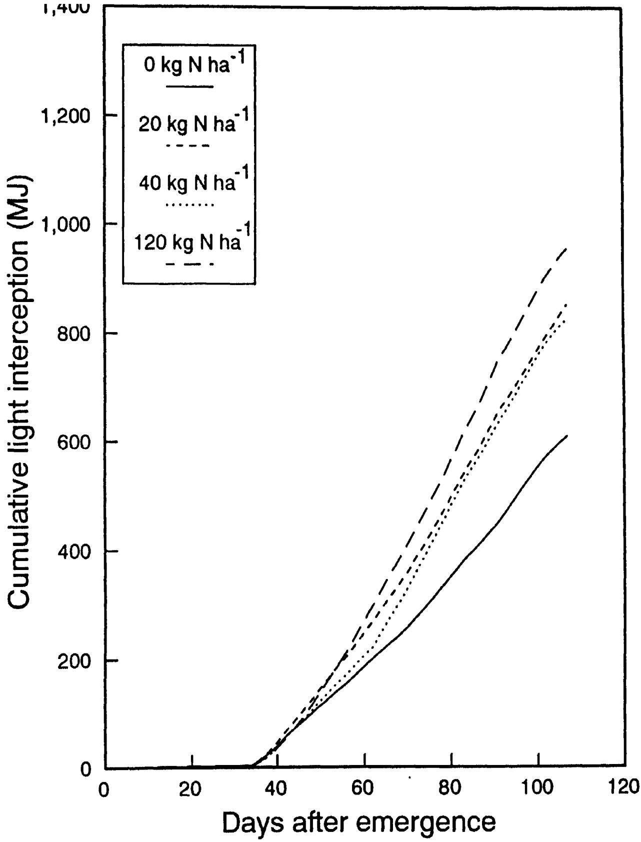


Fig : 4.58 Cumulative light interception by ICSH 86646 in different nitrogen treatments in dry plots in 1991-92.

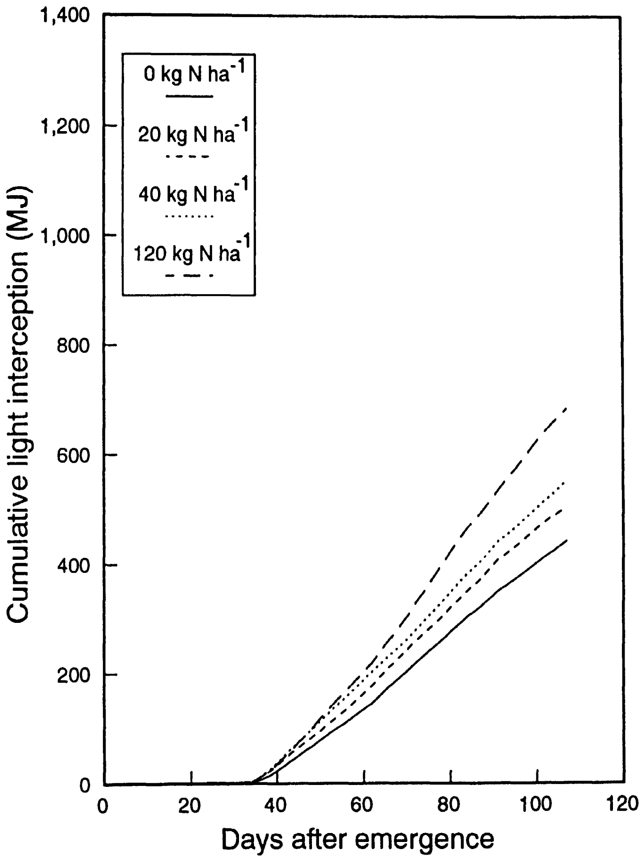


Fig : 4.59 Cumulative light interception by SPV 783 in different nitrogen treatments in irrigated plots in 1991-92.

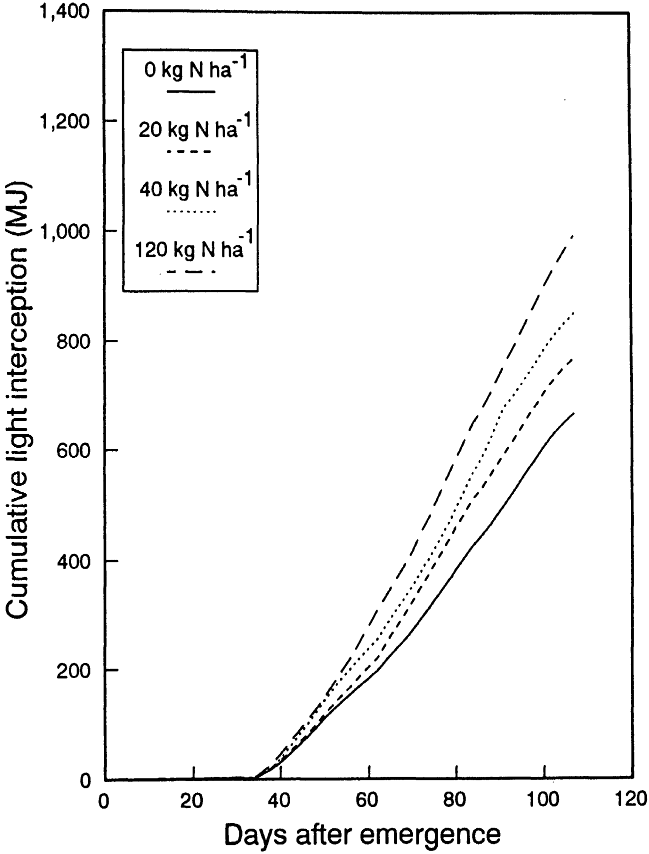


Fig : 4.60 Cumulative light interception by SPV 783 in different nitrogen treatments in dry plots in 1991-92.

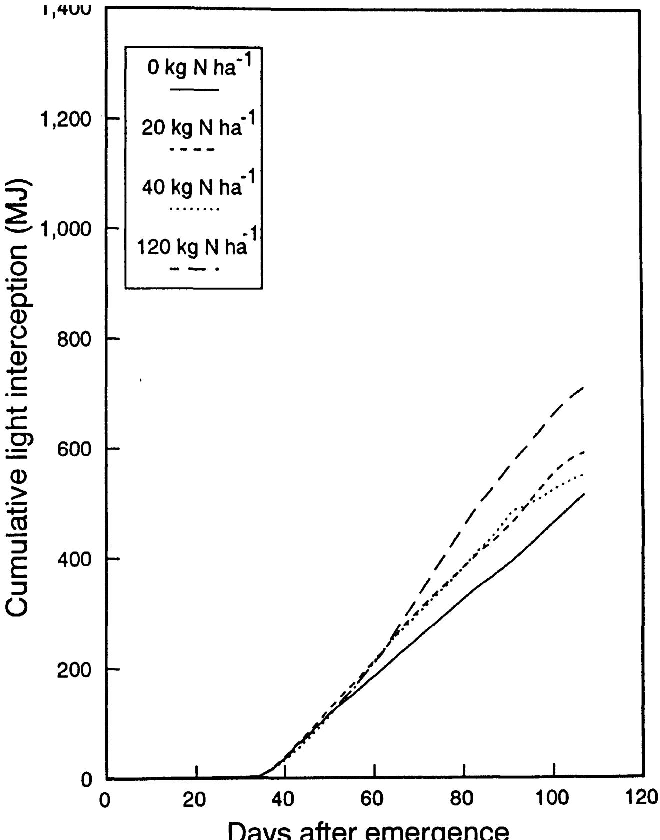


Fig : 4.61 Cumulative light interception by M 35-1 in different nitrogen treatments in irrigated plots in 1991-92.

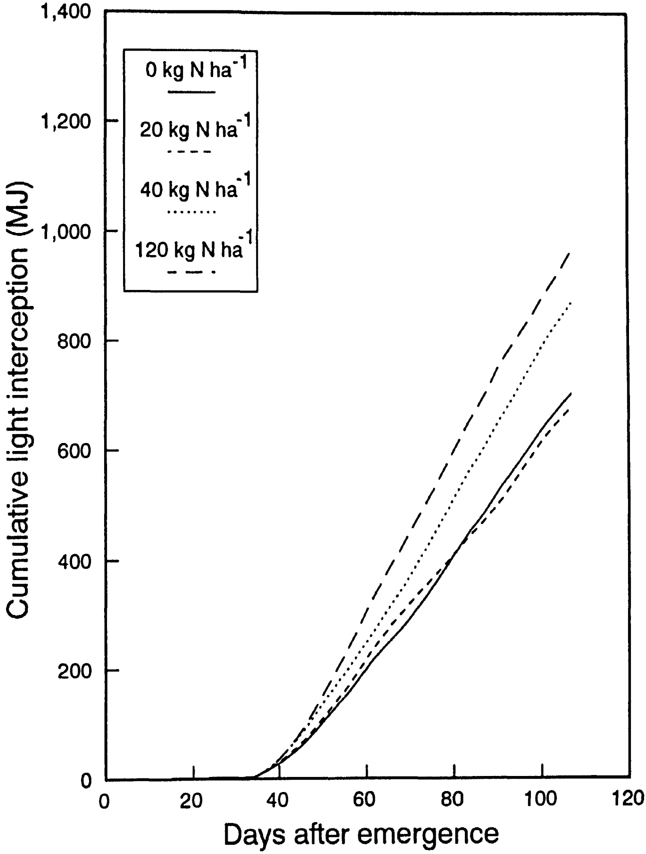
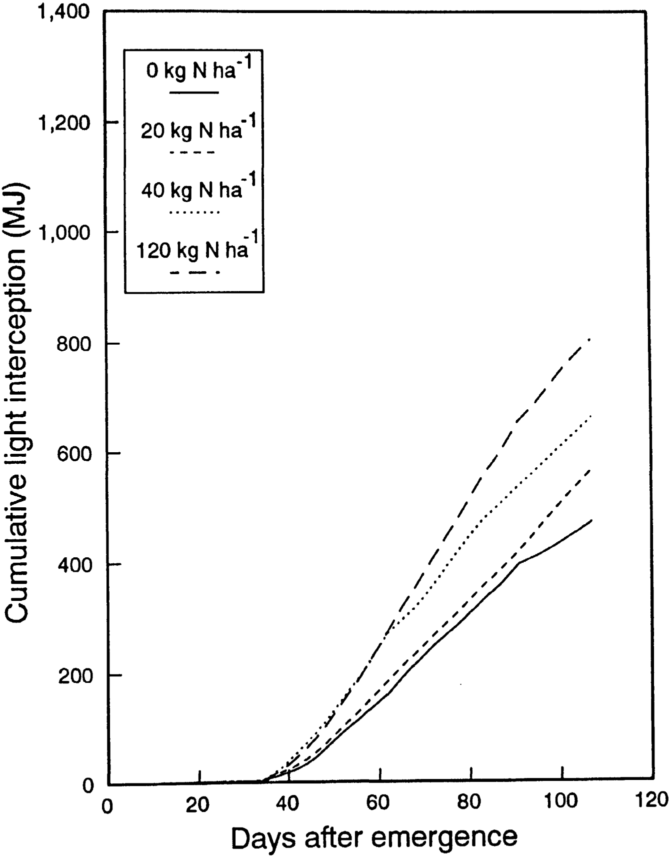


Fig : 4.62 Cumulative light interception by M 35-1 in different nitrogen treatments in dry plots in 1991-92.



Appendix table : 1. **Mean plant height of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Plant height (cm)	
	1990-91	1991-92
Water (W) :		
Irrigated	77.63 A	34.85 A
Dry	75.51 A	27.50 A
LSD (0.05)	21.59	17.31
Nitrogen (N) :		
0 kg N ha^{-1}	67.94 B	19.41 C
20 kg N ha^{-1}	74.59 BA	29.32 B
40 kg N ha^{-1}	80.55 BA	35.35 A
120 kg N ha^{-1}	83.20 A	40.63 A
LSD (0.05)	9.26	5.77
Genotypes (G) :		
ICSH 86646	85.84 B	30.56 A
SPV 783	72.62 B	30.96 A
M 35-1	71.24 A	32.00 A
LSD (0.05)	3.33	2.42
Interactions : SE		
Days after emergence (DAE)		
W * DAE	17.28 *	15.57 **
N * DAE	24.34 **	22.02 **
G * DAE	21.08 **	19.87 **
W * N * DAE	34.43	31.15
W * G * DAE	29.81	26.98
N * G * DAE	42.16	38.15
W * N * G * DAE	59.62	53.95

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 2. **Mean leaf area index of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Leaf area index	
	1990-91	1991-92
Water (W) :		
Irrigated	1.53 A	0.77 A
Dry	1.19 B	0.49 B
LSD (0.05)	0.32	0.22
Nitrogen (N) :		
0 kg N ha^{-1}	1.07 C	0.42 D
20 kg N ha^{-1}	1.30 B	0.55 C
40 kg N ha^{-1}	1.43 B	0.69 B
120 kg N ha^{-1}	1.63 A	0.86 A
LSD (0.05)	0.16	0.10
Genotypes (G) :		
ICSH 86646	1.31 B	0.68 A
SPV 783	1.36 BA	0.54 B
M 35-1	1.40 A	0.67 A
LSD (0.05)	0.06	0.07
Interactions : SE		
Days after emergence (DAE)		
W * DAE	0.55 **	0.63 **
N * DAE	0.78 **	0.89 **
G * DAE	0.67 *	0.77 **
W * N * DAE	1.10 *	1.26 *
W * G * DAE	0.95	1.09 **
N * G * DAE	1.35	1.55
W * N * G * DAE	1.91	2.19 *

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 3. Mean total above ground biomass of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.

Treatment	Total above ground dry biomass ($g\ plant^{-1}$)	
	1990-91	1991-92
Water (W) :		
Irrigated	31.83 A	16.11 A
Dry	26.72 A	10.26 B
LSD (0.05)	11.46	4.51
Nitrogen (N) :		
0 kg N ha^{-1}	21.31 C	8.11 D
20 kg N ha^{-1}	28.16 B	10.67 C
40 kg N ha^{-1}	31.99 AB	14.26 B
120 kg N ha^{-1}	35.65 A	19.68 A
LSD (0.05)	4.26	2.51
Genotypes (G) :		
ICSH 86646	28.05 B	14.22 A
SPV 783	29.72 A	12.67 B
M 35-1	30.06 A	12.65 B
LSD (0.05)	1.23	1.47
Interactions : SE		
Days after emergence (DAE)		
W * DAE	14.09 **	15.09 **
N * DAE	19.92 **	21.35 **
G * DAE	17.25 **	18.49 **
W * N * DAE	28.18	30.19 **
W * G * DAE	24.40	26.15 **
N * G * DAE	34.51	36.98 *
W * N * G * DAE	48.80	52.30 **

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 4. **Mean total dry leaf weight of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total dry leaf weight (g plant^{-1})	
	1990-91	1991-92
Water (W) :		
Irrigated	5.30 A	3.06 A
Dry	4.68 A	2.45 A
LSD (0.05)	1.70	0.84
Nitrogen (N) :		
0 kg N ha^{-1}	3.88 C	1.93 C
20 kg N ha^{-1}	4.86 B	2.36 C
40 kg N ha^{-1}	5.31 B	2.97 B
120 kg N ha^{-1}	5.91 A	3.77 A
LSD (0.05)	0.58	0.44
Genotypes (G) :		
ICSH 86646	4.55 C	2.92 A
SPV 783	5.43 A	2.67 A
M 35-1	5.00 B	2.68 A
LSD (0.05)	0.22	0.27
Interactions : SE		
Days after emergence (DAE)		
W * DAE	2.01 **	2.17 **
N * DAE	2.84 **	3.08 **
G * DAE	2.46 **	2.67 **
W * N * DAE	4.02	4.36 *
W * G * DAE	3.48	3.77 **
N * G * DAE	4.92	5.34 *
W * N * G * DAE	6.96	7.55 *

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 5. **Mean total dry stem weight of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total dry stem weight (g plant^{-1})	
	1990-91	1991-92
Water (W) :		
Irrigated	16.30 A	8.61 A
Dry	14.11 A	5.67 B
LSD (0.05)	5.45	2.35
Nitrogen (N) :		
0 kg N ha^{-1}	11.59 C	4.46 C
20 kg N ha^{-1}	14.99 B	5.82 C
40 kg N ha^{-1}	16.46 A	7.82 B
120 kg N ha^{-1}	17.79 A	10.47 A
LSD (0.05)	2.17	1.47
Genotypes (G) :		
ICSH 86646	12.01 C	6.46 B
SPV 783	16.17 B	7.40 A
M 35-1	17.45 A	7.56 A
LSD (0.05)	0.80	0.85
Interactions : SE		
Days after emergence (DAE)		
W * DAE	7.71 **	7.67 **
N * DAE	10.91 **	10.84 **
G * DAE	9.44 **	9.39 **
W * N * DAE	15.42	15.33 *
W * G * DAE	13.36	13.28 **
N * G * DAE	18.89	18.78 **
W * N * G * DAE	26.72	26.56 **

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 6. Mean total above ground dry vegetative matter of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.

Treatment	Total above ground vegetative dry matter (g $plant^{-1}$)	
	1990-91	1991-92
Water (W) :		
Irrigated	17.73 A	11.67 A
Dry	17.20 A	8.12 B
LSD (0.05)	6.28	3.19
Nitrogen (N) :		
0 kg N ha^{-1}	14.24 C	6.38 C
20 kg N ha^{-1}	18.07 B	8.17 C
40 kg N ha^{-1}	19.95 AB	10.79 B
120 kg N ha^{-1}	21.60 A	14.24 A
LSD (0.05)	2.46	1.89
Genotypes (G) :		
ICSH 86646	15.04 B	10.49 A
SPV 783	19.85 A	9.13 B
M 35-1	20.49 A	10.07 AB
LSD (0.05)	0.89	1.10
Interactions :		
SE		
Days after emergence (DAE)		
W * DAE	9.14 **	9.21 **
N * DAE	12.92 **	13.03 **
G * DAE	11.19 **	11.28 **
W * N * DAE	18.27	18.43 *
W * G * DAE	15.82	15.96 **
N * G * DAE	22.38	22.57 **
W * N * G * DAE	31.65	31.92 **

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 7. **Mean total dry earhead and grain weight of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91.**

Treatment	1990-91	
	Total dry earhead weight (g plant^{-1})	Total dry grain weight (g plant^{-1})
Water (W) :		
Irrigated	15.34 A	10.28 A
Dry	11.87 A	7.53 A
LSD (0.05)	6.89	5.22
Nitrogen (N) :		
0 kg N ha^{-1}	8.76 D	5.67 C
20 kg N ha^{-1}	12.46 C	7.97 B
40 kg N ha^{-1}	15.29 B	10.17 A
120 kg N ha^{-1}	17.92 A	11.81 A
LSD (0.05)	2.52	1.89
Genotypes (G) :		
ICSH 86646	17.22 A	11.18 A
SPV 783	12.17 B	8.07 B
M 35-1	11.43 B	7.48 B
LSD (0.05)	1.01	0.97
Interactions :		
SE		
Days after emergence (DAE)		
W * DAE	6.73 **	5.43 **
N * DAE	9.52 **	7.68 **
G * DAE	8.25 **	6.65 **
W * N * DAE	13.47	10.86
W * G * DAE	11.66	9.41
N * G * DAE	16.49	13.30
W * N * G * DAE	23.33	18.82

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 8. **Mean leaf nitrogen content of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Leaf nitrogen content (%)	
	1990-91	1991-92
Water (W) :		
Irrigated	2.72 A	2.36 A
Dry	2.54 B	2.10 B
LSD (0.05)	0.18	0.20
Nitrogen (N) :		
0 kg N ha^{-1}	2.32 D	2.10 B
20 kg N ha^{-1}	2.54 C	2.15 B
40 kg N ha^{-1}	2.66 B	2.20 B
120 kg N ha^{-1}	2.99 A	2.47 A
LSD (0.05)	0.10	0.12
Genotypes (G) :		
ICSH 86646	2.63 B	2.20 B
SPV 783	2.52 C	2.12 C
M 35-1	2.73 A	2.38 A
LSD (0.05)	0.60	0.08
Interactions : SE		
Days after emergence (DAE)		
W * DAE	0.28 *	0.46 **
N * DAE	0.39 **	0.66 *
G * DAE	0.34	0.57 **
W * N * DAE	0.56 *	0.93 *
W * G * DAE	0.48	0.81 **
N * G * DAE	0.68	1.14 *
W * N * G * DAE	0.97	1.61

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 9. **Mean stem nitrogen content of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Stem nitrogen content (%)	
	1990-91	**1991-92**
Water (W) :		
Irrigated	1.77 A	1.24 A
Dry	1.70 A	1.08 B
LSD (0.05)	0.25	0.01
Nitrogen (N) :		
0 kg N ha^{-1}	1.49 C	1.05 B
20 kg N ha^{-1}	1.68 B	1.09 B
40 kg N ha^{-1}	1.75 B	1.14 B
120 kg N ha^{-1}	2.02 A	1.35 A
LSD (0.05)	0.15	0.11
Genotypes (G) :		
ICSH 86646	1.77 A	1.31 A
SPV 783	1.70 A	1.29 A
M 35-1	1.77 A	0.88 B
LSD (0.05)	0.08	0.06
Interactions : SE		
Days after emergence (DAE)		
W * DAE	0.30 **	0.46 *
N * DAE	0.42 **	0.65 **
G * DAE	0.37	0.56 **
W * N * DAE	0.60	0.92
W * G * DAE	0.52	0.79 *
N * G * DAE	0.73	1.13
W * N * G * DAE	1.04	1.59 *

* = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 10. **Mean total leaf nitrogen uptake of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total leaf nitrogen uptake (kg ha^{-1})	
	1990-91	**1991-92**
Water (W) :		
Irrigated	15.20 A	6.92 A
Dry	11.59 B	4.13 A
LSD (0.05)	3.49	3.10
Nitrogen (N) :		
0 kg N ha^{-1}	8.04 D	3.18 D
20 kg N ha^{-1}	11.80 C	4.38 C
40 kg N ha^{-1}	14.45 B	5.77 B
120 kg N ha^{-1}	19.27 A	8.76 A
LSD (0.05)	2.22	1.10
Genotypes (G) :		
ICSH 86646	13.48 A	5.90 A
SPV 783	12.78 A	5.62 AB
M 35-1	13.92 A	5.91 B
LSD (0.05)	1.22	0.69
Interactions : SE		
Days after emergence (DAE)		
W * DAE	3.79 **	5.15 **
N * DAE	5.36 **	7.29 **
G * DAE	4.64	6.31 *
W * N * DAE	7.58 *	10.31 **
W * G * DAE	6.57	8.93 **
N * G * DAE	9.29	12.63
W * N * G * DAE	13.13	17.86 **

Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 11. **Mean total stem nitrogen uptake of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total stem nitrogen uptake (kg ha^{-1})	
	1990-91	1991-92
Water (W) :		
Irrigated	7.01 A	4.68 A
Dry	5.12 A	2.25 B
LSD (0.05)	2.63	1.71
Nitrogen (N) :		
0 kg N ha^{-1}	3.52 C	1.66 D
20 kg N ha^{-1}	5.29 B	2.50 C
40 kg N ha^{-1}	6.32 B	3.55 B
120 kg N ha^{-1}	9.13 A	6.17 A
LSD (0.05)	1.19	0.70
Genotypes (G) :		
ICSH 86646	5.42 B	3.39 AB
SPV 783	5.63 B	3.14 B
M 35-1	7.13 A	3.88 A
LSD (0.05)	0.64	0.55
Interactions : SE		
Days after emergence (DAE)		
W * DAE	2.99 **	4.26 **
N * DAE	4.24 **	6.02 **
G * DAE	3.67 **	5.22 **
W * N * DAE	5.99	8.52 **
W * G * DAE	5.19	7.38 **
N * G * DAE	7.34	10.43 **
W * N * G * DAE	10.39	14.76 **

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 12. Mean total nitrogen uptake by above ground vegetative matter of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.

Treatment	Total nitrogen uptake by above ground vegetative matter (kg ha^{-1})	
	1990-91	1991-92
Water (W) :		
Irrigated	22.21 A	11.60 A
Dry	16.70 A	6.38 B
LSD (0.05)	5.66	4.80
Nitrogen (N) :		
0 kg N ha^{-1}	11.56 D	4.84 D
20 kg N ha^{-1}	17.09 C	6.88 C
40 kg N ha^{-1}	20.77 B	9.32 B
120 kg N ha^{-1}	28.40 A	14.93 A
LSD (0.05)	3.12	1.72
Genotypes (G) :		
ICSH 86646	18.91 B	9.30 A
SPV 783	18.41 B	8.75 A
M 35-1	21.05 A	8.93 A
LSD (0.05)	1.58	1.19
Interactions : SE		
Days after emergence (DAE)		
W * DAE	5.85 **	9.08 **
N * DAE	8.27 **	12.84 **
G * DAE	7.16 **	11.12 **
W * N * DAE	11.70 *	18.16 **
W * G * DAE	10.13	15.72 **
N * G * DAE	14.33	22.24 *
W * N * G * DAE	20.27	31.45 **

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 13. **Mean grain nitrogen content and uptake of sorghum as affected by water, nitrogen and genotype, over the growing period in 1990-91.**

Treatment	1990-91	
	Grain nitrogen content (%)	**Grain nitrogen uptake (kg ha^{-1})**
Water (W) :		
Irrigated	1.08 A	25.97 A
Dry	1.05 A	17.62 B
LSD (0.05)	0.19	8.11
Nitrogen (N) :		
0 kg N ha^{-1}	1.06 B	12.70 D
20 kg N ha^{-1}	1.03 B	17.83 C
40 kg N ha^{-1}	1.03 B	23.52 B
120 kg N ha^{-1}	1.13 A	33.13 A
LSD (0.05)	0.06	4.93
Genotypes (G) :		
ICSH 86646	1.01 B	25.78 A
SPV 783	1.10 A	19.34 B
M 35-1	1.08 A	20.26 B
LSD (0.05)	0.05	2.25
Interactions : **SE**		
Days after emergence (DAE)		
W * DAE	0.38	18.38 **
N * DAE	0.54	25.99 **
G * DAE	0.46	22.51 **
W * N * DAE	0.76	36.75
W * G * DAE	0.65	31.83
N * G * DAE	0.93	45.01
W * N * G * DAE	1.32	63.66

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 14. **Mean total soil ammonical nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total soil ammonical nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	20.26 A	42.78 A
Dry	19.02 A	45.24 A
LSD (0.05)	22.23	18.97
Nitrogen (N) :		
0 kg N ha^{-1}	11.68 B	38.32 B
20 kg N ha^{-1}	13.89 B	43.21 B
40 kg N ha^{-1}	17.32 B	39.75 B
120 kg N ha^{-1}	35.67 A	54.78 A
LSD (0.05)	13.10	9.01
Genotypes (G) :		
ICSH 86646	19.21 AB	43.49 A
SPV 783	19.08 B	44.28 A
M 35-1	20.11 A	42.11 A
FALLOW	20.16 A	46.18 A
LSD (0.05)	0.97	4.43
Interactions : SE		
Days after emergence (DAE)		
W * DAE	2.53	7.43 **
N * DAE	3.58 **	10.51 *
G * DAE	3.58	10.51
W * N * DAE	5.06 *	14.86 *
W * G * DAE	5.06	14.86
N * G * DAE	7.15	21.02
W * N * G * DAE	10.12	29.72

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 15. **Mean total soil ammonical nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, at sowing in 1990-91 and 1991-92.**

Treatment	Total soil ammonical nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	7.80 A	8.83 A
Dry	7.21 A	6.65 A
LSD (0.05)	11.84	5.00
Nitrogen (N) :		
0 kg N ha^{-1}	3.69 B	6.01 B
20 kg N ha^{-1}	4.88 B	7.22 AB
40 kg N ha^{-1}	6.45 B	6.59 B
120 kg N ha^{-1}	15.00 A	11.15 A
LSD (0.05)	6.38	4.41
Genotypes (G) :		
ICSH 86646	7.50 A	7.74 A
SPV 783	7.50 A	7.74 A
M 35-1	7.50 A	7.74 A
FALLOW	7.50 A	7.74 A
LSD (0.05)	0.00	0.00
Interactions : SE		
SOIL PROFILE (DEPTH)		
W * DEPTH	10.81	8.85 *
N * DEPTH	15.29 **	12.52 **
G * DEPTH	-	-
W * N * DEPTH	21.63	17.70 *
W * G * DEPTH	-	-
N * G * DEPTH	-	-
W * N * G * DEPTH	-	-

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 16. **Mean total soil ammonical nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, at anthesis in 1990-91 and 1991-92.**

Treatment	Total soil ammonical nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	1.28 A	8.15 A
Dry	1.05 A	10.13 A
LSD (0.05)	0.32	3.41
Nitrogen (N) :		
0 kg N ha^{-1}	1.05 A	8.58 A
20 kg N ha^{-1}	1.13 A	9.23 A
40 kg N ha^{-1}	1.26 A	8.68 A
120 kg N ha^{-1}	1.30 A	10.06 A
LSD (0.05)	0.33	1.64
Genotypes (G) :		
ICSH 86646	0.91 B	9.05 A
SPV 783	1.08 AB	9.15 A
M 35-1	1.26 AB	8.62 A
FALLOW	1.36 A	9.73 A
LSD (0.05)	0.38	1.35
Interactions : SE		
SOIL PROFILE (DEPTH)		
W * DEPTH	2.37	6.68 *
N * DEPTH	3.35 *	9.45
G * DEPTH	3.35	9.45 *
W * N * DEPTH	4.73	13.36
W * G * DEPTH	4.73	13.36 *
N * G * DEPTH	6.69	18.90
W * N * G * DEPTH	9.47	26.73

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 17. **Mean total soil ammonical nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, at harvest in 1990-91 and 1991-92.**

Treatment	Total soil ammonical nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	1.06 A	4.41 A
Dry	1.25 A	5.84 A
LSD (0.05)	0.81	1.74
Nitrogen (N) :		
0 kg N ha^{-1}	1.10 AB	4.57 B
20 kg N ha^{-1}	0.94 B	5.16 AB
40 kg N ha^{-1}	1.05 AB	4.60 B
120 kg N ha^{-1}	1.53 A	6.17 A
LSD (0.05)	0.54	1.37
Genotypes (G) :		
ICSH 86646	1.16 A	5.61 A
SPV 783	0.95 A	5.25 A
M 35-1	1.29 A	4.69 A
FALLOW	1.22 A	5.61 A
LSD (0.05)	0.36	1.29
Interactions : **SE**		
SOIL PROFILE (DEPTH)		
W * DEPTH	2.02 *	6.96 *
N * DEPTH	2.86 *	9.84 *
G * DEPTH	2.86	9.84
W * N * DEPTH	4.05	13.92 *
W * G * DEPTH	4.05	13.92
N * G * DEPTH	5.72	19.68
W * N * G * DEPTH	8.10	27.83

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 18. **Mean total soil nitrate nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total soil nitrate nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	25.86 A	23.25 A
Dry	34.92 A	23.36 A
LSD (0.05)	12.41	10.36
Nitrogen (N) :		
0 kg N ha^{-1}	10.97 C	9.90 C
20 kg N ha^{-1}	18.06 C	19.29 B
40 kg N ha^{-1}	31.04 B	19.91 B
120 kg N ha^{-1}	61.50 A	44.11 A
LSD (0.05)	11.64	6.27
Genotypes (G) :		
ICSH 86646	26.97 B	22.16 AB
SPV 783	27.35 B	22.50 AB
M 35-1	26.17 B	20.29 B
FALLOW	41.07 A	28.26 A
LSD (0.05)	5.69	7.54
Interactions : SE		
Days after emergence (DAE)		
W * DAE	12.90 *	16.80 **
N * DAE	18.25	23.76 **
G * DAE	18.25 *	23.76
W * N * DAE	25.81	33.60 *
W * G * DAE	25.81	33.60
N * G * DAE	36.49	47.52
W * N * G * DAE	51.61	67.21

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 19. **Mean total soil nitrate nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, at sowing in 1990-91 and 1991-92.**

Treatment	Total soil nitrate nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	8.43 A	4.32 A
Dry	7.58 A	0.73 B
LSD (0.05)	2.61	2.74
Nitrogen (N) :		
0 kg N ha^{-1}	3.16 C	1.37 A
20 kg N ha^{-1}	5.51 BC	3.47 A
40 kg N ha^{-1}	9.35 AB	1.67 A
120 kg N ha^{-1}	14.01 A	3.58 A
LSD (0.05)	5.12	2.91
Genotypes (G) :		
ICSH 86646	8.01 A	2.52 A
SPV 783	8.01 A	2.52 A
M 35-1	8.01 A	2.52 A
FALLOW	8.01 A	2.52 A
LSD (0.05)	0.00	0.00
Interactions : SE		
SOIL PROFILE (DEPTH)		
W * DEPTH	6.83	6.77 **
N * DEPTH	9.66 **	9.57 **
G * DEPTH	-	-
W * N * DEPTH	13.66	13.54 **
W * G * DEPTH	-	-
N * G * DEPTH	-	-
W * N * G * DEPTH	-	-

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 20. Mean total soil nitrate nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, at anthesis in 1990-91 and 1991-92.

Treatment	Total soil nitrate nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	3.11 B	5.00 A
Dry	5.15 A	5.12 A
LSD (0.05)	0.37	2.90
Nitrogen (N) :		
0 kg N ha^{-1}	1.46 C	2.49 C
20 kg N ha^{-1}	2.55 BC	3.48 BC
40 kg N ha^{-1}	3.94 B	4.99 B
120 kg N ha^{-1}	8.58 A	9.28 A
LSD (0.05)	1.49	2.17
Genotypes (G) :		
ICSH 86646	2.42 B	4.91 AB
SPV 783	3.49 B	4.28 B
M 35-1	2.93 B	4.36 B
FALLOW	7.69 A	6.69 A
LSD (0.05)	2.16	2.07
Interactions : SE		
SOIL PROFILE (DEPTH)		
W * DEPTH	5.69 **	13.97 **
N * DEPTH	8.05 **	19.76 **
G * DEPTH	8.05 **	19.76 *
W * N * DEPTH	11.38 **	27.94 *
W * G * DEPTH	11.38	27.94
N * G * DEPTH	16.09	39.51
W * N * G * DEPTH	22.75	55.88

* = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 21. **Mean total soil nitrate nitrogen in the 120 cm soil profile as affected by water, nitrogen and genotype, at harvest in 1990-91 and 1991-92.**

Treatment	Total soil nitrate nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	1.39 A	5.83 B
Dry	4.73 A	8.30 A
LSD (0.05)	4.33	0.58
Nitrogen (N) :		
0 kg N ha^{-1}	0.86 B	1.09 C
20 kg N ha^{-1}	0.97 B	2.70 B
40 kg N ha^{-1}	2.23 B	3.28 B
120 kg N ha^{-1}	8.16 A	9.19 A
LSD (0.05)	2.46	1.57
Genotypes (G) :		
ICSH 86646	3.06 AB	3.65 A
SPV 783	2.18 B	4.44 A
M 35-1	2.15 B	3.26 A
FALLOW	4.14 A	4.91 A
LSD (0.05)	2.47	2.42
Interactions : SE		
SOIL PROFILE (DEPTH)		
W * DEPTH	8.69 **	15.23 **
N * DEPTH	12.29 **	21.54 **
G * DEPTH	12.29	21.54
W * N * DEPTH	17.39 **	30.46 **
W * G * DEPTH	17.39	30.46 **
N * G * DEPTH	24.58	43.08
W * N * G * DEPTH	34.77	60.93

*, ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 22. **Mean total soil available nitrogen ($NH_4 + NO_3$) in the 120 cm soil profile as affected by water, nitrogen and genotype, over the growing period in 1990-91 and 1991-92.**

Treatment	Total available nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	46.12 A	66.03 A
Dry	53.94 A	68.60 A
LSD (0.05)	21.73	16.13
Nitrogen (N) :		
0 kg N ha^{-1}	22.65 C	48.23 C
20 kg N ha^{-1}	31.95 BC	62.50 B
40 kg N ha^{-1}	48.36 B	59.65 BC
120 kg N ha^{-1}	97.17 A	98.89 A
LSD (0.05)	19.54	12.63
Genotypes (G) :		
ICSH 86646	46.18 B	65.66 AB
SPV 783	46.43 B	66.78 AB
M 35-1	46.28 B	62.40 B
FALLOW	61.23 A	74.43 A
LSD (0.05)	5.83	9.38
Interactions : SE		
Days after emergence (DAE)		
W * DAE	13.83 *	18.61 **
N * DAE	19.56 **	26.31
G * DAE	19.56	26.31
W * N * DAE	27.67 *	37.21 **
W * G * DAE	27.67	37.21
N * G * DAE	39.13	52.63
W * N * G * DAE	55.34	74.43

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 23. Mean total soil available nitrogen ($NH_4 + NO_3$) in the 120 cm soil profile as affected by water, nitrogen and genotype, at sowing in 1990-91 and 1991-92.

Treatment	Total available nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	16.23 A	13.15 A
Dry	14.79 A	7.38 A
LSD (0.05)	13.31	6.65
Nitrogen (N) :		
0 kg N ha^{-1}	6.85 B	7.38 B
20 kg N ha^{-1}	10.39 B	10.69 AB
40 kg N ha^{-1}	15.80 B	8.26 B
120 kg N ha^{-1}	29.01 A	14.73 A
LSD (0.05)	9.02	5.88
Genotypes (G) :		
ICSH 86646	15.51 A	10.27 A
SPV 783	15.51 A	10.27 A
M 35-1	15.51 A	10.27 A
FALLOW	15.51 A	10.27 A
LSD (0.05)	0.00	0.00
Interactions : **SE**		
SOIL PROFILE (DEPTH)		
W * DEPTH	14.91	12.98 **
N * DEPTH	21.09 **	18.35 **
G * DEPTH	-	-
W * N * DEPTH	29.82 *	25.95 *
W * G * DEPTH	-	-
N * G * DEPTH	-	-
W * N * G * DEPTH	-	-

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 24. **Mean total soil available nitrogen ($NH_4 + NO_3$) in the 120 cm soil profile as affected by water, nitrogen and genotype, at anthesis in 1990-91 and 1991-92.**

Treatment	Total available nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	4.39 B	13.15 B
Dry	6.20 A	15.25 A
LSD (0.05)	0.41	1.00
Nitrogen (N) :		
0 kg N ha^{-1}	2.52 C	11.07 B
20 kg N ha^{-1}	3.67 BC	12.71 B
40 kg N ha^{-1}	5.10 B	13.68 B
120 kg N ha^{-1}	9.88 A	19.35 A
LSD (0.05)	1.54	3.54
Genotypes (G) :		
ICSH 86646	3.36 B	13.96 AB
SPV 783	4.57 B	13.43 B
M 35-1	4.19 B	12.98 B
FALLOW	9.05 A	16.42 A
LSD (0.05)	2.28	2.74
Interactions : **SE**		
SOIL PROFILE (DEPTH)		
W * DEPTH	6.66 **	14.05 **
N * DEPTH	9.42 **	19.86 **
G * DEPTH	9.42 **	19.86 *
W * N * DEPTH	13.32 **	28.09 *
W * G * DEPTH	13.32	28.09
N * G * DEPTH	18.83	39.73
W * N * G * DEPTH	26.63	56.18

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Appendix table : 25. **Mean total soil available nitrogen (NH_4 + NO_3) in the 120 cm soil profile as affected by water, nitrogen and genotype, at harvest in 1990-91 and 1991-92.**

Treatment	Total available nitrogen (ppm)	
	1990-91	1991-92
Water (W) :		
Irrigated	2.45 A	6.71 B
Dry	5.98 A	11.68 A
LSD (0.05)	4.20	1.17
Nitrogen (N) :		
0 kg N ha^{-1}	1.96 B	5.67 C
20 kg N ha^{-1}	1.91 B	7.85 B
40 kg N ha^{-1}	3.29 B	7.88 B
120 kg N ha^{-1}	9.69 A	15.37 A
LSD (0.05)	2.94	2.07
Genotypes (G) :		
ICSH 86646	4.22 AB	8.60 A
SPV 783	3.14 B	9.69 A
M 35-1	3.44 B	7.96 A
FALLOW	6.06 A	10.53 A
LSD (0.05)	2.53	2.78
Interactions : **SE**		
SOIL PROFILE (DEPTH)		
W * DEPTH	8.87 **	18.71 **
N * DEPTH	12.55 **	26.47 **
G * DEPTH	12.55	26.47 *
W * N * DEPTH	17.74 **	37.43 **
W * G * DEPTH	17.74	37.43 **
N * G * DEPTH	25.09	52.97
W * N * G * DEPTH	35.49	74.86 *

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Table : 18. Mean leaf potassium content of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Leaf potassium content (%)		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	1.19 A	1.35 A	1.27 A
Dry	1.28 A	1.37 A	1.33 A
LSD (0.05)	0.06	0.44	0.32
Nitrogen (N) :			
0 kg N ha^{-1}	1.20 B	1.25 C	1.23 C
20 kg N ha^{-1}	1.19 B	1.28 CB	1.23 C
40 kg N ha^{-1}	1.23 B	1.40 AB	1.32 B
120 kg N ha^{-1}	1.33 A	1.51 A	1.42 A
LSD (0.05)	0.09	0.14	0.07
Genotypes (G) :			
ICSH 86646	0.91 C	1.38 A	1.15 A
SPV 783	1.26 B	1.37 A	1.32 B
M 35-1	1.54 A	1.32 A	1.43 A
LSD (0.05)	0.06	0.08	0.05
Interactions : SE			
YEAR (Y)	-	-	0.03 **
W * Y	-	-	0.05
N * Y	-	-	0.07
V * Y	-	-	0.06 **
W * N * Y	0.11	0.22	0.10
W * G * Y	0.09	0.20	0.08
N * G * Y	0.14 *	0.28	0.12
W * N * G * Y	0.20	0.39	0.17
CV %	7.74	10.70	11.32

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.

Table : 19. Mean stem potassium content of sorghum as affected by water, nitrogen and genotype, at harvest (1990-91, 1991-92 and pooled years).

Treatment	Stem potassium content (%)		
	1990-91	1991-92	Pooled
Water (W) :			
Irrigated	2.14 A	2.09 A	2.12 A
Dry	1.90 A	1.66 B	1.78 A
LSD (0.05)	0.46	0.34	0.36
Nitrogen (N) :			
0 kg N ha^{-1}	1.96 AB	1.74 B	1.85 B
20 kg N ha^{-1}	1.80 B	1.75 B	1.77 B
40 kg N ha^{-1}	2.01 AB	1.90 AB	1.96 B
120 kg N ha^{-1}	2.31 A	2.12 A	2.22 A
LSD (0.05)	0.40	0.26	0.22
Genotypes (G) :			
ICSH 86646	2.57 A	2.10 A	2.34 A
SPV 783	1.88 B	1.97 A	1.93 B
M 35-1	1.61 C	1.56 B	1.59 C
LSD (0.05)	0.19	0.13	0.11
Interactions : SE			
YEAR (Y)	-	-	0.08 *
W * Y	-	-	0.11
N * Y	-	-	0.15
V * Y	-	-	0.13 *
W * N * Y	0.41	0.28 *	0.22 *
W * G * Y	0.36	0.24 *	0.19
N * G * Y	0.50	0.35	0.27
W * N * G * Y	0.71	0.49	0.38
CV %	15.95	11.53	18.41

* , ** = Significant at p = <0.05 and 0.01 % level, respectively.