AGRONOMIC EVALUATION OF RICE CULTIVARS FOR RAINFED CONDITIONS OF KERALA

BY

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DECLARATION

I hereby declare that this thesis entitled "**AGRONOMIC EVALUATION OF RICE CULTIVARS FOR RAINFED CONDITIONS OF KERALA** is a bonafide record of research work done by mo during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other university or society

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CERTIFICATE

Certified that this thesis entitled "AGRONOMIC EVALUATION OF RICE CULTIVARS FOR RAINFED CONDITIONS OF KERALA" is a record of research work done independently by Smt Sheela K R under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to her

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Abbreviations used in this thesis

t		Tonnes
kg		Kilogram
g	-	Gram
mg	-	Milligram
µg		Microgram
cm	-	Centimetre
mm	-	Millimetre
@		At the rate of
ha^{-1}		Per hectare
^oC		Degrees celsius
M Pa		Mega Pascal
%	-	Per cent
DAS	-	Days after sowing
LAI	-	Leaf area index
RWC		Relative water content
HI	-	Harvest index
DMP		Dry matter production
RBD	-	Randomised block design
CRD		Completely randomised design
NaH_2PO_4	-	Sodium dihydrogen orthophosphate
KH_2PO_4	-	Potassium dihydrogen orthophosphate
Na_2HPO_4		Disodium hydrogen phosphate
KCl	-	Potassium chloride
NAA	-	Naphthalene acetic acid
IAA	-	Indole acetic acid
PEG		Polyethylene glycol

INTRODUCTION

1 INTRODUCTION

Rice which plays an important role in providing food to the majority of the world population is cultivated in a wide range of ecosystems In South and South East Asia where rice accounts for 75 per cent of the calories intake of its people, rainfed rice accounts for about 60 per cent of the total area under rice cultivation and provides about 45 per cent of the production (Singh and Bhattacharyya 1989)

In India out of the 41 million ha of land under rice, about 60 per cent is exposed to risk prone rainfed ecology

Despite significant strides made in the productivity of rice and other food grains the food situation in India is precarious due to the unabated increase in population Of the estimated additional production need of over 75 million tonnes of food grains to sustain self sufficiency by 2000 AD the share of rice would be no less than 30 million tonnes (about 40 per cent) With limited scope for expansion of area under rice a vertical yield improvement from the present 1 75 to 2 50 t ha^{-1} is the only way to achieve the targeted production (Siddiq 1990)

The scope for bringing more land under irrigated rice is rather limited due to prohibitive costs Hence one of the major options to step up rice production is intensification of cropping and maximising yield levels in the diverse rainfed ecosystems The high yield technology designed exclusively for risk free irrigated conditions has so far bypassed the ecologically demanding rainfed environment This has prompted for a shift in research and development from irrigated to the rainfed environment The development of rainfed rice and effective transfer of improved technology has to be translated into a mission oriented production programme to achieve self sufficiency in the food front in the years to come

Rainfed agriculture is exposed to varying levels of moisture stress which results in ups and downs in production Enhanced and stabilized productivity on a sustainable basis is possible to a considerable extent through the adoption of improved varieties (Paroda and Rai 1991) A suitable variety is the first requirement for improved rice yields The development of high yielding varieties have been primarily aimed for areas with adequate soil moisture A number of varieties have been identified in the past for rainfed areas However soil and other ecological conditions vary so much throughout the country that all the cultures or varieties recommended do not satisfy fully the requirements of different rainfed regions. Hence the suitability of the high yielding varieties available have to be tested for specific rainfed agro-ecologies

The nutrient management problems in rainfed regions have received low priority and most of the rainfed areas are malnourished Moreover occurrence of moisture stress or flooding in rainfed rice culture results in comparatively poor utilisation of applied nutrients The highly diverse agro-ecology characteristic of the rainfed environment requires precise location specific technology Choice of varieties through a cafetaria approach and improved agronomic package for the major rainfed ecologies would go a long way in improving productivity

In Kerala out of the total rice area approximately ten per cent is irrigated during the first crop season (FIB 1992) The remaining area depends entirely on rainfall Ample rainfall if received during that period ensures a successful crop whereas inadequate and uncertain rainfall may result in moisture stress either in early or later stages of crop development Crop losses caused by moisture stress is considerable though not estimated The selection of a suitable variety and induction of drought resistance by seed hardening has been suggested as a panacea to reduce drought injury ~~and~~ to the crop ~~damage~~

Hitherto research and development efforts have not been made to standardise the agronomic management of rice under rainfed lowland conditions of Kerala Hence, the present investigation was undertaken with the following objectives

1 To select a suitable rice variety for the rainfed first crop of Southern Kerala

2 To investigate the effect of seed hardening with chemicals in inducing stress tolerance

3 To work out the nutrient levels required for maximum rice yield under rainfed conditions

REVIEW OF LITERATURE

2 REVIEW OF LITERATURE

In India with nearly 60 per cent of rice area exposed to rainfed ecology and the limited scope for bringing more area under irrigated rice the scientists and policy makers have been prompted alike to shift the research and development emphasis from irrigated to rainfed environment (Siddiq 1990) Moreover the increased contribution to the rice pool from the rainfed areas created a new impetus in rainfed research From these research efforts studies on moisture stress effects seed hardening methods to alleviate stress varietal suitability for rainfed areas and nutrient management for such conditions are reviewed in this chapter

2 1 Stress effects on plants

2 1 1 Seed germination and seedling vigour

Drought resistance in seedling stage is an important parameter that decides the establishment of plants under moisture stress conditions

In a laboratory study to correlate seedling vigour to later stand establishment in upland rice genotypes Chauhan et al (1985) obtained positive correlation between the speed of germination and third day germination count Among the varieties tried IR-20 had the highest values for both factors followed by Nan Sagui-19 Continued field trials showed that seedling vigour was positively correlated with dry weight of seedlings under mild soil moisture stress

Turner and Nicholas (1988) observed that vigorous early growth resulted in high dry matter yield and improved grain yield in rice with no decrease in harvest index Genotypes of rice with early vigour and good seedling establishment enhanced transpiration at the expense of direct soil evaporation particularly where the surface soil was wet by frequent rains Tanaki (1991) reported inhibition in the germination of rice seeds by decrease in water potential of the medium

Drought resistance at the seedling stage did not necessarily correlate with that at older stages of development But this initial resistance improved the vigour of the plant and enabled the plant to pass through the moisture stress period without much morphological abnormalities

2 1 2 Growth and growth characters

Senewiratne and Mikkelsen (1961) reported that rice plants under unflooded culture made an initial vigorous start but soon showed poor tillering depressed growth of leaves than flooded plants

Chang et al (1972) showed a nearly constant leaf area in rice under different soil moisture regimes

De Datta and Beachell (1972) observed that low tillering habit under varied soil moisture condition was a distinctive feature of upland rice

Plant growth was significantly reduced in rice with increase in soil moisture tension from zero to 1000 m bar (Pradhan et al 1973)

Sahu and Rao (1974) observed that the growth of three rice cultivars viz Ptb 10 Jaya and ADT-27 were adversely affected by soil moisture stress at any phase of growth and development Stress during the vegetative phase reduced plant height number of tillers and functional leaves and delayed maturity whereas drought at reproductive stage brought about death of tillers

Leopold and Kriedemann (1975) observed that a decline in leaf area or its photosynthetic effectiveness would result in lowered growth of rice under moisture stress conditions

Moisture stress in rice resulted in reduced plant height leaf area and number of tillers (Boyer and Pherson 1976)

Basu Raychaudhuri and Das Gupta (1981) observed that soil moisture stress resulted in reduced plant height of rice However the reduction was more pronounced in lowland and susceptible types rendering them relatively more prone to drought effects than the upland and drought tolerant types Similarly lowland and susceptible rice varieties showed wide variation in leaf number and average leaf area under different soil moisture regimes while the upland types varied less in these aspects They also pointed out that drought tolerance in rice was characterized by low to moderate tillering stable leaf dimensions predominantly large and thick crown and fairly deep roots

Aragon and De Datta (1982) reported a linear increase in plant height and DMP with increase in total water applied

Soil moisture stress at the vegetative stage of rice caused a decrease in tiller number leaf area index photosynthetic rate and plant dry matter leading to permanent strain and increased the ratio of shoot to root dry mass (Cruz and O Toole 1984)

Turner et al (1986) recorded reduced plant height relative growth rate and daily rate of leaf expansion due to moisture stress during the pre-flowering stage of rice

Rice cultivars which produced lesser number of tillers under well watered conditions were less susceptible to drought than cultivars producing a higher number of tillers (Ichwantoari et al 1989)

Ramakrishnayya and Murty (1991 a) reported from studies on fifty rice varieties that imposition of soil moisture stress caused reduction in plant height and tiller number and further relief of stress caused an increase in tiller number

From the above results it was evident that soil moisture stress adversely affects the growth characters viz plant height tiller number and leaf area and the effect is more pronounced in lowland susceptible types

2 1 3 Yield and yield attributes

Chaudhry and McLean (1963) observed that the most striking effects of moisture stress in rice were delayed flowering and high spikelet sterility resulting in significant reduction in yield

Sahu and Rao (1974) reported that moisture stress during the vegetative phase of rice caused reduction in grain yield of 26 to 27 per cent depending upon the plant type whereas stress at grain filling and ripening phases resulted in death of earbearing tillers reduction in the number of filled grains leading to twelve to fifteen per cent reduction in grain yield They also observed that stress during reproductive phase delayed heading by a week and reduced the length of panicle and number of grains panicle^{-1}

Occurrence of moisture stress at the panicle initiation stage of rice caused reduction in yield whereas stress at the dough stage had no effect on yield (Singh and Misra 1974)

From a field experiment to study the effect of soil drought at different physiological stages of upland direct sown rice Nayak et al (1974) reported that prolonged soil moisture stress continuously over two growth stages and particularly during boot to yellow ripe stage had pronounced harmful effect on grain production They also observed that prolonged soil drought of 60 days during the crop growth period was less harmful than soil drought during a short period in the reproductive stage

Soil moisture stress reduced the number of spikelets panicle^{-1} and ripe grain percentage resulting in yield reduction upto 49 3 per cent in rice (Lee et al 1985)

Rahman and Yoshida (1985) reported that moisture stress of 50 per cent field capacity decreased the yield but had little effect on the duration of grain filling in rice

Similar observations were also made by Ekanayake et al (1989) and they observed that panicle exertion showed an inhibitory effect due to low panicle water status under moisture stress condition Spikelet opening was completely inhibited at water potentials below -0 18 MPa and -2 30 MPa in varieties IR-20 and IRAT-13 and at low water potentials, severe desiccation of spikelets and anthers were noted

Sudhakar et al (1989) reported that moisture stress during tillering stage resulted in significant reduction of panicle number while stress during panicle development and ripening reduced the percentage of filled grains in rice

While reviewing the physiology and breeding for drought tolerance in cereals Fussell et al (1991) pointed out that grain yields were reduced by 45 to 49 per cent under stress mainly due to reduction in grain yield panicle^{-1} rather than a reduction in panicle number Variations in the grain yield of rice varieties were observed under the same degree of stress

Ramakrishnayya and Murty (1991 b) observed that tillers produced at the end of drought were mostly productive and contributed to yield whereas those that developed during recovery phase had no influence on yield

The study of Basu Raychaudhuri and Das Gupta (1981) on morphological characters of rice associated with drought tolerance revealed large differences in rooting pattern among the upland and lowland varieties In rice largest roots were observed at field capacity and shortest under continuous submergence (Katare and Upadhyay 1981) The upland and drought tolerant types had predominantly long thick and dense roots with many deep roots Root shoot ratio was found higher in the drought resistant rice varieties (O'Toole and Moya 1981 and Gomathinayagam and Soundarapandian, 1987)

Yoshida and Hasengawa (1982) opined that a deep widespreading and much branched root system could exploit water from deeper layers and might be an essential feature of drought tolerance But Passioura (1983) questioned the value of deep roots because the water transpired to produce carbon for extra root growth might offset the extra water gained by deep roots Further the cost of root growth and maintenance represented clear diversion of assimilate which might have been used for shoot growth resulting in decreased yield So he pointed out that selection for small root system, particularly in the top soil was a better alternative to select drought tolerant varieties

Heenan and Thompson (1984) observed reduced root production under intermittent irrigation compared to flooded plants

Sankaran and De Datta (1984) reported that weeds in the upland system had deeper roots and high root length density which might decrease the advantage of deeper root systems of rice in terms of drought resistance

Jeena and Mani (1989) observed that root length density of drought susceptible variety Jaya was least at early stages, but it increased to almost double at harvest stage In spite of this Jaya could not perform well as rains ceased to occur at critical stages

In rainfed and insufficiently irrigated lowland fields, root growth of rice was thought to be inhibited by the physiological consequences of plant water stress accompanied by an increase in soil mechanical impedanoe (Thangaraj et al 1990)

Klepper (1991) reported that under limited irrigation growth of roots might be limited by lack of water or high soil strength and when the surface soil was wet most of the root system was found in the upper part of the profile

There is controversy regarding the growth of roots under moisture stress conditions Some opined that lesser amounts of water increased the root length which enable the plants to absorb water from deeper layers But majority of the studies revealed that in rainfed or insufficiently irrigated fields root growth was comparatively poor Among varieties the upland types had long thick and dense roots

2 1 5 Physio-chemical parameters

2 1 5 1 Stomatal characters

Control of stomatal aperture is important in drought avoidance because some species and cultivars close their stomata early during development of drought while others do not

Vaughan and Wiehe (1939) observed that stomatal frequency increased under adverse environment

Cook (1943) reported more number of deep and sunken stomata in moisture stress conditions

Under severe drought conditions the stomata opened partially and subsequently lost its function (Iljin, 1957) This caused reduction in photosynthesis by reduced carbon dioxide absorption

Losavio et al (1987) observed that in wheat, stomatal resistance was influenced by soil water content, physiological stage and radiation load but not by stomatal frequency They also noticed that stressed wheat plants tended to close stomata in advance of irrigated plants and the difference in stomatal resistance between rainfed and irrigated treatments was about 3 cm second [1]

Jing and Ma (1991) could not obtain any stomatal response to water deficits in upland rice and maize However stomatal resistance increased with commensurate increase in water stress

2 1 5 2 Water relation in plant

While relating the leaf water potential with soil and climatic descriptors in upland rice production O'Toole and Moya (1981) observed that soil matric potential at fifteen cm depth and total evaporative demand could be used to predict daily minimal leaf water potential for rice cultivars They also established the critical leaf water potential for determinations of degree and duration of water stress during yield determining growth stages as -17 bar

Ishihara and Saito (1983) observed that at leaf water potential less than -2 bar the photosynthetio rate decreased in rice and reached almost zero at -12 bar The RWC in leaves of field grown rice ranged from 88 to 96 per cent under saturated conditions compared to 80 to 86 per cent under stress conditions (Nayak et al 1983) From field trials at IRRI it was observed that water deficit had no effect on midday water potential in rice (IRRI 1989)

Studies by Agarwal et al (1990) revealed that the upland rice variety Azucena maintained high leaf water potential through out the stress period as compared to the lowland type IR 36

Jing and Ma (1991) observed that when the leaf water potential values were higher than - 1 20 MPa the water use efficiency of upland rice was lower than maize

When five upland rice varieties were subjected to soil moisture stress of 25 per cent field capacity at seedling stage Ramakrishnayya and Murty (1991 b) observed that with increase in soil moisture stress there was decrease in RWC and water potential of leaf They also reported that the cultivar which maintained high RWC and positive turgor had optimum photosynthesis and solute accumulation inspite of reduced leaf water potential during stress

2 1 5 3 Chlorophyll content

Jayabal (1971) could not obtain any correlation between drought and chlorophyll content of rice and he pointed out that chlorophyll synthesis was a varietal character and was not very much altered by drought conditions

From studies conducted at CRRI Cuttack Sudhakar et al (1989) reported that the rice cultivar which exhibited the highest drought resistance had maximum chlorophyll content and yield when stress was imposed at three stages of growth viz tillering panicle initiation and ripening

Stuhlfauth et al (1990) observed that in stressed plants in which the leaf water potential fell from -0 70 to -2 50 MPa the contents of chlorophyll a and b on leaf area basis were not significantly altered This indicated that the photosynthetic apparatus remained basically intact under moisture stress

2 1 5 4 Proline content

Accumulation of proline occurs in leaves subjected to drought Several workers suggested that proline content could be used as a measure of drought resistance (Barnett and Naylor 1966 and Singh et al 1972)

Parker (1968) suggested that proline accumulation could not be taken as a protective mechanism against drought but might have resulted from some protein break down or it might simply be a storage compound of N

Naylor (1972) reported that water stress led to blockage in the synthesis of some amino acids at one or more points in the metabolic pathway

While studying the response of seven diverse rice cultivars to water deficits Dingkuhn et al (1991) observed that water stress induced proline accumulation differed among cultivars and was negatively correlated with midday leaf water potential and positively with osmotic adjustment

Accumulation of proline in wheat leaves under moisture stress was reported by Rajagopal et al (1977) They pointed out that in such conditions proline accumulation could provide a quick mechanism for maintaining the osmoticum of cells and tissues

Stewart (1981) observed that though a negative correlation contradicted the proline content on drought tolerance the functional role of proline in osmo-regulation and energy conservation during moisture stress could not be ruled out

More negative values of leaf water potential were associated with higher amounts of free proline in wheat cultivars (Karamanos et al 1983) and it was evident that the increased amounts of free proline could be associated with more effective dehydration and drought avoidance mechanisms But Garc Ia Girou and Curvetto (1990) observed no relationship between proline accumulation during heading or anthesis and drought resistance in wheat

Hence it may be inferred that varieties which withstand moisture stress conditions usually had stomatal control mechanisms and low leaf water deficits It was also evident that though a positive correlation existed between accumulation of free proline and moisture stress in most cases proline accumulation could not be taken as the single criterion for drought tolerance

2 1 6 Grain protein

Jayabal (1971) observed higher content of N in drought tolerant rice varieties under upland condition

The protein per cent of wheat increased during drought although total protein yield decreased Wheat cultivars that maintained a higher level of foliar nitrate reductase activity during moisture stress produced grains with higher protein content (Boyer and Pherson 1976)

Thanigasalam (1982) observed increased content of protein in pearl millet grains when stress occurred at flowering and boot leaf stages

2 1 7 Nutrient uptake

Chaudhry and McLean (1963) found that N content in all plant parts of rice was higher under unflooded conditions whereas P and Mn contents were lesser compared to submerged conditions The concentration of P Fe and Mn was higher under submerged conditions than under upland conditions (Gangawar and Mann 1972 Chahal et al 1980 and Padhihar and Dikshit 1985)

In rice increased uptake of N P or both due to submergence was reported by Yoshida and Patre (1975)

Increased uptake of K by rice under submergence was reported by Jha et al (1978) and Pillai and De (1979 and 1980)

Biswas and Mahapatra (1980) noticed significantly higher N content in plants at dough stage under water logging

Rice plants grown at field capacity showed higher concentration of N and K than plants grown under submergence (Mali and Varade 1981)

Patil and Ghildyal (1983) found that maximum absorption of nutrients (N P K Mn and Zn) was with submergence compared to unsaturated conditions Das and Mandal (1986) also observed increased uptake of P Fe Mn and Zn by roots straw and grains by plants grown under water logged conditions than under unsaturated conditions

Tanguilig et al (1987) reported decline in total N P and K uptake by both root and shoot nine days after the imposition of drought as compared to control ~~without stress~~

Ichwantoari et al (1989) observed that uptake of N by rice was more sensitive to drought than other nutrients

In short it could be concluded that rice plants grown under reduced moisture levels usually had lower uptake values of major nutrients than those grown under submerged conditions

2 2 Seed hardening for drought tolerance

Under rainfed condition moisture stress was likely to occur during any of the growth stages of crop which might adversely affect the growth and yield   Tailoring the plant to withstand moisture stress by seed hardening was reported to be effective under such conditions The influence of seed hardening on growth yield and physiological aspects are reviewed here

2 2 1 Seed germination and seedling vigour

Parija and Pillai (1945) found that rice seeds when soaked in water for 24 hours followed by drying at 40 to 42°C resulted in production of vigorous seedling and such seedlings in pot culture studies were shown to exhibit lower water requirement# In continued summer field trials, these seedlings survived better after wilting and transpired less

The dehydration of seeds after soaking conferred high drought resistance and did not interfere with germination growth and yield All these parameters decreased when untreated plants were subjected to soil moisture stress during the growing period (Henckel 1964)

Mehrotra et al (1967) reported that when rice seeds of variety T_9 were subjected to soaking in KH_2PO_4 solutions of different concentration for eighteen hours| the initial germination was retarded but the total germination at the end of seven days was not affected

Rice seeds soaked for 48 hours in one per cent sodium hypochlorite enhanced the germination as well as the rate of elongation of plumule and radicle (Singh and Tomar, 1972)

Basu et al (1974) reported that the germinability and vigour of upland rice seedlings in the early stages could be enhanced by seed hardening

Basu (1977) suggested that a simple soaking and drying method was enough for the maintenance of vigour and viability of seeds in a number of field and vegetable crops

Veliehko et al (1979) reported increased germination percentage in rice seeds by seed treatment with 0 5 per cent hydrogen peroxide

Singh and Chatterjee (1981) pointed out that best stands of upland rice could be obtained by treating rice seeds with water Na_2HPO_4 or NaH_2PO_4 solutions Similar results were reported by Chatterjee (1982)

On the contrary Narayanasamy (1985) obtained no effect on seed germination and crop stand by hardening rice seeds

Jose Mathew (1989) reported that seed hardening with 100 ppm succinic acid and two per cent KH_2PO_4 induced earliness and uniformity in germination and produced vigorous and healthy seedlings

Germination and seedling vigour of hardened paddy seeds were studied by Kamalam Joseph and Rajappan Nair (1989) and observed that cowdung extract treatment was significantly superior in inducing earliness in germination followed by water soaking Among the varieties Ptb-23 showed earliness and higher germination percentage

Seedling emergence was the highest when rice seeds were soaked in 0 1 per cent potassium permanganate or water and coated with gypsum and ferric phosphate (Reddy et al 1989)

The results of several studies revealed that the earliness in germination and vigour of rice seedlings in early stages could be significantly improved by seed hardening with suitable chemicals This also helped the seedlings to withstand moisture stress during its growth period

2 2 2 Growth and growth characters

Growth characters like plant height and tiller number were little influenced by soaking paddy seeds in KH_2PO_4 solution of five to twentyfive per cent concentration (Mehrotra et al 1967)

Sinha (1969) reported increased plant height tiller number leaf number and DMP of rice by pre-sowing seed treatment with NAA and IAA

Devika (1983) observed that pre-sowing seed hardening in water for 48 hours had no effect on plant height of rice but showed increased tiller production LAI and dry weight

Increase in plant height and tiller number in rice by seed hardening with Na_2HPO_4 $AI(NO_3)_3$ and water was reported by Singh and Chatterjee (1981) Similar results were also reported by Narayanasamy (1985)

Chockalingam (1986) observed that seed treatment had no influence in plant height and tiller number in kharif but in summer seed treatment with one per cent KCl recorded a significant increase in plant height

Plant height tiller number shoot dry weight and leaf area were increased in rainfed rice by water hardening and subsequent soaking in 0 10 per cent PEG (Das et al , 1989)

Jose Mathew (1989) obtained significant increase in plant height leaf area and tiller production of rice by pre-sowing seed hardening with 100 ppm succinic acid

Fletcher and Hofstra (1990) reported the use of triazoles as seed treatment chemical to induce protection to the plant against several stresses including drought low and high temperature salinity and air pollution

Nian et al (1991) reported reduced senescence of lower leaves and plant height of rice by seed treatment with triazole compounds

Though some studies revealed that seed hardening had little response on plant growth characters most of them pointed out the favourable influence of seed hardening on plant height leaf area and tiller production

2 2 3 Yield and yield attributes

As early as in 1934 increased grain yields of rice by pre-sowing seed hardening were claimed by Henckel and Kolotova

Mehrotra et al (1967) reported that soaking paddy seeds in KH_2PO_4 solutions increased yield components like number of grains panicle^{-1} grain yield and straw yield

According to Urs et al (1970) pre-sowing hardening of rice seeds in water increased yield under normal conditions Similar results were also reported by Borthakur et al (1973) by treating rice seeds in KH_2PO_4 and sodium molybdate solutions

Experiments conducted at Aduthurai Tamil Nadu revealed that pre-sowing soaking of rice seeds in water and subsequent soaking in KH_2PO_4 solution resulted in an yield increase of 626 kg ha^{-1} (Directorate of Agriculture Tamil Nadu 1978)

The positive trend in increasing rice yield by pre-sowing seed hardening was reported with 0 50 per cent hydrogen peroxide (Veliehko et al 1979) and one per cent KCl (Kalaimani et al 1979)

Rajagopalan et al (1979) reported that pre-sowing seed soaking in water for ten hours and subsequent soaking in four per cent manganese sulphate solution for twelve hours increased rice yields

Seed hardening of rice with four per cent KH_2PO_4 increased grain yield by 13 29 per cent and straw yield by 13 9 per cent over control (Ramanathan 1980)

Peeran and Natanasabapathy (1980) obtained highest rice yield when the seeds were treated with one per cent KCl

Singh and Chatterjee (1980) reported 14 to 26 per cent higher rice yields when upland rice was raised after pre-sowing seed hardening with Na_2HPO_4 Al $(NO_3)_3$ and water Seed hardening with NaH_2PO_4 (0 358 g $litre^{-1}$ for six hours) and water treatment (over-night) gave 25 per cent and 20 per cent respective yield increase in rice over untreated control (Chatterjee, 1982)

Devika (1983) reported that seed treatment with water for 48 hours increased panicle number, 1000 grain weight and grain yield of rice varieties raised during the first crop season at Onattukara

Kundu and Biswas (1985) obtained significant increase in panicle number and yield of direct seeded rainfed rice by seed hardening They observed that seed hardening in Sodium chloride and ethephon solutions was better than simple hydration though ten per cent yield increase was obtained by simple hydration of seeds

Narayanasamy (1985) reported that panicle length test weight of grains grain and straw yields of rice were significantly improved by seed hardening with succinic acid

The favourable influence of seed hardening with one per cent KCl solution in increasing the 1000 grain weight and grain yield of rice was reported by Chookalingam (1986)

Jose Mathew (1989) recorded significant increase in the yield components and grain yield of rice by seed hardening with 100 ppm succinic acid

Hence it could be concluded that under moisture stress conditions the yield of rice crop could be improved by seed hardening with suitable chemicals

2 2 4 Root characteristics

Rice crop established from seeds treated with water Na_2HPO_4 NaH_2PO_4 and $Al(NO_3)_3$ solution had greater root mass when compared with untreated control (Singh and Chatterjee 1981)

Chatterjee (1982) stated that pre-sowing seed treatment of paddy with water or suitable chemicals improved deep roots and root shoot ratio of plants

Seed hardening with 100 ppm succinic acid increased drought resistance in rice plants by increasing root length root dry matter and root shoot ratio (Narayanasamy, 1985 and Jose Mathew 1989)

Chockalingam (1986) observed increased root length in summer rice by pre-sowing seed hardening with one per cent KCl

Yield improvement by seed hardening could be attributed to the ability of the hardened seed to produce deep roots and enhance their ability to absorb nutrients and water from deeper layers This also increased the root shoot ratio of the plant

2 2 5 Physio chemical properties

2 2 5 1 Water relation

Singh and Chatterjee (1981) reported that the leaves of rice plants raised from treated seeds had significantly lower water saturation deficit than the leaves of plants raised from untreated seeds

Biswas et al (1982) and Nayak et al (1983) claimed that seed treatment with calcium chloride helped rice to maintain better leaf water potential under moisture stress conditions

Wang and Shen (1991) reported that treating rice seeds with multi-effect triazole decreased the effect of drought on water potential but not on osmotic potential

2 2 5 2 Chlorophyll content

Fletcher and Hofstra (1990) reported a striking increase in synthesis of chlorophyll of fresh leaves of wheat raised after uniconazole seed treatment and uniconazole in combination with KCl increased the chlorophyll content more than twice that of the control

Babu and Singh (1992) observed an increase of 32 and 35 per cent of chlorophyll a and b in triadimefon treated wheat plants

2 2 5 3 Stomatal characters

Santhakumari and Fletcher (1987) demonstrated that seed treatment with triadimefon at the rate of 0 03 g kg^{-1} seed caused partial closure of stomata in wheat plant and reduced the drought injury

Increased stomatal diffusive resistance of wheat plants raised from uniconazole treated seeds was reported by Fletcher and Hofstra (1985)

2 2 5 4 Proline content

Wang and Shen (1991) observed that treatment of rice seeds with triazole delayed the accumulation of free proline which became rapid with decrease in water potential

Nilima and Malik (1983) observed that soluble carbohydrates free amino acids and proline contents of pigeonpea leaves were more in hardened plants than control

Seed hardening helped the plant to maintain higher leaf water potential and proline under moistures stress conditions It also caused partial closure of stomata thereby reducing water loss from the leaves All these tailored the plant to withstand moisture stress conditions in a better way

2 3 Evaluation of rice varieties for rainfed conditions

De Datta (1981) noticed that high yielding varieties under rainfed upland conditions were semi-dwarf to intermediate in height medium to heavy tillering tolerant to moderate drought stress resistant to lodging and resistant to blast and bacterial leaf blight

Shahi (1981) reported the suitability of rice variety Bhideshwari for rainfed wetlands of Nepal

Coffman and Nanda (1982) observed that early maturity and high yield potential of IR-52 enabled this variety for cultivation in rainfed dry seeded conditions

A study on the performance of rice varieties under rainfed conditions in Konkan revealed that rice variety Jaya produced significantly higher grain yield than the other varieties tried except IET 1991 (Sona) (Kalara et al , 1983)

On-farm research studies in rainfed uplands at Cuttack revealed that the variety CR-222 MW 10 gave better yields than other varieties like Annapurna China Keshari and Kalinga-III (CRRI 1984)

Mahapatra and Srivastava (1984) reported that high yield potential and early maturity are obvious requirements for dry seeded rainfed rice Varieties with appropriate growth duration and drought tolerance could give stable yield under rainfed conditions

Among the varieties released for rainfed lowland situation IET-5882 IET-5897 and IET 6212 were found suitable for shallow lowland situations (Mohanty et al 1984) Though these lines had good plant type and high yield potential because of their narrow genetic base, they did not have an adequate level of adaptability

Murty and Rao (1984) observed that early maturing varieties with fully exerted panicles and with medium or short grains were suitable for rainfed conditions

While discussing the varietal improvement for rainfed upland situations with special reference to Kerala Nair (1984) pointed out that rice varieties like Ptb-28 and 1907 gave higher yields than modern semi-dwarf varieties

The ability of rice variety Jaya to produce better grain yields in different moisture regimes was reported by Harbir Singh et al (1985)

Maurya et al (1985) reported that three new rice lines NDR-84 NDR-85 and NDR-118 had consistently out yielded the tall local standard cultivar N-22 in rainfed uplands

Akanda and Youssouf (1986) observed that rice cultivar Kalchina raised by direct sowing produced higher yield under rainfed conditions

From advanced yield trials of rainfed rice, differential response was obtained for different varieties (Bazoni 1986) In some locations medium duration varieties gave higher yield while early cultivars were found to be promising in some locations

Shah et al (1986) recommended ACV-5 as a suitable variety for direct sowing or transplanting in rainfed conditions

Sinha and Prasad (1986) compared the yield performance of rice varieties in rainfed lands and observed that higher yield and better tolerance to moisture stress was exhibited by Chandragrahi a tall non-lodging cultivar Singh and Singh (1986) reported that the variety IET-63 gave fifteen per cent more yield than local varieties in rainfed uplands and had higher nutrient use efficiency

For the rainfed uplands of Orissa Satpathy et al (1987) observed that a short duration moderate tillering and fertilizer responsive variety Subhadra could give better rice yields

The suitability of CR varieties viz CR 635 202 CR-635 232 CR-634 1 CR-634 2 CR-634 41 and CR-636 7 for rainfed uplands was reported by Sreenivasalu and Reddy (1987)

Among the four short duration varieties tried maximum grain yield was recorded by the variety Saket-4 indicating the suitability of this variety for rainfed kharif season (Deshmukh et al 1988)

For the dry sown lowlands of Onattukara Kerala, varieties like Bhagya and Onam were found suitable, whereas, for dry sown uplands of Kerala varieties like Suvarnamodan and Swarnaprabha proved good (KAU 1989)

From a varietal trial under rainfed conditions of Dharwad Hanagodimath et al (1989) observed that the local variety D6-2-2 along with Rasi and Jaya gave higher yields in 1976 In 1977 the variety D6-2 2 gave the lowest yield while the yields of Jaya and IR-5 improved

N fertilizers (Kumar and Sharma 1980 and Singh et al 1981) but the tall upland rice varieties at times do not respond to fertilizers economically (Nair et al 1976 Ram et al 1985 and Singh et al 1987)

Studies conducted under semi-deep water situation at CRRI Cuttack revealed that early vigour in terms of more tillers and plant height was observed with the use of N They also observed that basal application of 40 kg N ha^{-1} increased the plant vigour in early growth stages of rainfed lowland rice (CRRI 1983)

Jashim et al (1984) observed increased plant height and tiller number with application of N upto 50 kg ha^{-1}

Ram et al (1985) Sudhakar et al (1986) and Munda (1989) reported that increased N levels significantly improved tiller production in rainfed rice

Increased plant height with increased N levels in rainfed rice was reported by Lal (1986) and Mishra et al (1988)

2 4 1 2 Yield and yield attributes as influenced by nitrogen

Field trials on rainfed upland rice showed that N @ 30 to 60 kg ha^{-1} applied as a single dose at seeding was

The Directorate of Rice Research Hyderabad (1990) recommended short / medium duration high yielding drought tolerant varieties like Rasi Ravi Tulasi Adithya and Prasanna suitable for rainfed cultivation

The superiority of CR-666 100 and Annada for rainfed uplands and IET-5914 for rainfed lowlands during kharif 1991 was observed from the studies conducted at CRRI, Cuttack (CRRI, 1991)

Dubey et al ((1991) reported that yield and yield attributing characters varied significantly among varieties under rainfed conditions and the variety Poorva gave higher yield consistently for two years

Medium and late duration varieties like CR-1009 (Savitri) CR-1018 (Gayatri) Tulasi Paridhan were found suitable for rainfed lowlands and short duration varieties like Annada Kalinga III Neela Annapurna and Tara were found good for rainfed uplands of Orissa (Paroda and Rai 1991)

For late planting under shallow rainfed lowland conditions the suitability of long duration and photosensitive semi-dwarf rice varieties like Savitri CR-292 8051 and Moti was reported by Sharma and Reddy (1991) Venkateswarlu (1992) reported that varieties such as Savitri considered to be a good fertilizer schedule to achieve 80 to 100 per cent increase in grain yield compared to control (Patnaik and Nanda 1965)

Ghildyal (1971) reported that upland rice responded well to increased levels of N upto 120 kg ha^{-1} in terms of DMP and grain yield

From the yield analysis of five locations Ten Have (1971) concluded that the average response of rice varieties (TN 1 IR 8 and Jaya) to 50 kg N ha^{-1} was 1407 kg ha^{-1} during rabi and only 692 kg ha^{-1} during kharif

Singh and Modgal (1978) reported that the rice varieties Jaya and Padma responded upto 90 kg N ha^{-1} during kharif in rainfed uplands

Singh et al (1979) observed marked and consistent increase in yield of rainfed rice with increased N levels upto 120 kg ha^{-1}

Average yield of direct sown rainfed cultivars increased from 1 33 to 2 5 t ha^{-1} with 40 kg N ha^{-1} and further increase in grain yield with 60 to 80 kg N ha^{-1} was not significant (Kumar and Sharma 1980)

Hooper (1982) obtained linear yield increase with N upto 135 kg ha^{-1}

Jashim et al (1984) also observed increased grain yields with application of N upto 50 kg ha^{-1}

Increased grain yield due to N application without marked difference amongst 40 80 and 120 kg ha^{-1} was reported by Krishnarajan et al (1984)

Differential response of rice varieties under uplands (Reddy et al 1983 and Lal 1986) depended upon the initial soil fertility previous crop grown moisture availability and seasonal conditions

Khatua and Sahoo (1983) reported that the grain yield increased with increased levels of N from 0 to 90 kg ha^{-1} the rate of increase being low after 60 kg ha^{-1} They also observed that application of 76 kg N ha^{-1} was found to be the economic optimum dose for the high yielding short duration rice varieties maturing in 75 to 104 days

Ram et al (1985) reported that drought at any stage of rice crop limited the response of applied N and if moisture was available throughout the growth stages application of 80 kg N ha^{-1} increased the grain yield significantly over 20 and 40 kg ha^{-1} For rice variety Ratna significant yield increase was obtained upto 60 kg N ha^{-1} while decreased grain yield was noticed at 80 kg N ha^{-1} under rainfed cultivation

Reports on dry land rice showed that the response of upland rice to N varied with location from 120 to 160 kg ha^{-1} (Sharma and Krishnamohan 1985) However, 80 kg ha^{-1} was the most profitable dose

Sudhakar et al (1986) observed that increasing N rates increased the DMP panicle number, number of spikelets and grain yield but decreased the percentage of filled grains in rainfed upland rice During periods of low rainfall similar trends were observed at consistently lower levels Lack of response beyond 60 kg N ha^{-1} for rainfed direct seeded rice was pointed out by Mishra et al (1988) and Rafey et al (1989)

Chakar and Sharma (1988) showed that irrigated rice produced 58 90 per cent higher grain yield than rainfed rice and application of 60 and 120 kg N ha^{-1} produced identical grain yield in both conditions

Panda and Sharma (1991) observed significant yield increase in rainfed lowland rice with 40 kg N ha^{-1} The same level was reported to give maximum response in rainfed uplands (Dinesh Chandra et al 1991)

2 4 2 Growth and yield of rainfed rice as influenced by P

The availability of P in upland soils was lower than that in flooded soils (Patrick and Mahapatra 1968)

Hence P deficiency might be a limiting factor in upland soils especially in strongly acid oxisols (Ponnamperuma 1975)

Increasing the rate of P application could increase rice yields The yields were low due to continuous cropping and low availability of P in upland alluvial soils (Uemura and Miyasaka 1973)

Fageria et al (1982) reported an optimum P level of 44 to 86 kg ha^{-1} to produce better yields of rice in rainfed uplands

Trials conducted at Ranchi on rainfed upland rice (Mahapatra and Srivastava 1984) revealed that the optimum P requirement of a variety of 100 to 110 days duration was about 40 kg P_2O_5 ha^{-1}

2 4 3 Combined application of nutrients

2 4 3 1 On the growth and yield of rainfed rice

Field trials with four rice varieties and four nutrient levels revealed that increasing nutrient levels from 20 15 10 to 80 60 40 kg N P_2O_5 and K_2O ha^{-1} significantly increased plant height and tiller number $plant^{-1}$ in rainfed kharif crop (Deshmukh et al 1988) Singh and Ghosh (1992) reported that better management in rainfed upland condition ensured better crop growth when compared with farmer's practice of no fertilizer application

From studies on rainfed upland rice Bhaumik (1957) found that application of N doubled the yields but combined application of N and P had greater effect than application of N alone

High grain yield of four t ha^{-1} was obtained with 160 kg N ha^{-1} from drilled rice on upland soil when applied along with P and K (Singh 1971) The optimum rate of 60 kg N + 40 kg P_2O_5 + 20 kg K_2O ha^{-1} gave grain yields in the range of 2 7 to 3 4 t ha^{-1} compared with the yield of 1 9 t ha^{-1} with no fertilizer control (Dixit and Singh 1977)

For rainfed rice grown in regions with 1000 mm or more precipitation 50 to 80 kg N 80 to 100 kg P_2O_5 ha^{-1} could give satisfactory results (CRRI 1979)

Singh et al (1981) reported that rice variety Bala produced higher yield with a basal application of 80 kg P_2O_5 and 20 kg K_2O ha^{-1} along with split or basal application of 50 kg N ha^{-1} under rainfed conditions

From experiments in cultivators field Randhawa and Tandon (1982) observed an increase in grain yield in all the fertilizer applied plots in rainfed areas and reported that placement of basal N P or N P and K and split application of N in kharif increased the N use efficiency Randhawa and Singh (1983) reported that for rainfed rice receiving 1400 mm rainfall a nutrient dose of 60 30 0 and 30 20 0 kg N P_2O_5 and K_2O ha^{-1} could give better yields from high yielding and local varieties of rice respectively In upland and medium lands with 1500 mm rainfall 75 to 90 kg N 60 kg P_2O_5 and 40 kg K_2O could be recommended for rice

Experiments at IITA recommended a blanket fertilizer dose of 80 kg N and 60 kg P_2O_5 ha^{-1} for rainfed upland rice and reported increased grain yield with increase in P levels (IITA 1984) Other studies conducted at the same institute under moderate bimodal rainfall or high rainfall upland conditions showed increased rice yield only upto 40 kg N ha^{-1} and other nutrients had little effect on yield

From farm trials conducted during Virippu at Regional Agricultural Station Pattambi, Kerala no significant difference was observed in the grain and straw yields of dry sown rice variety Mashoori fertilized with two NPK levels of 70 45 45 and 50 25 25 kg ha^{-1} This indicated that lower nutrient levels were sufficient for obtaining moderate rice yields in Virippu season (KAU 1984)

According to AICARP (1984) the newly released and locally popular rice cultures recorded highest response to a fertilizer level of 90 45 45 kg N P_2O_5 and K_2O ha^{-1} under rainfed conditions

Mahapatra et al (1984) reported that application of 40 kg each of P_2O_5 and K_2O in addition to 65 kg N ha^{-1} increased rainfed rice yield by 1 5 to 2 0 t ha^{-1}

From a study on the effect of fertility levels on rice Agarwal et al (1985) reported that 160 kg N 80 kg each of P_2O_5 and K_2O ha^{-1} gave the highest grain yield in rainy season However significant yield increase was obtained only upto 120 kg N and 60 kg each of P_2O_5 and K_2O

Under rainfed conditions response to fertilizer levels varied with location but in most areas economic yield could be realised with 40 20 20 or 60 30 30 kg N P_2O_5 and K_2O ha^{-1} (AICARP 1987) These studies also indicated that the response to 40 kg K_2O ha^{-1} was more along with N only than with combined application of N and P in rainfed areas

Purushotham et al (1987) conducted farm trials in cultivators field and observed that during kharif the average yield increase of rice at 40 20 20 80 40 40 and 120 60 40 kg N P_2O_5 and K_2O ha^{-1} over control were 37 60 54 60 and 89 80 per cent respectively

The best grain yield was obtained from direct seeded rice at Delhi with an application of 100 kg N 50 kg P_2O_5 and 50 kg K_2O ha^{-1} (Singh et al 1987)

Deshmukh et al (1988) reported that progressive increase in nutrient levels increased the yield and yield attributing characters in early rice varieties raised in kharif as rainfed crop They also observed that a nutrient level of 80 60 40 kg N, P_2O_5 and K_2O ha^{-1} gave maximum yield during both the years under study

When compared with unfertilized plots rainfed rice yield got doubled by the application of 80 40 40 kg N P_2O_5 and K_2O ha^{-1} but this level resulted only in marginal increase in yield over 60 30 30 kg N P_2O_5 and K_2O ha^{-1} (AICARP, 1969)

Munda (1989) recorded increased grain yield in upland rice of Japan by increasing N levels upto 150 kg ha^{-1} and P_2O_5 level upto 80 kg ha^{-1}

A nutrient level of 90 45 45 kg N P_2O_5 and K_2O ha^{-1} gave highest grain yield in upland rainfed rice (Pradhan and Das 1990)

Similar results were also reported ~~by~~ from CRRI trials (CRRI 1991) They revealed that lowland rice varieties like CR-666 100, Red Heera Swarnaprabha and Annada exhibited marked yield increase upto 90 kg N ha^{-1} when applied along with 30 kg each of P_2O_5 and K_2O

Dubey et al (1991) observed favourable effects on yield attributes of rainfed rice by increased N levels (with constant P_2O_5 and K_2O levels of 30 kg and 20 kg ha^{-1} respectively) but the response was more with lower doses and reduced gradually as the levels of N increased

For stepping up rice yield in rainfed uplands, Dinesh Chandra (1992) suggested a fertilizer dose of 30 to 40 kg N and 15 to 20 kg each of P_2O_5 and K_2O ha^{-1}

From the above studies it was observed that the response to applied nutrients was comparatively less in rainfed conditions than under submerged conditions This response also varied with variety availability of soil moisture, and initial fertility status of the soil

2 4 3 2 On the quality and water relations

Singh and Modgal (1978) observed an increase in protein content of rice grains with increased N levels

The translocation of N from plant to grain was higher in semi-dwarf varieties than in tall varieties (Reddy et al 1983)

Nowick and Hoffpauir (1984) also observed that alternate drainage and submergence the loss of N could be as high as 95 per cent within eight weeks

Direct seeded rice when sown in an aerobic soil with lower moisture content reduced the supply of nutrients to the roots (Ponnamperuma 1975)

The apparent recovery of applied N was found to be 52 20 per cent for transplanted rice but only 38 40 per cent for direct seeded rice (Prasad and Prasad 1980)

Mohankumar and Singh (1984) reported 37 per cent apparent recovery of N with 100 kg applied N ha^{-1} in rainfed uplands Though the uptake of N increased with increased doses of N upto 150 kg ha^{-1} the apparent recovery was found to decline beyond 100 kg N ha^{-1}

In rainfed uplands increased N levels improved N uptake (Sudhakar et al 1986 and CRRI 1991) and N and P uptake (Munda 1989)

Singh and Ghosh (1992) reported that combined application of organic manure (10 t ha^{-1}) and chemical fertilizers at the rate of 40 13 17 kg N P_2O_5 and K_2O ha^{-1} markedly improved N P and K uptake in rainfed kharif rice

In rainfed cultivation due to alternate submergence and drying the loss of applied nutrients especially N was comparatively higher than under submerged conditions

Rainfed rice thrives in a different agro-ecological environment compared to irrigated low land rice The scarcity of information on nutrient management of rainfed rice necessitates the need to undertake research work on these lines

MATERIALS AND METHODS

3 MATERIALS AND METHODS

This investigation envisages the selection of a rice variety and nutrient combination required to produce maximum yield under rainfed conditions of Southern Kerala Besides seed hardening techniques are also adopted to induce tolerance to moisture stress during the crop growth period The procedure adopted are discussed below

3 1 Experimental site

Field trials were conducted over a period of two years during 1991 and 1992 in the wet land of Cropping Systems Research Centre (CSRC) Karamana Thiruvananthapuram and pot culture study was conducted at the College of Agriculture Vellayani in the year 1991-92

3 1 1 Location

The CSRC Karamana and College of Agriculture Vellayani are situated at 8 5° N latitude and 76 9° E longitude and at an altitude of 29 m above mean sea level

3 1 2 Soil

The soil of the experimental site is riverine alluvium acidic in reaction low in cation exchange capacity medium in organic carbon and medium in available N P and K

Table 1 Physico chemical properties of soil at the experimental site

Parameter	Content in soil (per cent) Field trial	Content in soil (per cent) Pot culture	Method used
<u>Physical composition</u>			
Sand	74 20	56 40	Bouyoucos Hydrometer (Bouyoucos 1962)
Silt	8 74	6 60	
Clay	17 80	33 00	
Soil texture	Sandy loam	Clay loam	
<u>Chemical composition</u>			
1 pH	5 30 (acidic)	5 40 (acidic)	pH meter with glass electrode (Jackson 1973)
2 E C (d Sm^{-1})	0 016 (Safe)	0 016 (Safe)	Conductivity bridge
3 C E C (Cmol (p^{+}) kg^{-1})	6 8	7 41	Buchner funnel method (Jackson 1973)
4 Organic carbon (%)	0 72 (medium)	1 20	Walkey and Black s rapid titration method (Jackson 1973)
5 Available N (kg ha^{-1})	287 00	206 00	Alkaline potassium permanganate method (Subbiah and Asija 1956)
6 Available P_2O_5 (kg ha^{-1})	40 00	38 00	Bray s calorimetric method (Jackson 1973)
7 Available K_2O (kg ha^{-1})	129 00	118 00	Ammonium acetate method (Jackson 1973)

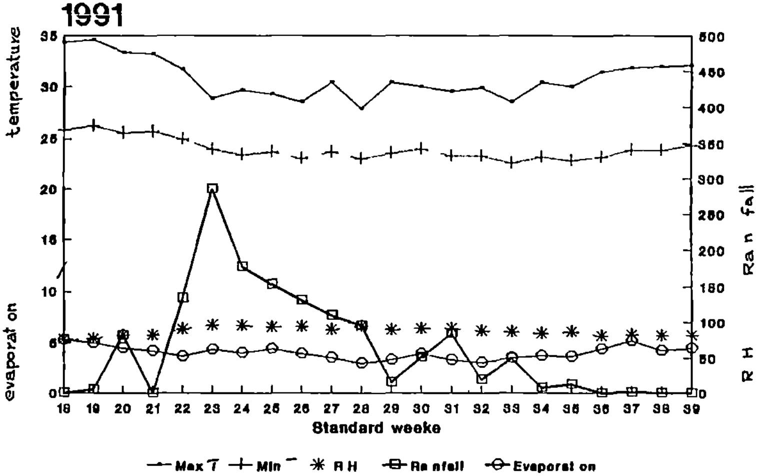
The soil used for the pot culture study was clay loam acidic in reaction medium in available N and P and low in K

The physico chemical properties of the soil are presented in Table 1

3 1 3 Climate

The area of the experimental site enjoys a humid tropical climate The data on various weather parameters during the cropping period and previous five years average are given in Appendix I and graphically presented in Fig 1 The mean values of weather parameters during the cropping period are presented below

Parameters	May to September 1991	December 1991 to April 1992	May to September 1992
Mean maximum temperature (^{o}C)	29 26	31 33	29 95
Mean minimum temperature (^{o}C)	23 41	22 36	23 74
Mean Relative humidity (%)	87 39	74 44	88 14
Mean Monthly rainfall (mm)	356 25	12 20	245 60
Total rainfall (mm)	1425 00	61 00	1000 00
Daily evaporation (mm)	4 04	4 33	3 47



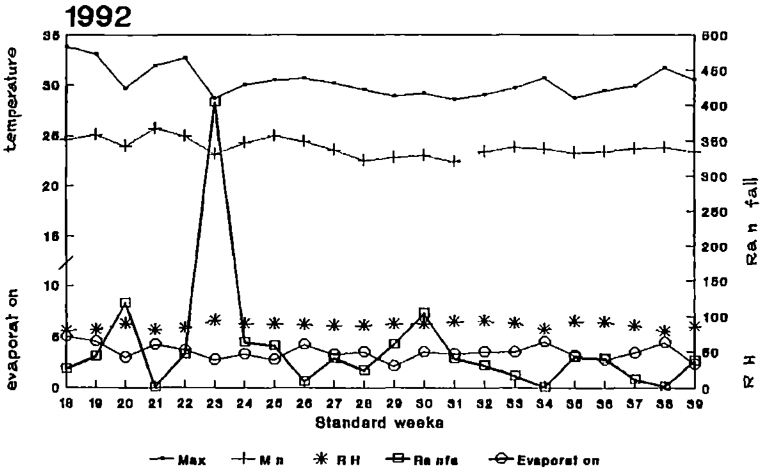


Fig 1 Weather parameters for the crop period (from April 30th to September 30th)

3 1 4 Season

The pot culture study (Experiment 1 b) was conducted under controlled conditions during the period from December 1991 to April 1992

The field trial of Experiment - 1 was conducted during the first crop season (Kharif) of 1992 and that of Experiment-2 was conducted during the Kharif seasons (May to September) of 1991 and 1992

3 2 Materials

3 2 1 Varieties used

The description of varieties used are presented in Table 2

3 2 2 Fertilizers used

Urea (46 per cent N) super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used for the experiment

3 2 3 Chemicals used for seed hardening

3 2 3 1 Triazole

The chemical triadimefon (Bayleton) manufactured by the Karnataka Insecticides and Fungicides Ltd Bangalore was

Table 2 Varietal description

Variety	Parentage	Duration (days)	Characteristics	Source
Jaya	IR-8 x TN-1	120	High yielding highly susceptible to brown plant hopper and other pests	CSRC Karamana
Culture-4 (Aarathi)	Jaya x Ptb-33	127	Red grains resistant to drought tolerant to brown plant hopper sheath blight and sheath rot	Department of Plant Breeding College of Agriculture Vellayani
M 102	Mutant of Ptb-28	105	Red grains high yielding and tolerant to brown plant hopper	Department of Plant Breeding College of Agriculture Vellayani
Rasi	TN-1 x Co-29	115	Medium slender grains resistant to blast and tolerant to low phosphate and zinc	Directorate of Rice Research Hyderabad
Ravi	M 63 83/RP-795 and Rikuta Norin-21	105	Long slender grains resistant to blast and tolerant to drought	Directorate of Rice Research Hyderabad
Tulasi	Rasi x Fine Gora	100	Medium slender grains resistant to blast and tolerant to drought	Directorate of Rice Research Hyderabad

used for the study It is (1-(4 chlorophenoxy) 3-3-dimethyl 1 (1 1-1-2 4 triazol 1 yl) 2 butanone) a systemic fungicide belonging to the triazole group This group of chemicals when applied through seeds are believed to induce stress tolerance (Fletcher and Hofstra 1988)

3 2 3 2 Sodium dihydrogen phosphate (NaH_2PO_4)

The common laboratory chemical NaH_2PO_4 was used for seed hardening

3 2 3 3 Potassium chloride (KCl)

The potassic fertilizer muriate of potash analysing 60 per cent K_2O was used

3 3 Methods

3 3 1 <u>Preliminary screening trial</u>

Five varieties of rice recommended by the Directorate of Rice Research Hyderabad for rainfed regions viz Rasi Ravi Adithya Prasanna and Tulasi were obtained They were subjected to preliminary screening From these the comparatively better varieties Rasi Ravi and Tulasi were selected for the trials

3 3 2 Cropping history of the experimental site

The field trials were conducted in the sites with previous bulk crops of rice in both the years (1991 and 1992)

3 3 3 Treatments

Treatment details of the two experiments are furnished in Table 3

3 3 4 Design and lay out

The details are presented in Table-4 and Fig 2 and 3

The allocation of various treatment combinations to different plots was as per the method advocated by Yates (1964)

3 3 5 Cultivation aspects

3 3 5 1 Land preparation

Germination study of experiment 1 a and 1 b

One hundred mature and well developed seeds were kept on a filter paper placed in a petridish The filter paper was always kept moist by water to facilitate seed germination

Table 3 Treatment details

Experiment 1 a Laboratory trial

Treatments	Notation
Seed without hardening	T_0
Seed hardening with 0 5 per cent KCl (18 hours)	T_1
Seed hardening with 1 0 per cent KCl (18 hours)	T_2
Seed hardening with 1 5 per cent KCl (18 hours)	T_3
Seed hardening with 2 0 per cent KCl (18 hours)	T_4
Seed hardening with 2 5 per cent KCl (18 hours)	T_5
Seed hardening with 3 0 per cent KCl (18 hours)	T_6
Seed hardening with 5 0 per cent KCl (18 hours)	T_7
Seed hardening with 7 5 per cent KCl (18 hours)	T_8
Seed hardening with 10 0 per cent KCl (18 hours)	T_9

Total treatments 10 Replications - Three

Experiment 1 b Germination trial (Laboratory)

Treatments	Notation
1 Varieties	
Jaya	V_1
Culture-4 / Aarathi	V_2
M-102	V_3
Rasi	V_4
Ravi	V_5
Tulasi	V_6
2 Pre-sowing seed hardening methods	
No pre-sowing seed hardening	T_0
Seed hardening with water for 24 hours	T_1
Seed hardening with triazole (triadimefon at 0 03 g kg^{-1} seeds)	T_2
Seed hardening with NaH_2PO_4 solution (156 ppm) for five hours	T_3
Seed hardening with KCl solution (2 5 per cent) for 18 hours	T_4
Seed hardening with cowdung extract (10 per cent) for 24 hours	T_5
Total treatment combinations - 36 Replications - Three	

Experiment 1 b Pot culture study

Treatments	Notation
1 Varieties (As in experiment 1 b laboratory trial)	
2 Pre- sowing seed hardening methods (As in experiment 1 b laboratory trial)	
3 Moisture regimes	
50 per cent available water	M_1
100 per cent available water	M_2
Total treatment combination = 72 Replications - Two	

Experiment 1 c (Field trial)

Treatments	Notation
1 Varieties	
Culture 4 / Aarathi	V_1
Rasi	V_2
Tulasi	V_3
2 Pre-sowing seed soaking methods	
No pre-sowing seed hardening	T_0
Seed hardening with water for 24 hours	T_1
Seed hardening with triazole (0 03 g triadimefon kg^{-1} seed)	T_2
Seed hardening with 2 50 per cent KCl for 18 hours	T_3

Total treatment combinations - 12 Replications = Three

Experiment 2 (Field trial)

Treatments	Notation
1 Varieties (As in experiment 1 b laboratory trial)	
2 Nutrient levels	
100 per cent of recommended dose for medium duration varieties (90 45 45 kg N P_2O_5 and K_2O ha^{-1})	F_1
75 per cent of recommended dose	F_2
50 per cent of recommended dose	F_3

Total treatment combinations - 18 Replications = Three

Table 4 Experimental details

Details	Experiment 1 a Laboratory trial	Experiment 1.b		Experiment 1.c Field trial	Experiment 2 Field trial
		Laboratory trial	Pot culture		
Seasons	—	—	Dec. 91 to April 92	May to Sept. 92	May to Sept. 91 May to Sept. 92
Date of sowing	—	—	20-12-91	21 5 92	8-5 91 22 5 92
Designs	Completely randomised design	Completely randomised design	Completely randomised design	Randomised block design	Factorial experiment in randomised block design
Replications	Three	Three	Two	Three	Three
Treatment combinations	10	36	72	12	18
Pot / plot size	—	—	30 x 30 cm	5 x 4 m	5 x 4 m
Number of pots / plots	—	—	144	36	54

Experiment 1.c.

Experiment 2

Plate 1. General view of experimental field

V_3T_3	V_1T_0	V_2T_2	V_3T_0	V_3T_2	V_1T_2	Replication 1
V_1T_3	V_2T_1	V_2T_0	V_1T_1	V_3T_1	V_2T_3	
V_2T_2	V_1T_0	V_3T_2	V_2T_0	V_1T_3	V_2T_1	Replication 2
V_2T_3	V_3T_3	V_1T_1	V_3T_1	V_3T_0	V_1T_2	
V_2T_3	V_3T_0	V_3T_1	V_2T_0	V_1T_2	V_1T_0	Replication 3
V_1T_1	V_2T_2	V_3T_3	V_3T_2	V_1T_3	V_2T_1	

← Buffer strip →

Treatments

1 Varieties

- V_1 Culture 4/Aarathi
- V_2 Rasi
- V_3 Tulasi

2. Pre sowing seed hardening

- T_0 No pre sowing hardening
- T_1 Seed hardening with water for 24 hours
- T_2 Seed hardening with triadimefon at 0 03 g kg^{-1} seed
- T_3 Seed hardening with 2.50 per cent KCl for 18 hours

Design 3 x 4 Randomised block design

Fig 2 Layout plan Experiment 1 c

V_5F_1	V_1F_3	V_6F_2	V_3F_2	V_4F_2	V_5F_3	
V_6F_3	V_3F_3	V_5F_2	V_1F_1	V_2F_1	V_2F_3	**Replication 1**
V_4F_3	V_6F_1	V_1F_2	V_2F_2	V_3F_1	V_4F_1	
V_5F_1	V_4F_1	V_3F_3	V_2F_3	V_6F_3	V_3F_2	
V_4F_2	V_5F_3	V_6F_2	V_5F_2	V_4F_3	V_2F_2	**Replication 2**
V_6F_1	V_1F_1	V_2F_1	V_3F_1	V_1F_3	V_1F_2	
V_1F_1	V_2F_3	V_3F_3	V_6F_1	V_1F_2	V_4F_3	
V_4F_2	V_5F_2	V_4F_1	V_2F_2	V_6F_3	V_5F_1	**Replication 3**
V_2F_1	V_6F_2	V_5F_3	V_3F_1	V_3F_2	V_1F_3	

Buffer strip

Treatments

1 Varieties

V_1	Jaya
V_2	Culture 4/Aarathi
V_3	M 102
V_4	Rasi
V_5	Ravi
V_6	Tulasi

2. Nutrient levels

F_1	100 per cent of recommended dose (90:45:45 kg N, P_2O_5 and K_2O ha^{-1})
F_2	75 per cent of recommended dose
F_3	50 per cent of recommended dose

Design: 6 x 3 factorial experiment in RBD

Fig 3 Layout plan Experiment 2

t

Experiment 1 b (Pot culture study)

The experiment was conducted in pots of 30x30 cm size and these pots were kept in a net house Uniformly oven dried and sieved soil was used for the study The field capacity of the soil was 19 90 per cent and the permanent wilting point 8 90 per cent Each pot was filled with 12 kg of soil The soil moisture was maintained at 50 and 100 per cent of available water as per the technical programme A polythene sheet of 300 gauge was fixed over the roof of the net house to exclude rain water

Experiment 1 c and 2

The experimental area was ploughed levelled and laid out as per the design Initial soil samples were taken for analysis A buffer strip of 4 m width was left barren around the experimental area The individual plots were perfectly levelled before sowing

3 3 5 2 Seed hardening

Experiment 1 a

The seeds of rice variety Jaya were immersed in KCl solution of different concentrations for eighteen hours Then the solution was drained and the seeds dried in shade to the original level of moisture

Experiment 1 b and 1 c

The seeds of different varieties were subjected to seed hardening as per the treatment In all seed hardening treatments except the triazole treatment after the soaking period the solution was drained and the seeds were dried in shade to the original moisture level In the triazole treatment the chemical was dissolved in small quantity of water and seed treatment was by imbibition

3 3 5 3 Sowing

Experiment 1 b

Twelve seeds were sown in each pot

Experiment 1 c and 2

Sowing was done by dibbling in rows 20 cm apart

3 3 5 4 Thinning and weeding

Experiment 1 b

Thinning was done on the twelfth day and four hills of two plants each were retained pot $^{-1}$ Weeds were removed as and when noticed

Experiment 1 c and 2

Twelve days after sowing thinning was done and plant spacing adjusted to 10 cm [with in the rows] Hand weeding was done at 20 and 40 days after sowing

3 3 5 5 Fertilizer application

Experiment 1 b

Fertilizers viz urea superphosphate and muriate of potash were applied uniformly to all pots at the rate of 90 45 45 kg N P_2O_5 and K_2O ha $^{-1}$ N was applied in three equal splits at sowing active tillering and panicle initiation stages Entire P was applied as basal dose K was given in two equal splits at sowing and at panicle initiation stage

Experiment 1 c

Fertilizers based on the previous year s study were applied uniformly to all plots at 75 per cent of the recommended dose for medium duration varieties One third N full P and half K were applied after thinning One third N at active tillering and one third N and half K were applied at panicle initiation stage

Experiment 2

The required quantity of fertilizers were applied to the individual plots as per the treatments The split application of nutrients were similar to experiment 1 c

3 3 5 6   Irrigation and drainage

Experiment 1 b

The loss of water from the pots was compensated by adding water daily to these pots based on the following relationship

ET   Eo c f where

ET   evapotranspiration in mm

Eo   evaporation in mm from USWB class A open pan evaporimeter

c f   crop factor (1 1 for rice)

Experiment 1 c and 2

The experiments were conducted under rainfed condition and hence no irrigation was provided to the crop

3 3 5 7   Plant protection

Plant protection measures were adopted as recommended in the Package of Practices Recommendations KAU (1989)

3 3 5 8   Harvest

Experiment 1 b

The crop from each pot was harvested separately One panicle was separated from each hill for observations on panicle characteristics and chemical analysis The grains were separated sundried and pot wise yield of grain and straw recorded

Experiment 1 c and 2

Two border rows all around the plot one line for destructive sampling and its adjustment line were discarded and the crop was harvested from the net plot

The harvested produce was threshed grains separated dried and plotwise grain and straw yields recorded

3 4 Observations

In pot culture study observations were recorded from all four hills

In field trials two sample units of 2x2 hills were randomly selected in the net plot of each plot as suggested by Gomez (1972) and the following observations were recorded at an interval of twenty days

3 4 1 Observations on growth characters

3 4 1 1 Height of plant

Plant height was measured from the base to the tip of the top most leaf At harvest the height was recorded from the base of the plant to the tip of the longest panicle and the mean height was computed and expressed in cm

3 4 1 2 Tiller number hill ^{1}

Tiller number was counted at twenty days interval from sample hills the mean values worked out and recorded

3 4 1 3 Leaf area index (LAI)

LAI was calculated at flowering stage using the length width method suggested by Gomez (1972) Accordingly leaf area k x l x w wl ro k is an adjustment factor (0 75) l is the length and w is the maximum width

LAI was calculated from the leaf area considering the area occupied by the plants

3 4 1 4 Dry matter production (DMP)

Dry matter production (DMP) was estimated at twenty days interval At each observation four sample hills were uprooted washed sundried ovendriel at 70 80^{o}C to constant weight and DMP computed and expressed in t ha ^{1} At harvest the sum total of processed grain and straw yields were taken as the total DMP

3 4 1 5 Dry matter production ha $^{-1}$ day $^{-1}$

This was worked out by dividing the total DMP with the duration of the crop and expressed in kg ha $^{-1}$ day $^{-1}$

3 4 2 Observations on yield attributes and yield

3 4 2 1 Number of productive tillers hill $^{-1}$

At harvest productive tillers were counted in four sample hills and the mean number worked out

3 4 2 2 Length of panicle

Ten panicles were collected from each plot length measured from the neck to the tip and the average expressed in cm

3 4 2 3 Weight of panicle

Ten panicles were separately weighed from each plot the mean weight worked out and expressed in g

3 4 2 4 Number of spikelets panicle $^{-1}$

The spikelets were removed from each panicle counted and the mean number of spikelets panicle $^{-1}$ worked out

3 4 2 5 Number of filled grains panicle ^{1}

The filled grains were then separated counted and mean number calculated

3 4 2 6 Number of unfilled grains panicle ^{1}

The remaining unfilled grains were counted and mean number worked out

3 4 2 7 Thousand grain weight

Thousand grain weight was calculated and adjusted to fourteen per cent moisture using the formula suggested by Gomez (1972)

$$1000 \text{ grain weight} \quad \frac{100 - M}{86} \times \frac{w}{f} \times 1000$$

where M Moisture content of filled grains

w - Weight of unfilled grains

f - Number of filled grains

3 4 2 8 Sterility percentage

Based on the total spikelet count panicle ^{1} and number of sterile grains panicle ^{1} the sterility percentage was computed

3 4 2 9 Grain yield

In pot culture study panicles were collected from four hills grains separated dried and weight expressed in g pot $^{-1}$

In field trials grain yields were recorded from the net plots weight adjusted to fourteen per cent moisture and expressed in t ha $^{-1}$

3 4 2 10 Straw yield

Straw obtained from each pot was uniformly sundried and weight expressed in g pot $^{-1}$

In field trials straw harvested from the net plots were uniformly sundried weighed and expressed in t ha $^{-1}$

3 4 2 11 Harvest Index (HI)

Harvest Index (HI) was calculated using the data on grain yield and straw yield as per the following formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3 4 3 Physiological and chemical estimations

3 4 3 1 Relative water content (RWC)

The method proposed by Weatherley (1950) which was later modified and described in detail by Slatyer and

Barrs (1965) was used to determine RWC It was calculated as

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

3 4 3 2 Chlorophyll content

Total chlorophyll content was estimated from the fully opened second leaf from the top at the panicle emergence stage by the method suggested by Arnon (1949)

Total chlorophyll chlorophyll a and b were estimated using the following equation and expressed in mg g^{-1} fresh weight of leaf

Total chlorophyll	8 05 A 663 +	20 29 A 645
Chlorophyll a	12 72 A 663	2 58 A 645
Chlorophyll b	22 87 A 645	4 67 A 663

3 4 3 3 Proline content

Proline content was estimated from the fully opened second leaf from the top at the panicle emergence stage by the technique suggested by Bates et al (1973) and expressed in $\mu g\ g^{1}$ fresh weight

3 4 3 4 Protein content of grains

Protein percentage was computed by multiplying the nitrogen content of the grain with the factor 6 25 (Simpson et al 1965)

3 4 3 5 Plant analysis

Sample plants collected from each plot at harvest were sundried ovendried to constant weight grain and straw separated ground digested and nutrient content estimated The N content (modified microkjeldahl method) P content (vanado molybdo phosphoric yellow colour method) and K content (Flame photometer method) were estimated for grain and straw separately (Jackson 1973)

3 4 3 6 Uptake studies

The quantity of nutrients absorbed by the crop was calculated by multiplying the content of nutrients in grain and straw with the respective dry weights at harvest stage and expressed in kg ha $^{-1}$

3 4 4 <u>Additional observations recorded in pot culture study</u>

3 4 4 1 Stomatal frequency

Stomatal frequency refers to the number of stomata per unit area of leaf

The fully opened second leaf from the top of the plant at panicle emergence was taken for calculating stomatal frequency Nail polish was smeared on the lower surface of these leaves and allowed to dry It was peeled gently and the peel was observed under microscope (40 x 10 X magnification)

Stomatal counts were taken from different microscopic fields and the mean number worked out

3 4 4 2 Stomatal index

Stomatal index is the proportion of the number of stomata to the number of epidermal cells per unit area As in the case of stomatal frequency the peel was taken observed under microscope the mean counts of stomata and epidermal cells were taken and the ratio worked out

3 4 4 3 Root studies

3 4 4 3 1 Root length

After harvest the roots of each hill were removed carefully washed maximum length measured and mean length expressed in cm

3 4 4 3 2 Root volume

Volume of roots $hill^{-1}$ was estimated by the displacement method and expressed in $cm^3\ hill^{-1}$

3 4 4 3 3 Root weight

Roots removed from each pot were dried and the dry weight recorded in g pot $^{-1}$

3 4 4 3 4 Root spread

Roots of each hill after washing were placed as such on a plain paper and maximum width of the root system measured and expressed in cm

3 4 4 3 5 Root shoot ratio

Root and shoot weights were recorded separately from each hill and the root to shoot ratio worked out

3 4 4 4 Total biomass production

Total biomass production was worked out at harvest time by adding root straw and grain weights and expressed as g pot^{-1}

3 4 5 <u>Observations recorded in laboratory trial</u>

3 4 5 1 Germination percentage

Germination counts were recorded on the fifth day and the mean germination percentage was worked out

3 4 5 2 Shoot and root length

On the eighth and fifteenth day after keeping seeds for germination the shoot and root lengths of ten seedlings were measured and the mean length expressed in cm

3 4 5 3 Vigour index

The vigour index was worked out on the eighth and fifteenth day after keeping seeds for germination using the following formula of Baki and Anderson (1973)

Vigour index Germination percentage x (shoot length + root length)

3 4 6 Soil moisture estimation

Soil moisture was estimated in experiment 2 at fortnightly intervals by the thermogravimetric method and expressed in percentage Changes in soil moisture status during the cropping period are presented in Fig 4

3 4 7 Soil analysis

Soil samples were collected from individual plots of experiment I c and experiment 2 after the harvest of the crop dried in shade sieved through 2 mm sieve and analysed

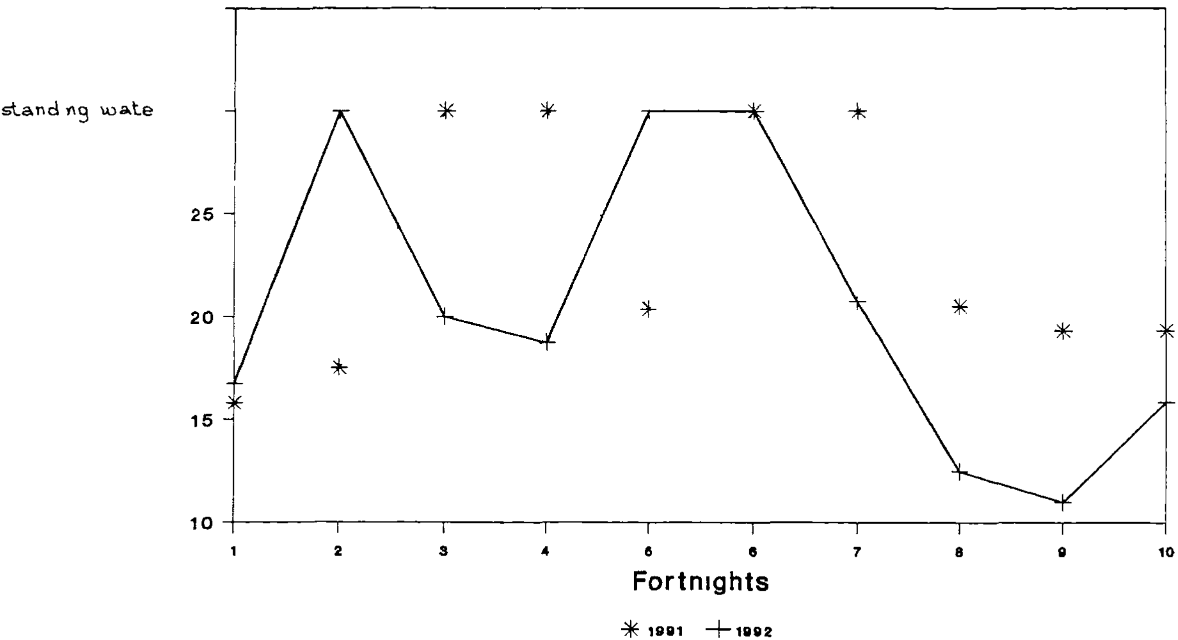


Fig 4 Soil moisture content (%) at fortnightly intervals during the crop period

The available N content of the soil was estimated by alkaline permanganate method (Subbiah and Asija 1956) available P by Bray s method and available K by ammonium acetate method (Jackson 1973)

3 4 8 <u>Economic analysis</u>

Economics of cultivation

Economics of cultivation was worked out for both the field experiments after taking into account the cost of cultivation of rice and prevailing market price of paddy and straw

The net income and benefit cost ratio were calculated as follows

Net income (Rs ha ^{1}) Gross income Total expenditure

$$\text{Benefit cost ratio} \quad \frac{\text{Net income}}{\text{Total expenditure}}$$

3 5 Statistical analysis

The data of the laboratory trial and pot culture study were analysed by the analysis of variance for completely randomised design and that of experiments 1 c and 2 were analysed employing the technique of analysis of variance for factorial experiment in randomised block design

Important correlations were worked out Linear regression of yield with nutrient uptake for each variety was also fitted as per the procedure suggested by Snedecor and Cochran (1967)

In pot culture the direct and indirect effect of drought parameters on yield was studied through Path Analysis technique (Wright 1934)

RESULTS

4 RESULTS

Experiments were conducted at the CSRC Karamana and College of Agriculture Vellayani to select a suitable variety and nutrient combination for getting maximum rice yield under rainfed conditions and to investigate the effect of different seed hardening methods in reducing the moisture stress effects on the crop The results obtained are presented below

4 1 Preliminary observational trial

The short duration photo insensitive drought tolerant varieties selected for the study viz Rasi Ravi Tulasi Prasanna and Adithya were obtained from the Directorate of Rice Research Hyderabad These varieties were subjected to a preliminary screening trial to assess their performance The observations recorded are presented in Table 5

The results revealed that these five varieties varied in growth characters and yield Maximum plant height (99 80 cm) was recorded by Rasi followed by Tulasi and Prasanna

Varieties Rasi and Tulasi produced the highest number of productive tillers (6 40) and Ravi had maximum panicle weight of 2 41 g Though Prasanna recorded maximum panicle length of 23 cm it had the lowest panicle weight

Table 5 Growth and yield of different rice varieties in the preliminary screening trial*

Varieties	Duration in this study (days)	Plant height (cm)	No of productive tillers	Wt of panicle (g)	Length of panicle (cm)	No of grains panicle ^{1}	1000 grain weight (g)	Grain yield (t ha ^{1})	Straw yield (t ha ^{1})	Yield day ^{1} (kg)
Ad thya	94	81 40	5 30	1 75	19 40	64 50	30 85	2 60	6 02	27 66
Prasanna	94	94 30	5 10	1 62	23 00	87 00	25 83	2 67	7 01	28 40
Ravi	90	87 20	6 00	2 41	21 70	81 00	28 10	2 79	6 25	31 00
Rasi	97	99 80	6 40	2 10	21 65	100 00	23 70	3 50	6 54	36 08
Tu asi	97	94 80	6 40	2 21	22 50	103 40	25 80	3 34	7 07	34 43

* Data not statistically analysed

Number of grains panicle ^{1} was the highest for Tulasi followed by Rasi Regarding 1000 grain weight Adithya had the highest value (30 85 g) followed by Ravi

The variety Rasi produced the maximum grain yield of 3 50 t ha ^{1} followed by Tulasi (3 34 t ha ^{1}) Ravi Prasanna and Adithya in the descending order

The variety Tulasi recorded the highest straw yield of 7 07 t ha ^{1} followed by Prasanna and Rasi Yield day ^{1} was maximum for Rasi followed by Tulasi and Ravi

The variety Prasanna had slender stems and was found to be susceptible to lodging at later stages Similarly Adithya was observed to be more susceptible to leaf roller attack

From among these five varieties based on grain yield Rasi Tulasi and Ravi were selected for the experiment

4 2 Experiment 1

4 2 1 Experiment 1 a Laboratory trial

The germination study conducted to assess the ideal concentration of KCl for seed hardening revealed the following results and are presented in Table 6

4 2 1 1 Germination percentage

It was observed that seed hardening with different concentrations of KCl significantly improved the germination percentage over control Among the different concentrations tried maximum germination percentage (98 00 per cent) was recorded by 4 00 per cent KCl which was on par with 2 50 1 50 1 00 3 00 and 0 50 per cent concentrations Control recorded significantly the lowest (93 67 per cent)

4 2 1 2 Root length

Seed treatment caused significant reduction in root length over control After eight days control recorded maximum root length of 4 00 cm Seed treatment with KCl at 2 00 2 0 and 3 00 per cent concentrations produced comparatively longer roots than the lower concentrations tried

4 2 1 3 Shoot length

KCl treatment significantly improved the shoot length of seedlings KCl concentration of 2 50 per cent recorded the maximum sh t length which was on par with 3 00 per cent concentration Control registered the lowest shoot length (2 83 cm) lable 6 Lffect of different coi entrations of KCl on germination (%) root and shoot length (cm) and vigour index

Treatments	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index
Control	93 67	4 00	2 83	640 07
0 5% KCl	97 33	2 10	3 23	519 33
1 0% KCl	97 67	2 50	4 90	722 83
1 5% KCl	97 67	2 33	3 37	546 80
2 0% KCl	97 00	3 43	4 87	805 10
2 5% KCl	97 67	3 23	5 77	879 00
3 0% KCl	97 33	3 20	5 20	817 23
4 0% KCl	98 00	2 43	4 30	659 87
5 0% KCl	96 33	3 03	3 33	613 20
7 5% KCl	96 00	3 37	3 40	649 60
10 0% KCl	95 00	3 67	3 23	655 50
F	25 66**	14 80**	14 11**	12 89**
SE	0 266	0 160	0 265	31 424
CD	0 779	0 472	0 778	92 17

** Significant at 0 01 level

4 2 1 4 Vigour index

KCl concentration of 2 50 per cent recorded the highest vigour index value (879 00) which was on par with 3 00 and 2 00 per cent concentations

4 2 2 Experiment 1 b Germination study

The results of the germination study conducted before the pot culture experiment are presented in Tables 7 to 11

4 2 2 1 Germination percentage

Germination percentage showed significant variation among varieties and Culture 4 recorded maximum value of 93 per cent which was on par with M 102 All varieties had more than 80 per cent germination though varietal variation was significant

Seed treatment significantly improved the germination percentage over control Treating seeds with 2 50 per cent KCl recorded the highest value of 91 44 per cent which was on par with seeds treated with water Control registered the lowest percentage

Var ty tr atment interactions also showed significant variation All varieties treated with KCl and water re r led higher germination percentages which were on par with Jaya treated with cowdung and Culture 4 treated with triazole

4 2 2 2 Root length

Varieties showed significant difference in root length of seedlings recorded at 8 and 15 DAS At both the stages Culture 4 recorded maximum root length of 5 58 cm and 8 03 cm respectively and was followed by Tulasi Rasi and Ravi At 15 DAS Jaya and Rasi were observed to be on par and followed Culture 4 During both observations M 102 recorded the lowest root length

The positive influence of seed treatment was observed on the root length of seedlings Water treatment recorded the highest root length followed by KCl NaH_2PO_4 and cowdung treatments at both the stages The lowest root length was observed in triazole treatment

Root length varied due to variety seed treatment interactions At 8 and 15 DAS Culture 4 with water treatment recorded the highest root length and was on par with KCl treatment at 8 DAS

4 2 2 3 Shoot length

At 8 DAS Tulasi recorded maximum shoot length (5 94 m) which was on par with Rasi and Culture 4 M 102 recorded the shortest shoot length at this stage At 15 DAS

Table 9 Interaction effect of varieties and seed treatments on root length (cm) of seedlings at 8 and 15 DAS

Seed t eatments / Va et es	T_0		T_1		T_2		T_3		T_4		T_5		Mean	
	8 DAS	5 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	5 DAS	8 DAS	15 DAS	8 DAS	5 DAS	8 DAS	5 DAS
V_1	3 04	6 20	5 37	8 40	3 07	6 0	3 08	6 30	4 23	6 73	6 3	7 50	4 15	6 87
V_2	4 27	4 3	8 13	12 83	2 80	7 13	5 77	7 47	7 93	8 23	4 60	8 40	5 58	8 03
V_3	3 40	6 53	5 7	8 80	2 98	5 80	5	6 0	4 13	6 37	2 87	3 90	3 95	6 28
V_4	4 3	6 53	4 53	6 83	2 70	4 90	5 27	6 53	6 13	7 20	6 57	7 03	4 89	6 5
V_5	4 73	6 73	5 50	7 03	3 30	3 77	5 77	6 50	4 73	7 27	4 80	6 43	4 81	6 29
V_6	3 13	6 77	6 80	7 07	2 90	4 27	6 50	7 01	4 77	6 93	5 70	6 63	4 97	6 45
Mean	3 79	6 5	5 92	8 49	2 96	5 33	5 26	6 69	5 32	7 12	5 1	6 65		

	8 DAS	15 DAS
F	18 66**	28 34**
SE	0 241	0 237
CD	1 022	006

* S gn f cant at 0 0 level

Table 10 Interaction effect of varieties and seed treatments on shoot length (cm) of seedlings at 8 and 15 DAS

Seed treatments	T_0		T_1		T_2		T_3		T_4		T_5		Mean	
Varieties	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS
V_1	5 53	9 03	5 37	8 90	4 40	6 13	5 07	7 50	3 53	9 67	5 50	8 57	4 90	8 30
V_2	3 63	8 47	6 40	8 80	4 67	6 30	5 10	7 40	5 60	9 20	7 80	10 00	5 53	8 36
V_3	6 33	8 00	5 40	7 07	3 77	5 60	3 13	6 13	4 77	9 53	5 40	9 40	4 80	7 62
V_4	6 53	7 37	6 13	7 80	4 97	6 23	4 53	7 93	5 90	9 20	5 83	7 37	5 65	7 65
V_5	6 33	8 00	5 17	8 17	4 60	5 77	4 73	7 73	4 50	7 26	5 60	8 33	5 16	7 54
V_6	5 57	7 20	6 83	7 67	4 47	5 87	6 17	6 97	5 77	8 77	6 83	9 13	5 94	7 60
Mean	5 66	8 01	5 88	8 07	4 48	5 98	4 79	7 28	5 01	8 94	6 16	8 80		

	8 DAS	15 DAS
F	10 66*	6 55**
SE	0 248	0 106
CD	1 053	1 104

* Significant at 0 05 level ** Significant at 0 01 level

Culture 4 registered the maximum shoot length (8 36 cm) which was on par with Jaya

Seed treatment resulted in significant changes in shoot length At 8 DAS seed treatment with cowdung registered maximum shoot length of 6 16 cm and was on par with water treatment At 15 DAS KCl treatment recorded the highest value (8 94 cm) closely followed by cowdung treatment Seed treatment with triazole recorded the lowest shoot length at 8 and 15 DAS

Variety - seed treatment interactions also resulted in varied shoot length At 8 and 15 DAS V_2T_5 recorded the highest shoot length At 8 DAS this was on par with Tulasi treated with water and cowdung whereas at 15 DAS it was on par with other varieties treated with KCl and cowdung treated M 102 and Tulasi

4 2 2 4 Vigour index

Vigour index varied significantly among the varieties and seed treatments At 8 and 15 DAS Culture-4 recorded maximum vigour index This was followed by Tulasi at 8 DAS However at 15 DAS Culture-4 was followed by Jaya M 102 and Tulasi

Table 11 Interaction effect of varieties and seed treatments on vigour index of seedlings at 8 and 15 DAS

Seed treatments / Varieties	T_0		T_1		T_2		T_3		T_4		T_5		Mean	
	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS	8 DAS	15 DAS
V_1	746 03	1325 73	915 93	1476 00	659 20	1080 63	709 05	1200 60	750 70	1585 47	1120 67	1547 80	816 90	1369 41
V_2	708 37	1346 87	1129 90	2004 90	719 10	1294 50	1025 10	1402 80	1254 17	1615 60	1144 80	1699 10	1033 07	1524 47
V_3	888 97	1007 37	1327 40	1512 60	611 92	1033 73	774 90	1160 47	848 30	1515 83	741 03	1192 70	812 08	1290 46
V_4	920 83	966 93	1200 23	1326 77	66 80	961 17	839 80	1239 47	1026 77	1399 43	1012 97	1175 97	904 85	1217 17
V_5	937 00	924 30	1247 23	1317 47	692 60	835 73	945 00	1281 00	833 67	1313 00	939 57	1333 87	878 69	1221 38
V_6	733 60	1317 87	1182 50	1424 27	623 77	858 00	1144 33	1263 22	929 93	1386 63	1140 63	1434 33	981 69	258 16
Mean	822 47	1235 53	1079 84	1510 33	661 40	1010 63	906 36	1257 93	940 59	1469 33	1016 61	1397 29		

	8 DAS	15 DAS
F	18 96**	12 97*
SE	30 551	35 210
CD	86 194	99 365

* Significant at 0 05 level ** Significant at 0 01 level

Among the different seed treatments tested water treatment registered the highest vigour index at 8 and 15 DAS whereas triazole treatment recorded the lowest value

At 8 DAS V_3T_1 combination recorded the highest vigour index and was on par with V_2T_4 and V_5T_1 At 15 DAS V_2T_1 recorded the highest index followed by V_2T_5 V_2T_4 and V_1T_4

4 3 Experiment 1 b Pot culture study

4 3 1 Growth and growth characters

4 3 1 1 Plant height (Tables 12 and 13)

Plant height varied significantly among the varieties at different growth stages At 20 and 40 DAS Tulasi recorded maximum plant height followed by Ravi and M 102 Ravi recorded maximum plant height at 60 and 80 DAS and was followed by M 102 and Tulasi which were on par at both the stages At harvest the highest plant height was registered by M 102 which was on par with Ravi and Tulasi Jaya recorded the lowest plant height

Though the seed treatments did not show appreciable difference in plant height at early stages of growth variation was observed towards the later stages of growth

Table 12 Effect of varieties seed treatments and moisture regimes on plant height (cm)

Treatments	20	40	60	80	Harvest
	Days after sowing				
Varieties					
V_1	16 66	18 25	23 76	26 10	27 33
V_2	16 38	19 65	27 07	29 26	30 17
V_3	16 93	19 69	29 49	32 07	37 21
V_4	16 70	18 68	27 62	29 22	34 67
V_5	17 28	20 34	31 93	36 67	36 91
V_6	18 21	21 04	29 27	31 82	36 36
F	4 74**	13 84**	41 09**	108 19**	87 06**
SE	0 306	0 282	0 438	0 353	0 446
CD	0 848	0 782	1 214	0 978	1 237
Seed treatments					
T_0	16 90	20 01	27 47	30 07	33 29
T_1	18 44	21 42	31 18	33 70	36 70
T_2	16 70	19 20	26 16	28 63	31 47
T_3	16 77	19 63	29 50	31 97	34 76
T_4	16 79	18 85	27 32	30 30	33 57
T_5	16 55	18 58	27 52	30 38	32 87
F	5 54**	13 81**	17 81**	25 67**	16 60**
SE	0 306	0 282	0 438	0 353	0 446
CD	0 848	0 782	1 214	0 978	1 237
Moisture regimes					
M_1	16 82	17 77	22 51	24 00	25 57
M_2	17 23	21 45	33 87	37 68	41 98
F	2 79	264 55**	1043 51**	2337 39**	2100 73**
SE	0 177	0 163	0 253	0 204	0 258
CD	NS	0 452	0 701	0 565	0 714

** Significant at 0 01 level

At all stages seed treatment with water recorded the highest plant height At 20 DAS all seed treatments except water treatment were on par with control Reduced plant height was observed in triazole KCl and cowdung treatments at 40 DAS At 60 and 80 DAS and at harvest triazole treatment resulted in reduced plant height than control

At all stages plant height at 100 per cent available water was higher than that at 50 per cent

Interaction between variety and soil moisture resulted in difference in plant height at all stages except at 20 DAS At 40 DAS Tulasi with 100 per cent available water recorded the maximum plant height (23 47 cm) and at 60 DAS M-102 at 100 per cent available water recorded maximum plant height (36 73 cm) Ravi and M 102 at M_2 moisture recorded the highest plant height at 80 DAS and at harvest respectively Jaya at 50 per cent available water registered the lowest plant height in all stages At lower levels of available water Ravi recorded higher plant height than the other varieties

At harvest stage the variety seed treatment moisture interactions showed variation Tulasi with water treatment at 100 per cent available water recorded the maximum plant height (52 63 cm)

Table 13 Interaction effect of varieties and moisture regimes on plant height (cm)

Moisture regimes / Varieties	Days after sowing 40		60		80		Harvest	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
V_1	16 29	20 21	18 95	28 56	20 66	31 33	22 23	32 43
V_2	18 13	21 17	21 44	32 71	22 52	36 00	23 52	36 82
V_3	17 06	22 32	22 25	36 73	23 95	40 19	27 32	47 10
V_4	17 54	19 81	21 72	33 53	23 30	35 15	23 88	45 47
V_5	18 98	21 71	28 46	35 41	29 45	43 90	29 80	44 02
V_6	18 60	23 47	22 27	36 27	24 10	39 54	26 70	46 02
Mean	17 74	21 45	22 51	33 87	24 00	37 68	25 57	41 98
F	4 72**		10 63**		1 38**		25 97**	
SE	0 399		0 620		0 240		0 258	
CD	1 106		1 718		0 565		0 714	

** Significant at 0 01 level

4 3 1 2 Tiller number hill $^{-1}$ (Tables 14 and 15)

At all stages of growth varietal variation was observed in tiller number hill^{-1} At 20 DAS M-102 recorded maximum tiller number and all other varietes except Jaya were on par Maximum tiller count of 1 53 hill^{-1} at 40 DAS was recorded by Culture-4 and Tulasi which were on par with other varieties except Ravi At 60 DAS Tulasi was observed to be on par with Culture 4 and M 102 However at 80 DAS and at harvest Culture 4 registered the maximum tiller count hill^{-1} followed by Tulasi At both stages Rasi recorded the lowest

Seed treatment had a favourable influence on tiller number hill $^{-1}$ at all stages except at 20 DAS Control pots recorded the lowest tiller number at all stages At 40 DAS triazole treatment resulted in maximum tiller number which was on par with water treatment At 60 DAS water triazole and KCl treatments were on par whereas at 80 DAS and at harvest water and triazole treatments were on par and was followed by KCl treatment The moisture regime of 100 per cent available water significantly improved tiller production from 40 DAS onwards

Variety moisture interactions influenced the tiller number from 40 DAS onwards At 40 and 60 DAS and at harvest Tulasi and Culture 4 at 100 per cent available water

Table 14 Effect of varieties seed treatments and moisture regimes on tiller number hill [1]

Treatments	Days after sowing 20	40	60	80	Harvest
Varieties					
V_1	0 00	1 44	2 95	4 40	4 45
V_2	0 03	1 53	3 27	4 97	5 41
V_3	0 10	1 44	3 09	3 89	3 97
V_4	0 02	1 43	3 07	4 20	4 60
V_5	0 03	1 29	3 07	3 57	3 88
V_6	0 02	1 53	3 34	4 65	5 22
F	2 74*	5 30*	2 49*	25 06*	33 65*
SE	0 013	0 039	0 094	0 102	0 110
CD	0 035	0 108	0 261	0 284	0 306
Seed treatments					
T_0	0 01	1 28	2 83	3 89	4 09
T_1	0 07	1 56	3 41	4 73	5 13
T_2	0 03	1 61	3 25	4 53	4 97
T_3	0 01	1 40	3 07	4 23	4 44
T_4	0 06	1 50	3 24	4 32	4 74
T_5	0 02	1 30	3 00	3 95	4 16
F	1 54	13 00**	4 89**	10 57**	15 57**
SE	0 013	0 039	0 094	0 102	0 110
CD	NS	0 108	0 261	0 284	0 306
Moisture regimes					
M_1	0 02	0 68	1 88	2 97	3 55
M_2	0 05	2 20	4 39	5 58	5 62
F	1 88	2379 27**	1098 36**	1015 21**	542 68**
SE	0 008	0 022	0 054	0 059	0 064
CD	NS	0 062	0 151	0 164	0 177

* Significant at 0 05 level ** Significant at 0 01 level

Table 15 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on tiller number hill[-1]

	Days after sowing							
	40		60		80		Harvest	
Moisture regimes	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Varieties								
V_1	0 67	2 21	1 71	4 19	3 13	5 67	3 10	5 79
V_2	0 67	2 40	1 73	4 81	2 96	6 98	3 84	6 98
V_3	0 65	2 23	1 81	4 38	2 90	4 88	3 06	4 88
V_4	0 71	2 15	1 83	4 31	2 85	5 54	3 65	5 54
V_5	0 75	1 83	2 34	3 81	3 00	4 15	3 52	4 23
V_6	0 65	2 42	1 88	4 81	2 96	6 29	4 15	6 29
Mean	0 68	2 20	1 88	4 39	2 97	5 58	3 55	5 62
F	10 53**		9 24**		25 01**		14 80**	
SE	0 055		0 133		0 145		0 156	
CD	0 153		0 369		0 402		0 433	
Seed treatments								
T_0	0 56	2 00	1 60	4 06	2 92	4 85		
T_1	0 69	2 44	1 90	4 92	3 06	6 40		
T_2	0 79	2 44	1 88	4 63	2 96	6 10		
T_3	0 63	2 17	1 92	4 23	3 00	5 46		
T_4	0 79	2 21	2 12	4 35	3 00	5 65		
T_5	0 63	1 98	1 88	4 13	2 85	5 04		
Mean	0 68	2 20	1 88	4 39	2 97	5 58		
F	3 89**		2 96*		7 23*			
SE	0 055		0 133		0 145			
CD	0 153		0 369		0 402			

* Significant at 0 05 level ** Significant at 0 01 level

were observed to be on par and superior to the others whereas at 80 DAS Culture 4 recorded significantly higher tiller number At 50 per cent available water also Tulasi and Culture 4 recorded maximum tiller number at harvest

Seed treatment moisture interactions were observed to influence the tiller number at 40 60 and 80 DAS Seed treatment with water at M_2 moisture level recorded significantly higher tiller number at 40 60 and 80 DAS though it was on par with triazole treatment at 40 DAS At 50 per cent available moisture regime also seed treatments recorded higher tiller count than control

4 3 1 3 Leaf area $hill^{-1}$ (Tables 16 and 17)

The variety Ravi recorded the maximum leaf area of 103 43 cm^2 $hill^{-1}$ followed by Rasi M-102 and Tulasi the latter three being on par Jaya had the lowest

Seed treatment with water and NaH_2PO_4 improved leaf area over other seed treatments which were on par with control Triazole treatment recorded the lowest leaf area of 76 98cm^2 $hill^{-1}$

Improvement in leaf area was observed with increase in moisture regime

Interaction between varieties and soil moisture also resulted in variation in leaf area Higher levels of

Table 16 Effect of varieties seed treatments and moisture regimes on leaf area hill^{-1} (cm^2 hill^{-1}) and total biomass production (g pot^{-1})

Treatments	Leaf area hill^{-1} (cm^2 hill^{-1})	Total biomass production (g pot^{-1})
Varieties		
V_1	75 23	25 14
V_2	78 67	27 28
V_3	93 54	24 04
V_4	93 65	24 54
V_5	103 44	19 28
V_6	92 77	24 36
F	9 68**	63 51**
SE	3 458	0 336
CD	9 586	0 932
Seed treatments		
T_0	81 70	21 19
T_1	112 96	26 42
T_2	76 98	24 04
T_3	98 68	24 54
T_4	81 59	24 36
T_5	85 38	19 28
F	16 14**	35 00**
SE	3 458	0 336
CD	9 586	0 932
Moisture regimes		
M_1	41 48	6 48
M_2	137 62	41 73
F	1200 83**	17075 13**
SE	1 997	0 194
CD	5 535	0 538

** Significant at 0 01 level

Table 17 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on leaf area hill ^{1} (cm^{2} hill ^{1}) and total biomass production (g pot ^{1})

Moisture regimes	Leaf area hill ^{1} (cm^{2} hill^{-1}) M$_1$	M$_2$	Total biomass production (g pot ^{1}) M$_1$	M$_2$
Varieties				
V_1	32 33	188 13	5 93	44 36
V_2	39 35	117 99	6 12	48 44
V_3	34 39	152 70	6 15	41 92
V_4	45 05	142 26	6 70	42 39
V_5	56 95	149 90	6 03	32 54
V_6	40 82	144 73	7 97	40 76
Mean	41 48	137 62	6 48	41 73
F	4 23**		65 49**	
SE	4 891		0 475	
CD	13 557		1 318	
Seed treatments				
T_0	38 17	125 24	5 14	37 25
T_1	53 67	172 25	6 94	45 90
T_2	32 81	121 16	6 63	42 41
T_3	51 55	145 80	6 80	41 81
T_4	34 28	128 90	7 30	44 09
T_5	38 41	132 36	6 09	38 94
Mean	41 48	137 62	6 48	41 73
F	2 84*		14 69**	
SE	4 891		0 475	
CD	13 557		1 318	

* Significant at 0 05 level ** Significant at 0 01 level

soil moisture increased the leaf area in all the varieties studied M 102 had maximum leaf area at M_2 level and was on par with Ravi Tulasi and Rasi whereas at lower level Ravi recorded maximum leaf area and was on par with Rasi

Seed treatment with water recorded higher leaf area under both moisture regimes Triazole treated plants had the lowest leaf area at both levels of soil moisture

4 3 1 4 Total biomass production

(Tables 16 and 17 Fig 5 6 and 7)

The total biomass production varied significantly among the varieties Culture-4 recorded the highest value of 27 28 g pot^{-1} and the lowest value was registered by Ravi

Biomass production was increased by different methods of seed hardening and water treatment resulted in maximum increase

Increasing moisture regime from 50 to 100 per cent resulted in an increase in biomass production from 6 48 g to 41 73 g pot^{-1}

All varieties recorded higher biomass production at 100 per cent available water the highest value being registered by Culture-4 (48 44 g pot^{-1}) At lower moisture level Tulasi and Rasi were on par and had higher biomass production than the other varieties while Jaya had the lowest

Seed treatment with water at M_2 moisture regime produced the highest biomass production followed by KCl and triazole treatments At M_1 moisture regime all seed treatments were on par and superior to control

Variety seed treatment interactions significantly increased biomass production Culture-4 with KCl NaH_2PO_4 and water treatments and M-102 with water treatment were on par and recorded higher biomass production compared to other combinations

The variety Culture-4 treated with NaH_2PO_4 KCl and water were on par at 100 per cent available water

4 3 2 Yield and Yield attributes

4 3 2 1 Number of productive tillers $hill^{-1}$ (Tables 18 and 19)

Productive tiller number $hill^{-1}$ varied significantly among varieties Culture-4 and Tulasi were on par and superior to the other varieties Ravi recorded the lowest number and was on par with M 102

Seed treatment also significantly improved the number of productive tillers $hill^{-1}$ Water KCl and triazole

Table 18 Effect of varieties seed treatments and moisture regimes on the yield attributes

Treatments	Number productive tillers hill^{-1}	Length of panicle (cm)	Weight of panicle (g)	No of grains panicle^{-1}	No of filled grains panicle^{-1}	No of unfilled grains panicle^{-1}
Varieties						
V_1	2 27	10 28	1 07	40 17	35 46	5 46
V_2	2 83	10 30	1 01	41 92	36 33	6 38
V_3	1 91	10 33	1 09	45 58	39 83	6 17
V_4	2 21	9 27	1 02	38 63	33 13	5 42
V_5	1 90	9 48	0 95	34 79	29 58	4 58
V_6	2 60	9 33	1 01	41 25	35 79	5 29
F	14 20**	35 35**	8 24**	76 39**	35 64**	12 34**
SE	0 102	0 089	0 017	0 418	0 585	0 187
CD	0 281	0 248	0 047	1 160	1 621	0 519
Seed treatments						
T_0	2 15	9 46	0 90	39 33	32 08	6 79
T_1	2 55	10 17	1 09	41 38	36 42	5 42
T_2	2 41	10 13	1 12	41 46	36 83	5 54
T_3	2 15	9 62	0 99	39 29	34 04	5 25
T_4	2 42	10 09	1 10	41 42	36 58	4 88
T_5	2 05	9 52	0 95	39 46	34 17	5 42
F	3 99**	14 22**	28 84**	7 52**	10 90**	12 54**
SE	0 102	0 089	0 017	0 418	0 585	0 187
CD	0 283	0 248	0 047	1 160	1 621	0 519
Moisture regimes						
M_1	0	0	0	0	0	0
M_2	4 57	19 67	2 05	80 78	70 06	11 10
F	3166 28**	75374 05**	22702 58**	57920 99**	22289 09**	5456 42**
SE	0 101	0 052	0 010	0 242	0 338	0 108
CD	0 281	0 143	0 0272	0 670	0 936	0 300

** Significant at 0 01 level

treatments were on par and produced more number of productive tillers compared to the other treatments

Moisture regime had a marked influence in the number of productive tillers Plants maintained at 100 per cent available water produced 4 57 panicles hill ^{1} whereas those at 50 per cent failed to produce any panicle

Variety-soil moisture interactions also had significant influence At M_2 level Culture-4 recorded maximum number of productive tillers (5 67) followed by Tulasi

Among the seed treatment-moisture interactions water treatment at 100 per cent available water recorded maximum number of productive tillers (5 11) and was on par with KCl and triazole treatments

4 3 2 2 Length of panicle (Tables 18 and 19)

Difference among varieties were significant in earhead length Maximum earhead length was recorded by M-102 which was on par with Culture 4 and Jaya Plants raised from seeds treated with water produced longer ears and was on par with triazole and KCl treated plants

M_2 moisture regime recorded an earhead length of 19 67 cm

Table 19 Interaction effect of varieties and moisture regime and seed treatments and moisture regimes on the number of productive tillers hill [1] length (cm) and weight (g) of panicle number of grains filled and unfilled grains panicle^{-1}

Moistu e regimes	Productive tiller hill [1]		Length of ea head (cm)		Wt of panicle (g)		No of gra ns panicle [1]		No of filled grains pan cle [1]		No of unfilled grains panicle [1]	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Varieties												
V_1	0	4 54	0	20 57	0	2 13	0	80 33	0	70 92	0	10 92
V_2	0	5 67	0	20 67	0	2 03	0	83 83	0	72 67	0	12 75
V_3	0	3 81	0	20 65	0	2 17	0	91 17	0	79 67	0	12 33
V_4	0	4 42	0	18 54	0	2 05	0	77 25	0	66 25	0	10 83
V_5	0	3 79	0	18 96	0	1 90	0	69 58	0	59 17	0	9 17
V_6	0	5 21	0	18 66	0	2 03	0	82 50	0	71 58	0	10 58
Mean	0	4 57	0	19 67	0	2 05	0	80 78	0	70 04	0	11 10
F	14 20**		35 35**		8 24**		76 40**		35 64**		12 34**	
SE	0 143		0 126		0 024		0 592		0 827		0 265	
CD	0 397		0 350		0 067		1 640		2 293		0 734	
Seed treatments												
T_0	0	4 29	0	18 93	0	1 80	0	78 67	0	64 17	0	13 58
T_1	0	5 11	0	20 34	0	2 17	0	82 75	0	72 83	0	10 83
T_2	0	4 81	0	20 27	0	2 24	0	82 92	0	73 67	0	11 08
T_3	0	4 29	0	19 24	0	1 98	0	78 58	0	68 08	0	10 50
T_4	0	4 83	0	20 18	0	2 20	0	82 83	0	73 17	0	9 75
T_5	0	4 0	0	19 04	0	1 91	0	78 92	0	68 33	0	10 83
Mean	0	4 57	0	19 67	0	2 05	0	80 78	0	70 04	0	11 10
F	4 00**		14 22**		28 84**		7 52**		10 90**		12 54**	
SE	0 143		0 126		0 024		0 592		0 827		0 265	
CD	0 397		0 350		0 067		1 640		2 293		0 734	

** Significant at 0 01 level

Variety-moisture and seed treatment-moisture interactions caused variation in the length of earhead M-102 Culture-4 and Jaya were on par at 100 per cent available water and produced longer ears Similarly water treatment at 100 per cent available water recorded maximum length of earhead and was on par with triazole and KCl treatment in the same moisture regime

4 3 2 3 Weight of panicle (Tables 18 and 19)

The variety M-102 recorded the highest panicle weight and was on par with Jaya Varieties Rasi Culture-4 and Tulasi were on par and Ravi recorded the lowest

Seed treatment with triazole produced heavier panicles and was on par with KCl and water treatments Control pots recorded the lowest panicle weight

The panicle weight was 2 05 g under M_2 moisture regime

Among variety-soil moisture interactions M-102 and Jaya at 100 per cent available water were on par and recorded higher panicle weight than other combinations

Triazole KCl and water treatments were on par at M_2 moisture regime and recorded higher panicle weights

Seed treatment improved the number of filled grains panicle ^{1} Triazole treatment recorded maximum number of filled grains and was on par with water and KCl treatments

Moisture regime of 100 per cent registered 70 04 filled grains panicle^{-1}

Among variety - soil moisture interactions M-102 at M_2 moisture regime recorded significantly higher number of filled grains panicle ^{1} while seed treatment with triazole KCl and water were on par at M_2 moisture regime

4 3 2 6 Number of unfilled grains panicle^{-1}
(Tables 18 and 19)

Varieties seed treatments and moisture regimes influenced the number of unfilled grains panicle^{-1} Culture 4 had maximum number of unfilled grains which was on par with M-102 and followed by Jaya Rasi and Tulasi the latter three being on par

Seed treatment significantly reduced the number of unfilled grains panicle ^{1} KCl treatment resulted in maximum reduction All other seed treatments were on par and better than control in reducing the number of unfilled grains

The number of unfilled grains recorded at 100 per cent available water was 11 10

4 3 2 4 Number of grains panicle^{-1} (Tables 18 and 19)

Varieties exhibited variation in this regard The variety M-102 recorded the maximum number of grains panicle^{-1} followed by Culture-4 and Rasi the latter being on par Ravi had the lowest

Among seed treatments triazole treatment produced maximum number of grains panicle^{-1} and was on par with KCl and water treatments

M_2 moisture regime recorded 80 78 grains panicle^{-1}

Variety - soil moisture and seed treatment-soil moisture interactions had a significant effect on the number of grains panicle ^{1} At 100 per cent available water M-102 recorded the highest grain number (91 17) and was on par with Culture 4 (83 83) Tulasi (82 50) and Jaya (80 83) The results also revealed that triazole and water treatments were on par at M_2 moisture regime and recorded 82 92 and 82 75 grains panicle ^{1} respectively

4 3 2 5 Number of filled grains panicle ^{1} (Tables 18 and 19)

The variety M-102 produced maximum number of filled grains panicle ^{1} which was significantly superior to others This was followed by Culture 4 and Tulasi which were on par

The analysis also revealed that variety and moisture along with seed treatment-moisture interactions influenced the number of unfilled grains panicle^{-1} Varieties Culture 4 and M-102 and untreated plants at M_2 moisture regime recorded more number of sterile grains Seed treatment with KCl at 100 per cent available water recorded the lowest number of unfilled grains

4 3 2 7 Sterility percentage (Tables 20 and 21)

All varieties except Tulasi were on par and recorded higher number of sterile grains

Seed treatment significantly reduced the sterility percentage the lowest being recorded by KCl treatment

Soil moisture regime of 100 per cent available water recorded 13 56 per cent sterility

Among the interactions Tulasi at M_2 level and KCl treatment at M_2 level recorded significantly lower sterility percentage

4 3 2 8 Thousand grain weight (Tables 20 21 and 22)

Varieties seed treatments and moisture regimes individually and in combination influenced 1000 grain weight

Among varieties M-102 recorded maximum 1000 grain weight and was on par with Jaya followed by Culture-4 Rasi and Tulasi Similarly seed treatment with KCl recorded maximum 1000 grain weight which was on par with water treatment Control pots registered the lowest weight

Moisture regime of 100 per cent available water recorded a 1000 grain weight of 29 21 g

At M_2 moisture regime the varieties M-102 Culture-4 and Jaya were on par whereas among seed treatments KCl and triazole treatments were on par

Among variety seed treatment combinations M-102 with KCl treatment recorded significantly heavier grains and was on par with M 102 with triazole and water treatments and Culture 4 with KCl water and triazole treatments

The varieties Culture 4 M 102 and Jaya with water triazole or and KCl treatment at 100 per cent available water recorded higher 1000 grain weight compared to other combinations and were on par among themselves

4 3 2 9 Grain yield (Tables 20 21 and 22 Fig 5 6 and 7)

Significant variation was observed among the varieties studied with regard to grain yield Culture 4 recorded maximum grain yield of 12 36g pot^{-1} The lowest yield was recorded by Ravi (8 76g pot^{-1})

Table 20 Effect of varieties seed treatments and moisture regimes on sterility percentage 1000 grain weight (g) grain yield and straw yield (g pot^{-1})

Treatments	Sterility (%)	1000 grain weight g	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
Varieties				
V_1	6 80(21 58)	15 36	11 16	8 54
V_2	7 62(22 89)	14 97	12 36	9 85
V_3	6 78(21 53)	15 42	10 79	9 13
V_4	6 52(21 00)	14 44	11 32	8 69
V_5	6 63(21 19)	13 48	8 72	7 08
V_6	6 34(20 79)	14 05	11 41	9 04
F	5 83*	42 63**	29 52**	41 04**
SE	0 723	0 119	0 224	0 146
CD	2 005	0 329	0 622	0 406
Seed treatments				
T_0	8 65(24 52)	13 42	9 64	7 95
T_1	6 56(21 18)	15 13	12 21	9 36
T_2	16 16(20 54)	15 39	11 39	8 58
T_3	6 57(21 24)	14 27	10 74	8 98
T_4	5 88(20 03)	15 52	11 52	9 06
T_5	6 87(21 72)	13 92	10 29	8 39
F	25 05**	54 90**	17 65**	12 83**
SE	0 723	0 119	0 224	0 146
CD	2 005	0 329	0 622	0 406
Moisture regimes				
M_1	0	0	0	4 32
M_2	13 56(42 67)	29 21	21 93	13 12
F	7641 47**	94415 09**	14839 21**	5608 06**
SE	0 675	0 068	0 130	0 084
CD	1 871	0 189	0 359	0 234

* Significant at 0 05 level ** Significent at 0 01 level
Figures in parentheses are transformed values

Table 21 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on sterility percentage 1000 grain weight (g) grain and straw yield (g pot^{-1})

Moisture regimes	Sterility (%)		1000 grain weight (g)		Grain yield (g pot^{-1})		Straw yield (g pot^{-1})	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Varieties								
V_1	0	13 59(21 58)	0	30 60	0	22 33	3 54	13 54
V_2	0	15 25(22 89)	0	29 93	0	24 71	4 65	15 04
V_3	0	13 55(21 53)	0	30 83	0	21 58	4 20	14 06
V_4	0	13 04(21 00)	0	28 88	0	22 64	4 54	12 83
V_5	0	13 26(21 19)	0	26 95	0	17 53	3 92	10 25
V_6	0	12 69(20 79)	0	28 09	0	22 81	5 08	12 99
Mean	0	13 56(21 53)	0	29 21	0	21 93	4 32	13 12
F	5 83**		42 63**		29 52**		29 53*	
SE	0 818		0 168		0 317		0 207	
CD	2 268		0 465		0 879		0 574	
Seed treatments								
T_0	0	17 30(24 52)	0	26 83	0	19 28	3 64	12 25
T_1	0	13 12(21 18)	0	30 26	0	24 42	4 59	14 14
T_2	0	12 32(20 54)	0	30 78	0	22 77	4 45	12 70
T_3	0	13 15(21 24)	0	28 54	0	21 50	4 31	13 66
T_4	0	11 75(20 03)	0	31 03	0	23 05	4 85	13 27
T_5	0	13 73(21 72)	0	27 83	0	20 58	4 08	12 70
Mean	0	13 56(21 53)	0	29 21	0	21 93	4 32	13 12
F	25 05**		54 90**		0 879**		0 575**	
SE	0 818		0 168		0 317		0 207	
CD	2 268		0 465		0 879		0 574	

** Significant at 0 01 level

Figures in parantheses are transformed values

Table 22 Interaction effect of varieties and seed treatment on 1000 grains weight (g) and grain yield (g pot $^{-1}$)

Seed treatments	1000 grain wt (g)							Gra n yield g pot ^{1}						
	T_0	T_1	T_2	T_3	T_4	T_5	Mean	T_0	T_1	T_2	T_3	T_4	T_5	Mean
Var eties														
V_1	14 45	16 13	15 83	14 58	15 98	14 85	15 30	9 77	11 87	12 09	10 38	12 13	10 75	11 16
V_2	13 28	15 75	16 03	14 93	15 98	13 85	14 97	9 75	13 69	13 00	12 73	13 42	11 57	12 36
V_3	14 75	15 88	15 98	14 95	16 05	14 90	15 42	8 88	13 15	1 81	10 65	11 00	9 25	10 79
V_4	13 25	14 80	14 88	14 38	15 18	14 15	14 44	10 25	12 60	12 20	10 38	11 70	10 80	11 32
V_5	11 45	14 10	15 20	12 75	15 33	12 03	13 48	8 00	9 18	8 40	8 42	9 58	9 01	9 76
V_6	13 33	14 13	14 45	14 05	14 60	13 73	14 05	11 20	12 25	10 84	11 94	11 33	10 37	11 41
Mean	13 42	15 13	15 39	14 27	15 52	13 92		9 64	12 21	11 39	0 75	11 52	10 29	
F	3 06**							1 78*						
SE	0 290							8 550						
CD	0 805							1 524						

* Sign ficant at 0 05 level ** S gnif cant at 0 01 level

When compared to control seed treatment significantly improved the grain yield Seed treatment with water recorded maximum grain yield (12 21g pot ^{1}) followed by KCl and triazole treatments the latter being on par

Pots maintained at 100 per cent available water produced a grain yield of 21 93 g pot^{-1} At 50 per cent available water panicle emergence was not generally observed In some plants sterile panicles partially emerged and had only chaff

Variety moisture interactions were observed to influence the grain yield in varying levels Culture-4 at 100 per cent available water recorded maximum grain yield of 24 71g pot ^{1} followed by Tulasi Rasi and Jaya at the same moisture regime Among seed treatment moisture interactions water treatment recorded the highest grain yield (24 42 g pot ^{1}) followed by KCl and triazole treatments the latter being on par at M_2 moisture regime At M_2 regime control pots recorded the lowest grain yield

Variety - seed treatment interactions were also influenced grain yield Culture-4 with water KCl and triazole treatments M-102 Rasi and Tulasi with water treatment were on par and superior to other combintions Control pots of Ravi registered the lowest grain yield (8 g pot ^{1})

At 100 per cent available water the combinations Culture-4 with water KCl and triazole and M-102 Rasi and Tulasi with water were observed to be on par and had higher grain yield than others

4 3 2 10 Straw yield (Tables 20 21 and 23 Fig 5 6 and 7)

The variety Culture-4 recorded significantly the highest straw yield (9 85 g pot^{-1}) followed by M-102 and Tulasi The lowest straw yield was recorded by Ravi (7 08g pot^{-1})

Seed treatment had significant influence on the straw yield and all seed treatments recorded higher straw yield compared to control Seed treatment with water recorded the highest and was on par with KCl and NaH_2PO_4 treatments

Plants raised at 100 per cent available water produced significantly higher straw yield (13 12g pot ^{1}) than those under M_1 moisture regime (4 32g pot^{-1})

All varieties registered higher straw yield at M_2 level and the highest yield was obtained by Culture-4 (15 04g pot^{-1}) while Jaya at 50 per cent available water recorded the lowest straw yield of 3 54g pot^{-1}

Seed treatment moisture interactions influenced straw yield significantly Plants raised by water treatment and kept at 100 per cent available water recorded the highest straw yield followed by NaH_2PO_4 and KCl treatments under the same moisture regime Control pots at 50 per cent available water produced the lowest straw yield

The variety M 102 with water treatment produced maximum straw yield (11 55g pot ^{1}) and was on par with Culture 4 treated with water NaH_2PO_4 KCl and cowdung The lowest straw yield was recorded by V_5T_0 combination

Variety seed treatment moisture interactions also influenced straw yield significantly M-102 with water treatment at M_2 moisture regime recorded the highest straw yield and was on par with Culture-4 treated with NaH_2PO_4 under the same moisture regime

4 3 3 <u>Physio-chemical parameters</u>

4 3 3 1 Relative water content (RWC) (Tables 24 25 and 26)

The RWC varied significantly among the varieties Rasi recorded the highest value of 82 33 per cent followed by Tulasi and Ravi which were on par The lowest RWC was recorded by Culture 4(78 67 per cent) which was on par with Jaya

Table 23 Interaction effect of varieties and seed treatments on straw yield (g pot ^{1})

	Seed treatments						
Varieties	T_0	T_1	T_2	T_3	T_4	T_5	Mean
V_1	7 63	9 31	8 44	8 94	9 13	7 81	8 54
V_2	8 13	9 58	9 13	11 00	10 63	10 63	9 58
V_3	8 30	11 55	9 43	8 38	9 31	7 81	9 13
V_4	8 25	8 88	8 63	9 00	8 75	8 63	8 69
V_5	6 88	7 38	6 26	6 97	7 68	7 35	7 08
V_6	8 50	9 50	9 60	9 63	8 88	8 13	9 04
Mean	7 95	9 36	8 58	8 98	9 06	8 39	
F	4 24**						
SE	0 359						
CD	0 994						

** Significant at 0 01 level

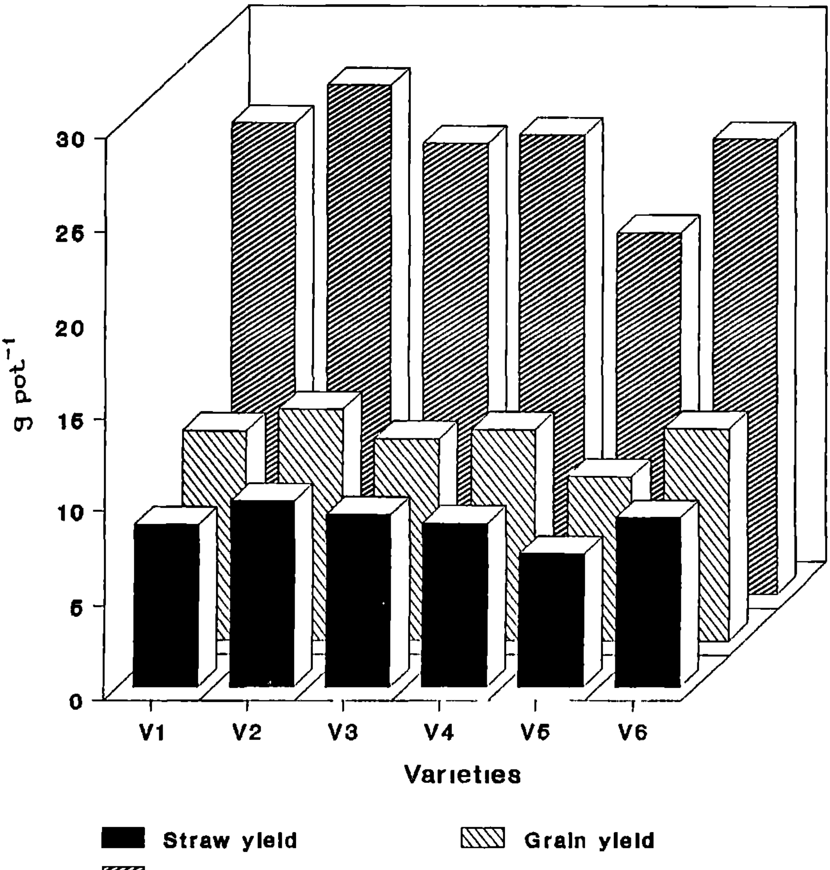


Fig 5 Effect of varieties on grain yield, straw yield

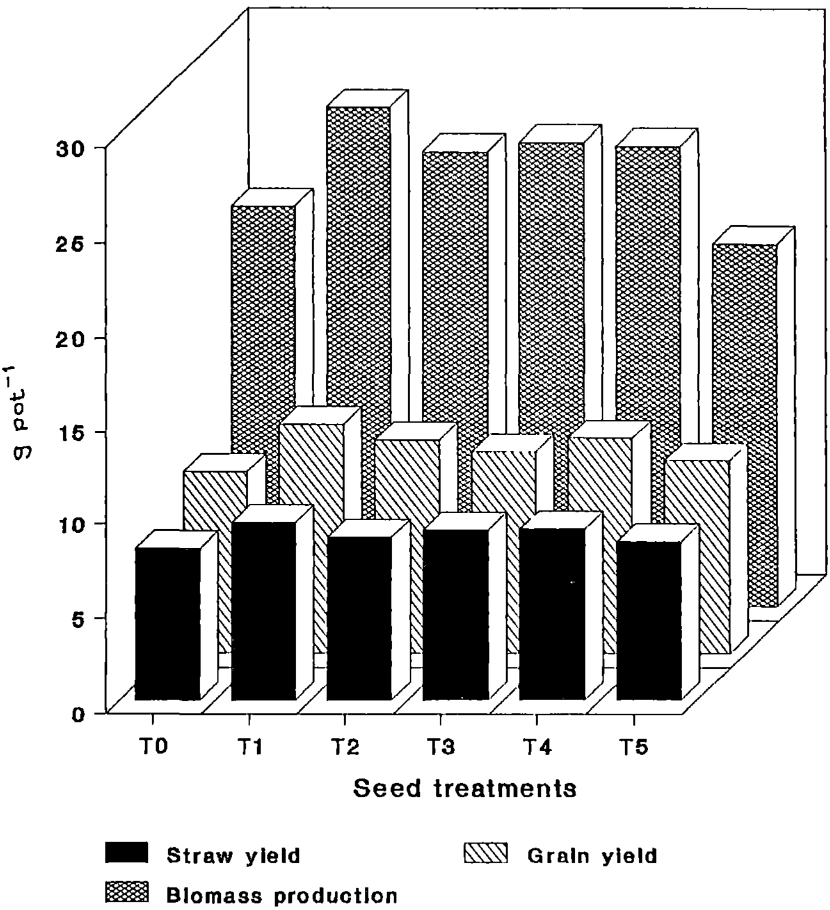


Fig 6 Effect of seed treatments on grain yield, straw yield and total biomass production (g pot^{-1})

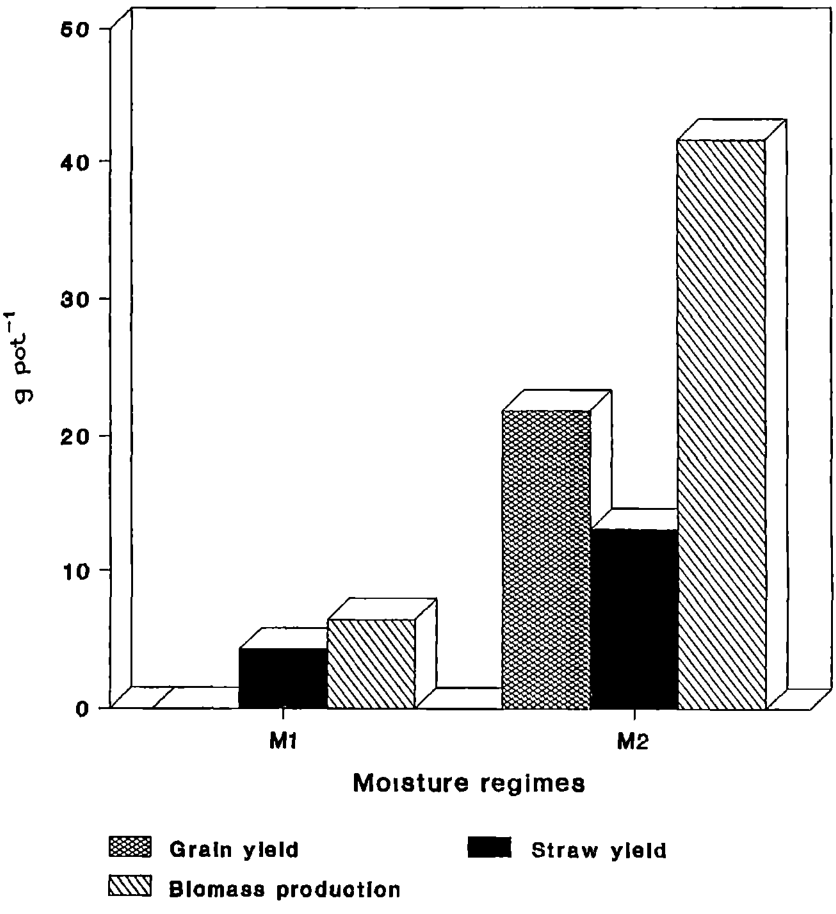


Fig 7 Effect of moisture regimes on grain yield, straw yield and total biomass production (g pot^{-1})

Favourable influence on RWC was observed by seed treatment Triazole treatment registered the highest RWC (82 92 per cent) This was followed by water and KCl treatments which were on par

Increased moisture regime improved RWC M_2 level recorded 82 64 per cent as against 77 82 per cent by M_1 level

The variety Rasi recorded maximum RWC both at M_1 and M_2 moisture regimes At M_1 level Rasi was on par with Tulasi and Ravi whereas at M_2 level it was on par with Culture 4 and Ravi

RWC was significantly influenced by seed treatment-moisture interactions Triazole treatment registered maximum RWC at 50 and 100 per cent available water At M_2 moisture regime triazole and KCl treatments were on par The lowest RWC (75 10 per cent) was recorded by control pots at 50 per cent available water

Among variety seed treatment combinations Rasi with water treatment registered maximum RWC which was on par with Jaya and Culture 4 treated with triazole

Significant difference in RWC was noticed among variety seed treatment - moisture combinations Culture 4 treated with triazole and kept at 100 per cent available water registered the maximum RWC (91 08 per cent)

Table 24 Effect of varieties seed treatments and moisture regimes on the physio chemical parameters

Treatments	RWC (%)	Chlorophyll Total	a	b	P ol ne (ug g^{-1} fresh wt)	Grain prote n (%)	Stomatal frequency	Stomatal index
		(mg g^{-1} fresh ve ght)						
Varieties								
V_1	78 71	2 83	2 22	0 61	0 48	3 43	22 29	0 12
V_2	78 67	2 32	1 77	0 55	0 53	3 45	19 50	0 10
V_3	79 55	3 43	2 72	0 75	1 19	3 38	22 38	0 12
V_4	82 33	2 13	1 58	0 54	0 86	3 62	20 38	0 09
V_5	81 03	2 10	1 66	0 44	0 92	3 52	20 96	0 09
V_6	81 10	2 95	2 26	0 69	1 05	3 57	21 83	0 11
F	25 19**	343 40**	324 86**	58 27**	108 57**	3 30**	23 04**	27 01**
SE	0 301	0 029	0 025	0 014	0 027	0 051	0 244	0 002
CD	0 834	0 081	0 069	0 040	0 076	0 142	0 675	0 006
Seed treatments								
T_0	78 03	2 33	1 90	0 44	0 74	3 39	23 75	0 12
T_1	82 05	2 68	1 99	0 70	0 93	3 57	21 38	0 11
T_2	82 92	2 72	2 14	0 62	0 87	3 60	19 46	0 09
T_3	78 88	2 66	2 09	0 56	0 78	3 37	22 33	0 11
T_4	81 89	2 54	2 02	0 52	0 85	3 50	17 88	0 08
T_5	77 62	2 81	2 07	0 74	0 87	3 54	22 54	0 12
F	61 27**	34 27**	12 33**	64 00**	6 492**	3 67**	82 75**	53 66**
SE	0 301	0 029	0 025	0 014	0 027	0 051	0 244	0 002
CD	0 834	0 081	0 069	0 040	0 076	0 142	0 675	0 006
Moisture reg mes								
M_1	77 82	2 11	1 80	0 31	1 07	0	22 10	0 11
M_2	82 64	3 14	2 26	0 88	0 61	6 99	20 35	0 10
F	399 79**	1917 19**	530 58**	2467 30**	427 26**	28965 82**	80 18**	70 25**
SE	0 174	0 017	0 014	0 008	0 016	0 030	0 141	0 001
CD	0 481	0 047	0 040	0 023	0 044	0 082	0 390	0 004

** Significant at 0 01 level

Table 25 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on RWC (%) and chlorophyll content (mg g^{-1} fresh weight)

Moisture regimes	RWC (%)		Chlorophyll (mg g^{-1} fresh weight) Total		a		b	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Varieties								
V_1	75 46	81 95	1 80	3 86	1 54	2 89	0 27	0 96
V_2	73 66	83 69	1 98	2 66	1 78	1 75	0 19	0 90
V_3	77 92	81 18	2 79	4 06	2 38	3 07	0 42	1 07
V_4	80 95	83 71	1 89	2 34	1 56	1 61	0 34	0 75
V_5	79 16	82 91	1 80	2 40	1 51	1 80	0 29	0 60
V_6	79 77	82 43	2 41	3 48	2 06	2 46	0 36	1 02
Mean	77 82	82 64	2 11	3 14	1 80	2 26	0 31	0 88
F	24 29**		105 84**		108 10**		35 92**	
SE	0 425		0 041		0 035		0 021	
CD	1 179		0 114		0 098		0 0570	
Seed treatments								
T_0	75 10	80 96	1 85	2 82	1 65	2 14	0 20	0 68
T_1	79 54	84 56	2 11	3 26	1 78	2 20	0 34	1 06
T_2	80 74	85 09	2 32	3 12	1 97	2 30	0 35	0 89
T_3	75 98	81 78	2 11	3 20	1 83	2 36	0 28	0 85
T_4	80 30	83 48	2 12	2 96	1 95	2 09	0 17	0 87
T_5	75 26	79 98	2 16	3 46	1 65	2 49	0 52	0 97
Mean	77 82	82 64	2 11	3 14	1 80	2 26	0 31	0 88
F	2 92**		10 90**		22 74**		15 35**	
SE	0 425		0 041		0 035		0 021	
CD	1 179		0 114		0 098		0 057	

** Significant at 0 01 level

Table 26 Interaction effect of varieties and seed treatments on RWC (%) and total chlorophyll content (mg g^{-1} fresh weight) of leaves

Seed treatments / Varieties	RWC (%)							Total chlorophyll (mg g^{-1} fresh weight)						
	T_0	T_1	T_2	T_3	T_4	T_5	Mean	T_0	T_1	T_2	T_3	T_4	T_5	Mean
V_1	76 23	80 90	84 08	75 36	80 84	74 84	78 71	2 76	2 92	2 73	2 93	2 52	3 11	2 83
V_2	73 55	79 63	84 67	77 48	80 40	76 32	78 67	1 84	2 61	2 18	2 46	2 22	2 60	2 32
V_3	79 25	81 86	80 10	77 59	81 88	76 34	79 55	3 11	4 02	3 10	3 71	3 23	3 39	3 43
V_4	80 88	86 06	83 92	80 38	83 08	79 65	82 33	1 76	2 28	2 61	1 91	1 98	2 21	2 13
V_5	78 31	81 85	82 75	81 43	83 21	78 65	81 03	1 81	2 00	2 19	1 86	2 20	2 54	2 10
V_6	79 97	82 01	82 00	81 09	81 93	79 63	81 10	2 71	2 29	3 52	3 08	3 09	3 00	2 95
Mean	78 03	82 05	82 92	78 89	81 89	77 62		2 33	2 68	2 72	2 66	2 54	2 81	
F	4 89*							17 71**						
SE	0 737							0 071						
CD	2 042							0 198						

* Significant at 0 05 level ** Significant at 0 01 level

4 3 3 2 Total chlorophyll content (Tables 24 25 and 26)

The variety M 102 recorded maximum chlorophyll content (3 43 mg g ^{1} fresh weight) followed by Tulası Ravi had the lowest chlorophyll content

The results revealed that seed treatment had a favourable ınfluence ın increasıng the chlorophyll content of leaves Seed treatment wıth cowdung extract recorded the maxımum chlorophyll content followed by trıazole treatment Control pots recorded the lowest chlorophyll content

Increasıng the moısture regıme from 50 to 100 per cent avaılable water ımproved the chlorophyll content from 2 11 to 3 14 mg g ^{1} fresh weıght of leaf

Varıetıes grown under dıfferent moısture levels dıffered sıgnıfıcantly ın the levels of total chlorophyll M 102 at M_2 moısture regıme recorded the hıghest chlorophyll content of 4 06 mg g ^{1} whereas the lowest value of 1 80 mg g^{-1} was recorded by Jaya and Ravı at 50 per cent avaılable water

Seed treatment ın combınatıon wıth moısture levels sıgnıficantly ınfluenced the chlorophyll content of leaves Cowdung extract treatment had the maxımum chlorophyll content at M_2 moısture regime (3 46 mg g ^{1}) followed by water NaH_2PO_4 and trıazole treatments at the same moısture level

Variation was also observed among variety - seed treatment combinations Seed treatments increased chlorophyll content in all varieties and was maximum in M-102 treated with water

The variety M 102 with NaH_2PO_4 seed treatment recorded maximum chlorophyll content at 100 per cent available water followed by water treatment of the same variety Control pots of Rasi at 50 per cent available water recorded the lowest chlorophyll content

4 3 3 3 Chlorophyll a content (Tables 24 25 and 27)

Among the varieties studied M 102 recorded significantly higher content of chlorophyll a followed by Tulasi

Seed treatment with triazole recorded the highest content of chlorophyll a which was on par with NaH_2PO_4 treatment

Moisture regime of 100 per cent improved the content of chlorophyll a over 50 per cent With respect to variety - moisture interactions M 102 at M_2 moisture regime recorded the highest content of chlorophyll a whereas Ravi at 50 per cent available water recorded the lowest value

Seed treatment - moisture interactions significantly influenced the chlorophyll a content Seed treatment with cowdung at 100 per cent available water was found superior to all other combinations

Among variety seed treatment interactions M 102 with NaH_2PO_4 treatment recorded the highest content of chlorophyll a This was on par with water treatment of M-102 and triazole treatment of Tulasi

Variety - seed treatment moisture interactions were also significant with respect to the content of chlorophyll a the highest value being registered by M-102 with NaH_2PO_4 treatment at 100 per cent available water

4 3 3 4 Chlorophyll b content (Tables 24 25 and 27)

Variety M 102 exhibited significantly higher levels of chlorophyll b followed by Tulasi The lowest content was registered by Ravi (0 44 mg g^{1} fresh weight)

Among seed treatments cowdung extract and water treatments were observed to be on par and recorded higher content of chlorophyll b than the others

Moisture regime of 100 per cent improved chlorophyll b content compared to 50 per cent

Table 27 Interaction effect of varieties and seed treatments on chlorophyll a and b content (mg g ^{1} fresh weight) of leaves

Seed treatments / Varieties	Chlorophyll a (mg g ^{1} fresh weight)							Chlorophyll b (mg g ^{1} fresh weight)						
	T_0	T_1	T_2	T_3	T_4	T_5	Mean	T_0	T_1	T_2	T_3	T_4	T_5	Mean
V_1	2 44	2 45	2 04	2 03	2 12	2 21	2 22	0 32	0 47	0 69	0 90	0 41	0 90	0 61
V_2	1 44	1 70	1 66	1 97	1 80	2 07	1 77	0 41	0 91	0 52	0 49	0 42	0 54	0 55
V_3	2 45	3 01	2 62	3 02	2 49	2 75	2 72	0 66	1 02	0 70	0 69	0 74	0 65	0 74
V_4	1 23	1 50	1 99	1 41	1 69	1 68	1 58	0 53	0 78	0 62	0 50	0 29	0 54	0 54
V_5	1 56	1 56	1 64	1 68	1 84	1 69	1 69	0 26	0 45	0 55	0 19	0 37	0 86	0 44
V_6	2 26	1 72	2 87	2 46	2 20	2 02	2 26	0 45	0 57	0 64	0 61	0 89	0 97	0 69
Mean	1 90	1 99	2 14	2 09	2 02	2 07		0 44	0 70	0 62	0 56	0 52	0 74	

	Chlorophyll a	Chlorophyll b
F	18 95**	26 91*
SE	0 062	0 035
CD	0 169	0 098

** Significant at 0 01 level

Variety moisture and seed treatment - moisture interactions had influence on chlorophyll b content The highest content was recorded by M 102 at 100 per cent available water and it was on par with Tulasi Similarly KCl seed treatment at M_2 moisture regime recorded maximum content of chlorophyll b

4 3 3 5 Proline content (Tables 24 and 28)

The proline content recorded at flowering stage differed among the varieties M-102 recorded maximum proline content of 1 19 $\mu g\ g^{-1}$ fresh weight followed by Tulasi Jaya was found to accumulate the lowest content of proline in its leaves

Water treatment given to seeds resulted in highest accumulation of free proline and was on par with triazole and cowdung treatments Control recorded the lowest proline content

Proline accumulation in plants varied under different moisture regimes Highest proline concentration of 1 07 $\mu g\ g^{-1}$ fresh weight was recorded at 50 per cent available water as against 0 61 $\mu g\ g^{-1}$ fresh weight at 100 per cent available water

Variety moisture interactions influenced the proline content All varieties accumulated more proline at

50 per cent available water than at 100 per cent The highest content (1 63 $\mu g\ g^{-1}$ fresh weight) being recorded by M-102 at 50 per cent available water followed by Tulasi Ravi and Rasi at the same moisture regime Jaya at 100 per cent available water recorded the lowest accumulation of proline (0 41 $\mu g\ g^{1}$ fresh weight)

4 3 3 6 Protein content of grains (Tables 24 and 28)

The variety Rasi had maximum protein content in grains and was on par with Tulasi and Ravi

Seed treatment improved the protein content in grains Triazole treatment recorded the maximum protein content and was on par with cowdung water and KCl seed treatments

The protein content was 6 99 per cent at M_2 moisture regime

Variety moisture and seed treatment - moisture interactions resulted in variations in protein content of grains Rasi at 100 per cent available water registered the highest protein percentage This was on par with Tulasi at the same moisture regime Similarly seed treatment with triazole cowdung water and KCl were observed to be on par at M_2 moisture regime and recorded significantly higher protein content than control treatment

Table 28 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on protein (%) and proline content (μg g [1] fresh weight)

Moisture regimes	Protein (%) M$_1$	Protein (%) M$_2$	Proline (μg g [1] fresh weight) M$_1$	Proline (μg g [1] fresh weight) M$_2$
Varieties				
V$_1$	0	6 86	0 56	0 41
V$_2$	0	6 89	0 58	0 48
V$_3$	0	6 76	1 63	0 75
V$_4$	0	7 24	1 14	0 57
V$_5$	0	7 03	1 18	0 65
V$_6$	0	7 15	1 29	0 80
Mean	0	6 99	1 07	0 61
F	3 30**		28 16**	
SE	0 073		0 039	
CD	0 201		0 108	
Seed treatments				
T$_0$	0	6 78		
T$_1$	0	7 14		
T$_2$	0	7 20		
T$_3$	0	6 74		
T$_4$	0	7 00		
T$_5$	0	7 15		
Mean	0	6 99		
F	3 67**			
SE	0 073			
CD	0 201			

** Significant at 0 01 level

4 3 3 7 Stomatal frequency (Table 24)

Variation was observed among varieties in stomatal frequency and it was maximum for M 102 which was on par with Jaya and Tulasi The lowest frequency was observed in Culture 4

Seed treatment resulted in decreased stomatal frequency Similarly decreasing moisture regime caused an increase in frequency from 20 35 to 22 10

4 3 3 8 Stomatal index (Table 24)

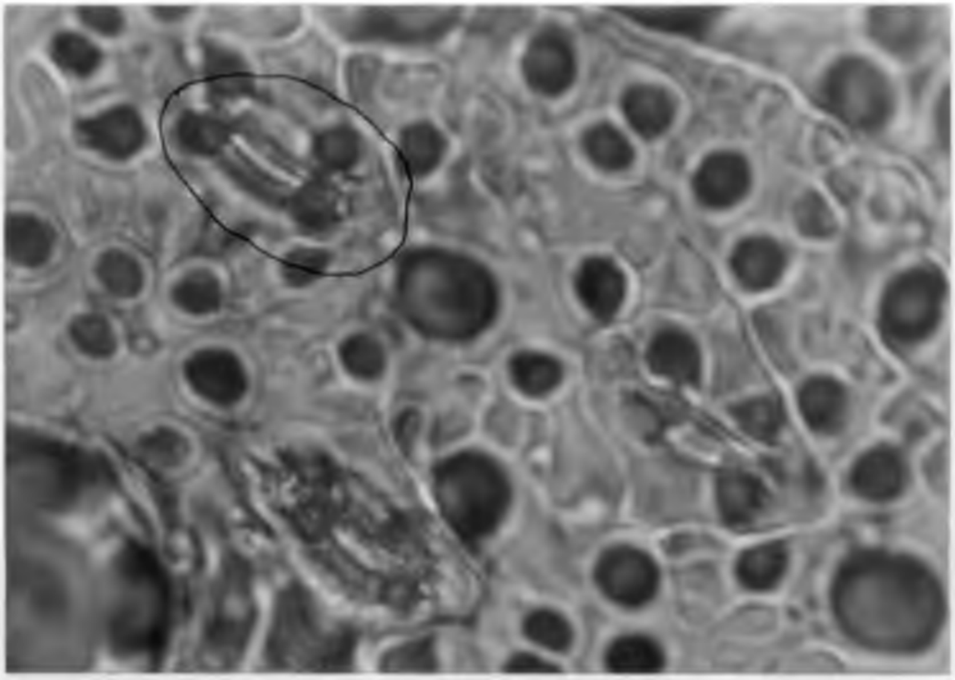
Stomatal index differed among the varieties Jaya recorded maximum value for stomatal index and was on par with M-102 and Tulasi

Seed treatment caused variation in stomatal index and the lowest index was recorded by KCl treatment which was on par with triazole Control pot plants recorded the maximum index of 0 12

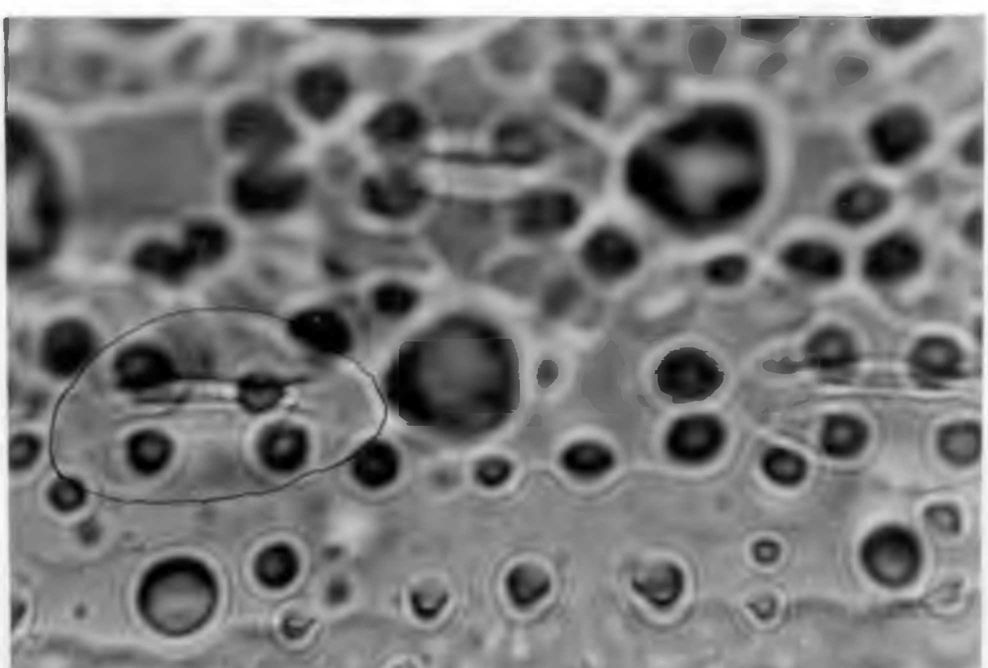
4 3 4 <u>Root parameters</u>

4 3 4 1 Root weight pot $^{-1}$ (Tables 29 30 and 31 Fig 8)

The variety Jaya was found to have the highest root weight (5 44 g pot $^{-1}$) followed by Culture-4 Ravi recorded the lowest root weight



Control



Treated

Plate 3. Stomatal observations in rice

Seed treatments produced a positive effect on the root weight KCl treatment recorded the maximum root weight of 4 95 g pot ^{1} and was on par with water treatment This was followed by triazole treatment

Increased level of moisture resulted in an increase in root weight

The different varieties produced more root weight at 100 per cent available water than at 50 per cent Under M_2 moisture regime Culture 4 recorded maximum root weight (8 68 g pot ^{1}) and was on par with Jaya whereas at lower moisture levels Tulasi recorded the highest root weight and was on par with Jaya and Rasi

Among seed treatment moisture interactions KCl treatment at M_2 level recorded the highest root weight This was on par with water treatment At 50 per cent available water all seed treatment methods were on par and recorded higher root weight than control

Among the variety seed treatment interactions Jaya and Culture 4 treated with water KCl and NaH_2PO_4 and Rasi and M 102 with water treatment were on par and recorded higher root weight compared to the other combinations

Culture 4 with NaH_2PO_4 treatment at 100 per cent available water recorded maximum root weight of 9 60 g pot ^{1}

Table 29 Effect of varieties seed treatments and moisture regimes on the root parameters

Treatments	Root weight g pot^{-1}	Root length (cm)	Root volume (cm^3 pot^{-1})	Root spread (cm)	Root shoot ratio
Varieties					
V_1	5 44	10 34	11 42	2 78	0 46
V_2	08	13 3	11 54	2 48	0 27
V_3	4 16	14 30	11 42	2 38	0 32
V_4	4 37	12 51	11 00	2 85	0 33
V_5	3 46	11 13	7 75	2 50	0 36
V_6	3 78	11 52	9 67	2 55	0 32
F	48 21**	47 38**	75 60**	6 36**	36 57**
SE	0 111	0 223	0 176	0 074	0 011
CD	0 308	0 618	0 487	0 206	0 031
Seed treatments					
T_0	3 60	10 91	8 92	2 25	0 30
T_1	4 89	13 49	11 63	2 76	0 36
T_2	4 56	12 56	11 00	2 83	0 36
T_3	4 44	12 49	10 08	2 63	0 33
T_4	4 95	12 60	11 83	2 73	0 36
T_5	3 86	11 28	9 33	2 34	0 34
F	25 11**	18 97**	49 17**	11 03**	4 80**
SE	0 111	0 223	0 176	0 074	0 011
CD	0 308	0 618	0 487	0 206	0 031
Moisture regimes					
M_1	2 11	8 76	5 96	2 13	0 50
M_2	6 66	15 68	14 97	3 05	0 19
F	2608 33**	1500 03**	4089 33**	243 78**	1201 47**
SE	0 064	0 129	0 101	0 043	0 006
CD	0 178	0 357	0 281	0 119	0 018

** Significant at 0 01 level

Table 30 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on the root parameters

Moisture regimes	Root wt (g pot^{-1})		Root volume (cm^3 pot^{-1})		Root shoot ratio		Root length (cm)		Root spread (cm)	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Varieties										
V_1	2 39	8 50	6 08	16 75	0 69	0 24	6 74	13 95	2 32	3 25
V_2	1 47	8 68	5 50	17 58	0 32	0 22	8 89	18 18	1 76	3 21
V_3	1 95	6 36	5 58	17 25	0 47	0 18	9 39	19 21	2 13	2 63
V_4	2 16	6 58	5 58	16 42	0 47	0 18	9 31	15 71	2 11	3 58
V_5	2 11	4 80	5 67	9 83	0 55	0 17	9 64	12 61	2 39	2 60
V_6	2 55	5 02	7 33	12 00	0 49	0 14	8 59	14 44	2 05	3 05
Mean	2 11	6 66	5 96	14 97	0 50	0 19	8 76	15 68	2 13	3 05
F	72 70**		108 87**		3 78**		32 47**		11 91**	
SE	0 157		0 101		0 016		0 315		0 105	
CD	0 436		0 281		0 043		0 873		0 291	
Seed treatments										
T_0	1 49	5 71	4 92	12 92	0 42	0 18				
T_1	2 35	7 42	6 83	16 42	0 54	0 19				
T_2	2 18	6 93	6 25	15 75	0 53	0 19				
T_3	2 15	6 73	5 58	14 58	0 48	0 19				
T_4	2 45	7 45	7 42	16 25	0 51	0 21				
T_5	2 01	5 70	4 75	13 92	0 51	0 17				
Mean	2 11	6 66	5 96	14 97	0 50	0 19				
F	5 68**		2 76*		3 92**					
SE	0 157		0 101		0 016					
CD	0 436		0 281		0 043					

* Significant at 0 05 level ** Significant at 0 01 level

Plate 2. a Root parameters of rice varieties as influenced by seed treatments and moisture regimes

0 – control 1 – water 2 – triazole 3 – NaH_2PO_4
4 – KCl 5 – cowdung AW – Available Water

Plate 2. b Root parameters of rice varieties as influenced by seed treatments and moisture regimes

0 - control 1 - water 2 - triazole 3 - NaH_2PO_4
4 - KCl 5 - cowdung AW - Available Water

Table 31 Interaction effect of varieties and seed treatments on root weight (g pot 1) and root length (cm)

Seed treatment / Varieties	0	T_1	T_2	T_3	T_4	T_5	Mean	T_0	T_1	T_2	T_3	T_4	T_5	Mean
	Root we ght g pot)							Root length (cm						
V	4 54	5 89	6 00	5 38	5 64	5 22	5 44	8 74	98	10 3	0 43	1 3	9 68	0 34
V_2	5 03	5 2	5 8	5 60	5 25	4 28	5 08	12 33	14 3	12 6	4 20	3 75	3 55	3 53
V_3	3 38	5 38	4 45	3 20	4 77	3 76	4 6	3 45	6 33	15 75	14 60	2 78	2 90	4 30
V_4	3 31	5 34	4 69	4 71	4 99	3 8	4 37	0 31	3 29	12 78	2 68	3 78	2 25	2 5
V_5	2 32	3 89	2 99	2 99	4 8	3 75	3 46	10 68	12 60	1 33	59	11 26	9 30	3
V_6	3 03	3 70	4 04	4 77	4 23	2 95	3 78	9 94	12 00	2 75	1 45	2 94	10 03	11 52
Mean	3 60	4 89	4 56	4 44	4 95	3 86		10 91	3 49	12 56	2 49	2 60	1 28	

	Root weight	Root length
F	4 6**	2 26**
SE	0 272	0 546
CD	0 754	513

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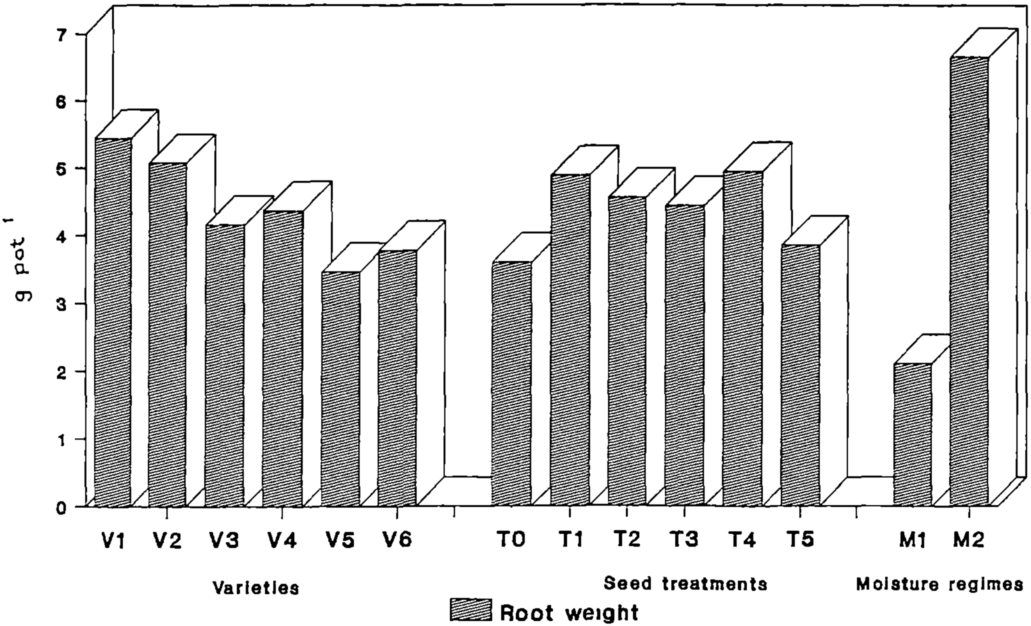

Fig 8 Root weight (g pot^{-1}) as influenced by varieties, seed treatments and moisture regimes

4 3 4 2 Root length (Tables 29 30 and 31 Fig 9)

Root length varied among varieties and M-102 recorded the highest root length of 14 30 cm followed by Culture 4 Rasi and Tulasi The lowest root length of 10 34 cm was recorded by Jaya

Plants raised from seeds treated with different chemicals and water produced longer roots The longest roots (13 49 cm) were produced by water treatment followed by KCl triazole and NaH_2PO_4 treatments the latter three being on par

Increasing soil moisture level from 50 to 100 per cent available water had a favourable effect on root length

Root length varied with variety moisture interactions At 100 per cent M 102 produced the longest roots followed by Culture 4 and Tulasi However the root length of Jaya was the shortest at 50 per cent available water

Among variety seed treatment combinations V_3T_1 and V_3T_2 were on par and recorded higher root lengths than the other combinations V_1T_0 recorded the least

The variety M 102 at 100 per cent available moisture with water treatment recorded the maximum root length of 23 50 cm

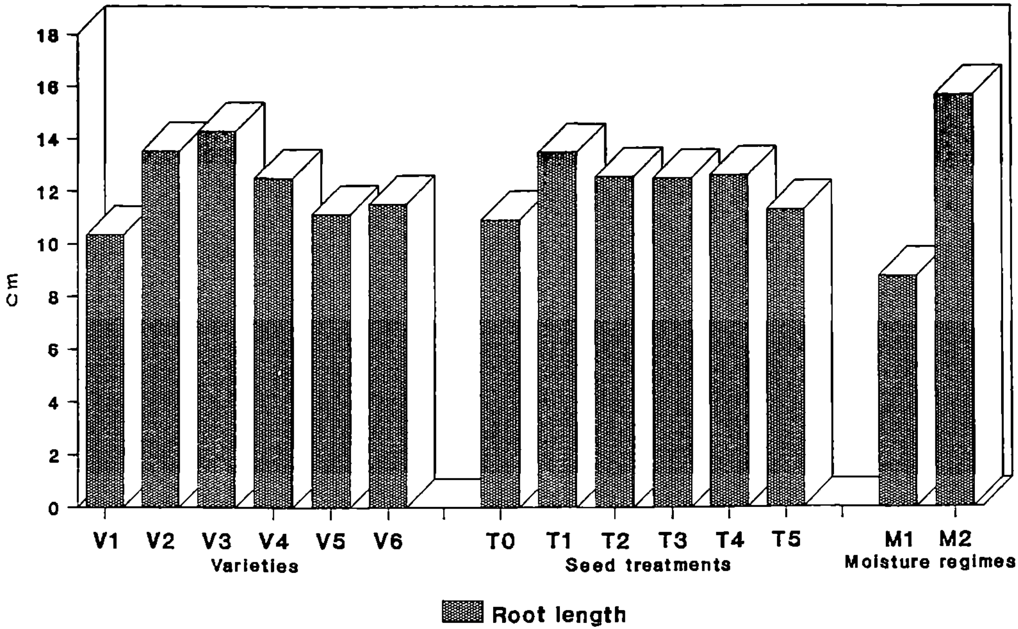

Fig 9 Root length (cm) as influenced by varieties, seed treatments and moisture regimes

Table 32 Interactıon effect of varıetıes and seed treatments on root volume (cm^3 pot^{-1}) and root shoot ratıo

Seed treatments / Varıetıes	T_0	T_1	T_2	T_3	T_4	T_5	Mean	T_0	T_1	T_2	T_3	T_4	T_5	Mean
	Root volume (cm^3 pot^{-1})							Root shoot ratıo						
V_1	9 50	13 00	11 00	11 50	13 00	10 50	11 42	0 38	0 50	0 54	0 47	0 39	0 52	0 46
V_2	10 50	11 75	12 75	12 00	11 75	10 50	11 54	0 29	0 27	0 25	0 28	0 27	0 25	0 27
V_3	10 50	13 25	11 75	9 75	13 00	10 25	11 42	0 30	0 33	0 32	0 30	0 37	0 32	0 32
V_4	9 50	12 00	12 50	9 75	12 25	10 00	11 00	0 25	0 42	0 36	0 28	0 35	0 33	0 33
V_5	6 25	9 00	7 50	7 73	8 50	7 50	7 75	0 33	0 38	0 39	0 34	0 37	0 35	0 36
V_6	7 25	10 75	10 50	9 75	12 50	7 25	9 67	0 28	0 29	0 33	0 33	0 38	0 30	0 32
Mean	8 92	11 63	11 00	10 08	11 83	9 33		0 30	0 36	0 36	0 33	0 36	0 34	
F	3 65**							2 22*						
SE	0 430							0 027						
CD	1 193							0 075						

** Sıgn f cant at 0 01 level   * S gnıfıcant at 0 05 level

4 3 4 2 Root length (Tables 29 30 and 31 Fig 9)

Root length varied among varieties and M-102 recorded the highest root length of 14 30 cm followed by Culture 4 Rasi and Tulasi The lowest root length of 10 34 cm was recorded by Jaya

Plants raised from seeds treated with different chemicals and water produced longer roots The longest roots (13 49 cm) were produced by water treatment followed by KCl triazole and NaH_2PO_4 treatments the latter three being on par

Increasing soil moisture level from 50 to 100 per cent available water had a favourable effect on root length

Root length varied with variety moisture interactions At 100 per cent M 102 produced the longest roots followed by Culture-4 and Tulasi However the root length of Jaya was the shortest at 50 per cent available water

Among variety seed treatment combinations V_3T_1 and V_3T_2 were on par and recorded higher root lengths than the other combinations V_1T_0 recorded the least

The variety M 102 at 100 per cent available moisture with water treatment recorded the maximum root length of 23 50 cm

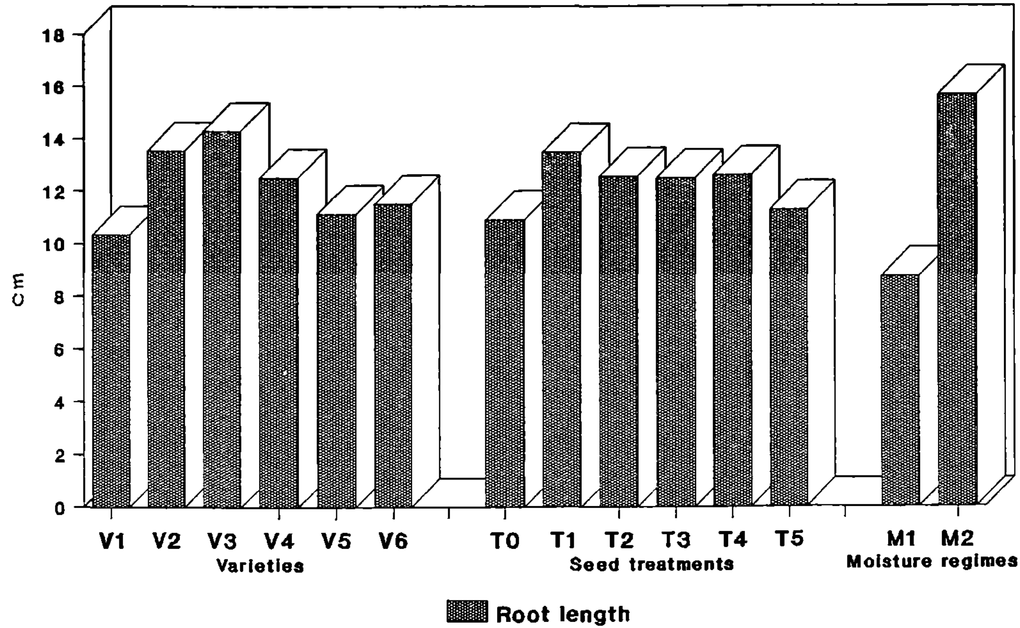

Fig 9 Root length (cm) as influenced by varieties, seed treatments and moisture regimes

4 3 4 3 Root volume (Tables 29 30 and 32)

The variety Culture 4 recorded maximum volume and was on par with Jaya and M 102 Ravi registered the lowest root volume of 7 75 cm^3 pot 1

Seed treatment caused an increase in root volume over control KCl and water treatment were on par and superior to other seed treatment methods

The moisture regime of 100 per cent available water produced more voluminous roots (14 97 cm^3 pot^{-1}) as against 5 96 cm^3 pot^{-1} produced at M_1 moisture level At M_2 level Culture 4 recorded the highest root volume Tulasi recorded the highest volume at M_1 level and all the other varieties were on par

Similarly seed treatment increased root volume both under 100 and 50 per cent available moisture levels though 100 per cent level recorded higher values In M_2 moisture regimes water and KCl treatments were on par and produced higher root volumes

Variety - seed treatment effect also caused variation in root volume Varieties Jaya Rasi and M-102 with KCl treatments produced more root volume compared to the other combinations

Table 32 Interaction effect of varieties and seed treatments on root volume (cm^3 pot^{-1}) and root shoot ratio

Seed treatments / Varieties	Root volume (cm^3 pot^{-1})							Root shoot ratio						
	T_0	T_1	T_2	T_3	T_4	T_5	Mean	T_0	T_1	T_2	T_3	T_4	T_5	Mean
V_1	9 50	13 00	11 00	11 50	13 00	10 50	11 42	0 38	0 50	0 54	0 47	0 39	0 52	0 46
V_2	10 50	11 75	12 75	12 00	11 75	10 50	11 54	0 29	0 27	0 25	0 28	0 27	0 25	0 27
V_3	10 50	13 25	11 75	9 75	13 00	10 25	11 42	0 30	0 33	0 32	0 30	0 37	0 32	0 32
V_4	9 50	12 00	12 50	9 75	12 25	10 00	11 00	0 25	0 42	0 36	0 28	0 35	0 33	0 33
V_5	6 25	9 00	7 50	7 73	8 50	7 50	7 75	0 33	0 38	0 39	0 34	0 37	0 35	0 36
V_6	7 25	10 75	10 50	9 75	12 50	7 25	9 67	0 28	0 29	0 33	0 33	0 38	0 30	0 32
Mean	8 92	11 63	11 00	10 08	11 83	9 33		0 30	0 36	0 36	0 33	0 36	0 34	
F	3 65**							2 22*						
SE	0 430							0 027						
CD	1 193							0 075						

** Significant at 0 01 level * Significant at 0 05 level

Among variety seed treatment - moisture interactions Jaya M 102 and Rasi with water treatment Culture 4 with triazole treatment and M-102 with KCl treatment were on par and recorded higher root volume than the other combinations under M_2 moisture regime At 50 per cent available water Tulasi with triazole KCl and water treatments registered higher root volume

4 3 4 5 Root spread (Tables 29 and 30)

The root spread of the varieties ranged from 2 38 cm to 2 85 cm Rasi recorded the maximum root spread and was on par with Jaya The minimum spread was recorded by M 102

Seed treatment caused an increase in root spread triazole treated plants recorded the maximum spread of 2 83 cm The root spread at M_1 and M_2 moisture regimes were 2 13 and 3 05 cm respectively

Variety moisture combinations had a profound effect on the root spread All varieties had larger root spread at 100 per cent available water Rasi at 100 per cent available water showed the maximum root spread of 3 58 cm

4 3 4 6 Root shoot ratio (Tables 29 30 and 32 Fig 10)

Root shoot ratio varied among varieties Jaya recorded maximum root shoot ratio of 0 46 followed by Ravi Rasi and Tulasi Culture 4 had the lowest ratio of 0 27

Seed treatment improved the root shoot ratio and all seed treatment methods recorded higher ratios compared to control Among seed treatments KCl triazole and water recorded the highest ratio of 0 36

The root shoot ratio at 100 per cent available water was lesser compared to that at 50 per cent

Variations was also observed in root shoot ratio as a result of variety - moisture interaction all varieties recording higher ratio at 50 per cent available water The highest ratio of 0 69 was registered by Jaya at 50 per cent available water and the lowest ratio was observed in Tulasi at 100 per cent available water

Among seed treatment moisture combinations water treatment at M_1 regime recorded the highest ratio (0 54) and this was on par with triazole KCl and cowdung treatments at the same moisture level At M_2 level all seed treatments were on par and the highest value was recorded in KCl seed treatment

Jaya with triazole treatment recorded maximum root shoot ratio and was on par with water and cowdung treatments

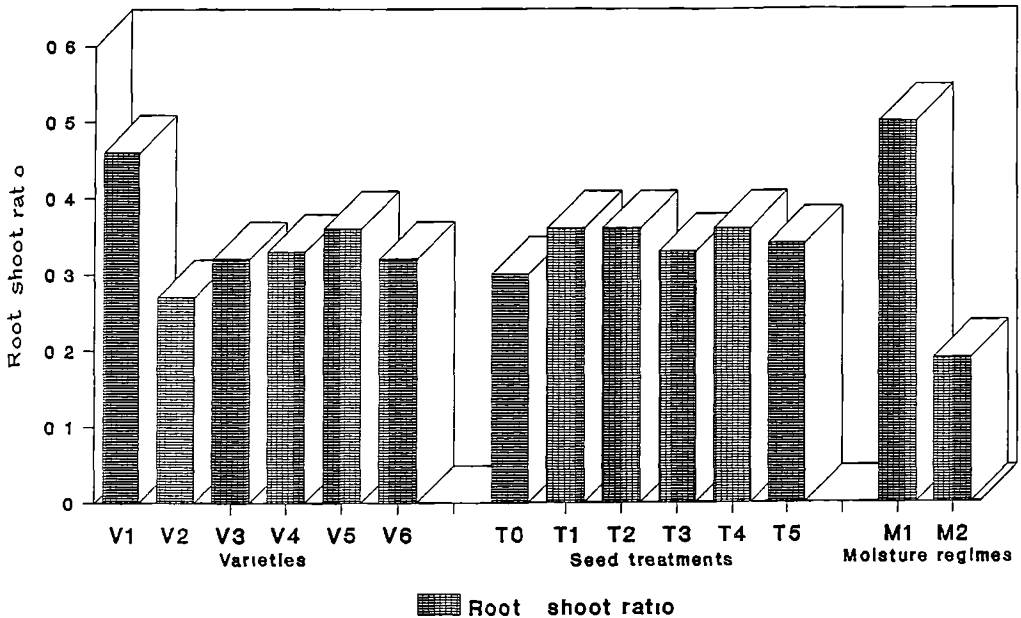

Fig 10 Root shoot ratio as influenced by varieties, seed treatments and moisture regimes

Jaya with triazole treatment had the maximum ratio at 50 per cent available water and this was on par with water and cowdung treatments at the same moisture level

4 3 5 <u>Nutrient uptake at harvest</u> (Tables 33 and 34)

Varieties differed significantly among themselves on the uptake of major nutrients at harvest Maximum uptake was recorded by Culture-4 and the lowest by Ravi Rasi Tulasi and M 102 were on par and followed Culture 4 with regard to N uptake Regarding P uptake Culture-4 was on par with Tulasi Rasi M-102 and Jaya In the case of uptake of K Culture 4 was on par with Tulasi and both of them were significantly superior to others

Seed treatment improved the uptake of the major nutrients Water treatment registered the highest uptake values for major nutrients Water and KCl treatments were on par with regard to N uptake Water treatment recorded the maximum P uptake followed by KCl triazole and NaH_2PO_4 treatments the latter three being on par Water KCl and triazole treatments were on par and superior to others on K uptake

Significant increase in nutrient uptake was observed by increasing soil moisture level from 50 to 100 per cent

Table 33 Effect of varieties seed treatments and moisture regimes on N P and K uptake (g pot^{-1}) at harvest

Treatments	N uptake (g pot^{-1})	P uptake (g pot^{-1})	K uptake (g pot^{-1})
Varieties			
V_1	29 80	4 05	41 16
V_2	35 28	4 33	46 13
V_3	32 18	3 95	37 51
V_4	32 85	3 90	39 47
V_5	26 52	3 24	31 93
V_6	32 57	4 28	43 51
F	14 78**	4 79**	9 45**
SE	0 789	0 182	1 641
CD	2 211	0 504	4 549
Seed treatments			
T_0	26 58	3 35	34 95
T_1	35 03	4 96	43 97
T_2	32 66	4 17	41 74
T_3	30 82	3 72	38 42
T_4	34 58	4 41	43 03
T_5	29 54	3 13	37 60
F	16 88**	14 77**	4 74**
SE	0 789	0 182	1 641
CD	2 211	0 504	4 549
Moisture regimes			
M_1	9 69	0 90	9 36
M_2	53 38	7 01	70 54
F	4661 99**	1758 09**	2160 12**
SE	0 461	0 105	0 947
CD	1 277	0 291	2 626

** Significant at 0 01 level

Nutrient uptake was influenced by variety - moisture interactions and all varieties recorded higher uptake values at 100 per cent available water Culture-4 at M_2 moisture regime recorded the highest uptake values of N P and K At 50 per cent moisture regime all varieties except Jaya were on par and recorded higher values for N whereas the varieties did not show any difference in P uptake at the same moisture level Regarding K uptake Culture 4 and Tulasi at 100 per cent available water were on par while all varieties except Jaya were on par at 50 per cent moisture regime

Seed treatment moisture interactions influenced the nutrient uptake Maximum uptake was recorded by water treatment at 100 per cent level of moisture and was followed by KCl and triazole treatments At 50 per cent available water all seed treatments were on par with control except in the case of N uptake where the treated plants gave higher uptake values than control

4 4 Experiment 1 c Field trial

4 4 1 Growth and growth characters

4 4 1 1 Plant height (Table 35)

Plant height varied among varieties at different growth stages At 20 and 40 DAS Culture-4 had maximum plant

Table 34 Interaction effect of varieties and moisture regimes and seed treatments and moisture regimes on N P and K uptake (g pot $^{-1}$) at harvest

Moisture regimes	N uptake (g pot $^{-1}$) M_1	N uptake (g pot $^{-1}$) M_2	P uptake (g pot $^{-1}$) M_1	P uptake (g pot $^{-1}$) M_2	K uptake (g pot $^{-1}$) M_1	K uptake (g pot $^{-1}$) M_2
Varieties						
V_1	7 15	52 45	0 75	7 35	7 75	74 56
V_2	10 55	60 02	1 01	7 64	10 58	81 69
V_3	9 13	55 23	0 90	7 00	9 14	65 89
V_4	11 06	54 64	0 93	6 88	9 49	69 45
V_5	9 19	43 86	0 76	5 72	7 98	55 89
V_6	11 05	54 08	1 06	7 49	11 25	75 76
Mean	9 69	53 38	0 90	7 01	9 36	70 54
F	10 06**		3 12**		6 51**	
SE	1 128		0 257		2 321	
CD	3 127		0 712		6 433	
Seed treatments						
T_0	7 55	45 60	0 66	6 04	7 69	62 21
T_1	10 91	59 16	1 04	8 88	10 06	77 87
T_2	9 57	55 74	0 87	7 46	9 66	73 83
T_3	9 68	51 96	0 95	6 50	9 53	67 32
T_4	11 24	57 93	1 10	7 72	10 90	75 15
T_5	9 18	49 90	0 79	5 48	8 33	66 87
Mean	9 69	53 38	0 90	7 01	9 36	70 54
F	6 41**		9 88**		2 41**	
SE	1 128		0 257		2 321	
CD	3 127		0 712		6 433	

** Signifcant at 0 01 level

height and was on par with Tulasi At 60 DAS Tulasi recorded maximum plant height of 59 17 cm Culture-4 and Rasi were on par At 80 DAS and harvest stage also Tulasi exhibited higher plant height and was on par with Rasi Culture 4 was found to have the lowest plant height

Different seed treatments were observed to influence plant height significantly Water treatment recorded maximum height followed by KCl treatment At 20 DAS all seed treatments were on par and superior to control whereas at 40 80 DAS and at harvest water treatment was found to influence the plant height to the maximum and it was on par with KCl treatment At 60 DAS all seed treatments except water treatment were on par with control After 40 DAS triazole treatment recorded the lowest height and was on par with control

4 4 1 2 Number of tillers hill^{1} (Tables 35 and 36)

The number of tillers hill^{1} did not vary significantly among varieties at 20 and 60 DAS Culture-4 recorded the highest tiller number at all growth stages except 40 DAS At 40 DAS Tulasi recorded maximum tiller number of 8 00 and was on par with Rasi

At all growth stages seed treatments improved tiller production except at 20 DAS Triazole treatment

Table 35 Effect of varieties and seed treatments on plant height (cm) and tiller number hill [1] at different intervals

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		Harvest	
	Height (cm)	Tille number	He ght (cm)	Tiller number	He ght (cm)	Tiller number	He ght (cm)	Tiller number	Height (cm)	T lle number
Va et es										
V_1	34 09	17	44 45	7 02	54 52	9 01	66 77	9 94	76 22	9 61
V_2	31 35	0 33	4 69	7 69	53 63	8 77	86 87	8 59	86 87	8 58
V_3	33 2	0 66	44 12	8 00	59 17	8 93	87 90	8 75	87 90	8 74
F	6 52**	0 72	6 40**	6 90**	11 73**	0 27	20 00**	10 11**	34 77**	5 92**
SE	0 548	0 129	0 595	0 192	0 868	0 240	0 843	0 232	1 096	0 228
CD	1 608	NS	1 745	0 562	2 546	NS	2 47	0 681	3 2 6	0 669
Seed treatments										
T_0	30 37	0 25	42 14	6 53	55 22	7 68	78 62	7 94	80 91	7 83
T_1	34 8	0 61	45 27	7 74	59 06	9 11	83 82	9 34	87 49	9 22
T_2	32 86	0 75	42 80	8 07	53 11	9 53	78 22	9 63	80 60	9 51
T_3	34 13	0 72	43 47	7 93	55 70	9 27	81 38	9 46	85 64	9 33
F	7 93**	2 37	3 83**	10 12**	6 03**	9 07**	7 23**	8 38**	7 39**	8 56**
SE	0 633	0 149	0 687	0 221	1 002	0 277	0 973	0 268	1 266	0 263
CD	857	NS	2 015	0 649	2 940	0 813	2 853	0 786	3 713	0 772

** Signif cant at 0 01 level NS Not S gnificant

Table 36 Interaction effect of varieties and seed treatments on tiller number $hill^{-1}$ at 40 and 60 DAS

	Seed treatments									
	40 DAS					60 DAS				
Varieties	T_0	T_1	T_2	T_3	Mean	T_0	T_1	T_2	T_3	Mean
V_1	5 00	7 50	7 57	8 00	7 02	6 50	9 93	9 60	10 00	9 01
V_2	7 50	7 87	7 93	7 47	7 69	8 40	8 60	9 40	8 67	8 77
V_3	7 10	7 87	8 70	8 33	8 00	8 13	8 80	9 60	9 27	8 93
Mean	6 53	7 74	8 07	7 93		7 68	9 11	9 53	9 29	
F	3 10*					2 56*				
SE	0 383					0 480				
CD	1 123					1 408				

* Significant at 0 05 level

recorded the highest number during all stages and was on par with KCl and water treatments

At 40 and 60 DAS variety - seed treatment interactions led to variation in tiller number At 40 DAS Tulasi with all seed treatments Rasi with water and triazole treatments and Culture 4 with KCl treatment were on par and significantly superior to others At 60 DAS all variety - seed treatment combinations were on par with regard to tiller number and significantly superior to control treatment of all varieties

4 4 1 3 Leaf area index at flowering (Table 37)

LAI recorded at flowering showed variation among varieties Rasi had the maximum of 5 73 and was on par with Tulasi

Seed treatment caused changes in LAI Water treatment recorded the highest value (6 19)

4 4 1 4 Dry matter production (Tables 37 and 38 Fig 11)

DMP varied among the varieties at different growth stages except at 20 DAS At 40 DAS Rasi produced maximum dry matter and was superior to Tulasi and Culture 4 From 40 DAS upto harvest Tulasi recorded the maximum DMP and was on

Table 37 Effect of varieties and seed treatments on LAI DMP (t ha^{-1}) and DMP ha^{-1} day^{-1} (kg)

Treatments	LAI at flowering	DMP t ha^{-1}					DMP ha^{-1} day^{-1} (kg)
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest	
Varieties							
V_1	5.50	0.36	0.61	1.95	2.73	5.94	49.50
V_2	5.73	0.39	0.78	2.80	4.88	6.18	63.68
V_3	5.68	0.38	0.74	2.90	5.03	6.36	65.57
F	4.39**	3.30	87.33**	140.96**	375.66**	5.60*	98.23**
SE	0.059	0.111	0.010	0.044	0.066	0.089	0.886
CD	0.179	NS	0.028	0.129	0.195	0.261	2.599
Seed treatments							
T_0	5.57	0.34	0.65	2.12	3.67	5.24	50.77
T_1	6.19	0.40	0.74	2.69	4.46	6.62	63.98
T_2	5.29	0.37	0.67	2.64	4.35	6.51	62.95
T_3	5.50	0.41	0.76	2.74	4.36	6.26	60.64
F	32.11**	6.94**	22.44**	31.68**	22.17**	37.56**	34.88**
SE	0.068	0.012	0.011	0.058	0.077	0.103	1.023
CD	0.200	0.036	0.032	0.149	0.225	0.301	3.001

* Significant at 0.05 level ** Significant at 0.01 level NS not significant

par with Rasi At all stages Culture-4 recorded the lowest dry matter accumulation

Seed treatment exerted a favourable influence on DMP During the entire growth phase the different seed treatments increased DMP over control At 20 60 and 80 DAS they were on par and superior to control At 40 DAS KCl and water treatments resulted in maximum DMP At harvest water treatment recorded the maximum DMP and was on par with triazole treatment

Variety seed treatment interactions had a significant influence on DMP at 60 DAS All seed treatment combination of Rasi and Tulasi were on par and superior to all treatment combinations of Culture 4 and control

4 4 1 5 Dry matter production ha^{-1} day^{1} (Table 37)

Varieties showed variation on production of dry matter ha^{1} day^{1} Tulasi recorded maximum value of 65 57 kg ha^{1} day^{1} and was on par with Rasi

Seed treatment significantly increased the DMP ha^{-1} day^{-1} over control Among seed treatments water and triazole treatments were on par and superior to KCl treatment

Table 38 Interaction effect of varieties and seed treatments on DMP (t ha^{-1}) at 60 DAS

Varieties	Seed treatments T_0	T_1	T_2	T_3	Mean
V_1	1 81	2 05	1 86	2 08	1 95
V_2	2 27	2 97	3 00	2 94	2 80
V_3	2 29	3 05	3 06	3 20	2 90
Mean	2 12	2 69	2 64	2 74	
F	4 16**				
SE	0 088				
CD	0 258				

** Significant at 0 01 level

4 4 2 Yield and yield attributes

4 4 2 1 Number of productive tillers hill^{-1} (Table 39)

Tulasi recorded maximum number of productive tillers and was on par with Rasi

Seed treatment imparted favourable influence on this character All seed treatment methods were on par and superior to control

4 4 2 2 Length of panicle (Table 39)

Culture-4 produced the longest panicles of 19 07 cm length and was on par with Tulasi Rasi had the lowest panicle length (18 25 cm)

All seed treatments were on par and produced longer panicles than control

4 4 2 3 Weight of panicle (Table 39)

The highest panicle weight (2 01 g) was recorded by Tulasi and superior to the other two varieties which were on par

All seed treatment methods were on par and superior to control

Table 39 Effect of varieties and seed treatments on yield attributes

	Number of productive tillers hill^{1}	Length of panicle (cm)	Weight of panicle (g)	No of grains panicle^{1}	No of filled grains panicle^{1}	No of unfilled grains panicle^{1}	Sterility %
Varieties							
V_1	5 23	19 08	1 76	76 93	72 92	4 01	5 34 (13 00)
V_2	6 13	18 25	1 83	77 35	73 58	3 78	5 02 (12 98)
V_3	6 14	19 07	2 01	79 72	76 17	3 63	4 70 (12 04)
F	31 31**	9 84**	6 05**	1 03	1 65	0 19	0 35 (0 47)
SE	0 094	0 152	0 053	1 480	1 335	0 44	2 007
CD	0 274	0 446	0 156	NS	NS	NS	NS
Seed treatments							
T_0	4 99	17 54	1 52	66 28	60 67	5 61	8 40 (15 16)
T_1	6 07	19 08	1 94	81 53	78 00	3 64	4 46 (11 20)
T_2	6 17	19 10	1 94	82 24	79 00	3 26	3 99 (11 17)
T_3	6 10	19 48	2 08	81 93	79 22	2 71	3 24 (10 33)
F	27 01**	23 82**	15 64**	20 92**	34 50**	6 20**	3 38 (5 77)*
SE	0 108	0 176	0 061	1 709	1 541	0 507	1 868
CD	0 317	0 515	0 180	5 013	4 520	1 488	3 875

* Significant at 0 05 level ** Significant at 0 01 level

NS Not Significant Figures in parantheses are transformed values

4 4 2 4 Number of grains panicle^{-1} (Table 39)

The varieties did not show any significant variation in the number of grains panicle^{-1} All seed treatments were on par and superior to control

4 4 2 5 Number of filled grains panicle^{-1} (Table 39)

The varieties did not vary significantly though Tulasi produced the maximum number

The different pre sowing treatments were on par and produced more number of filled grains than control

4 4 2 6 Number of unfilled grains panicle ^{1} (Table 39)

Culture 4 had maximum number of unfilled grains panicle ^{1} but varietal variation was not significant

All the seed treatment methods were effective in reducing the number of unfilled grains panicle ^{1} Of the treatments KCl treatment recorded the lowest number

4 4 2 7 Sterility percentage (Table 39)

Varieties showed no significant variation in sterility percentage Seed treatment significantly decreased the sterility percentage over control and all seed treatments were on par

4 4 2 8 Thousand grain weight (Table 40)

The variety Culture-4 registered the maximum 1000 grain weight followed by Tulasi and Rasi Seed treatment had no influence on this character

4 4 2 9 Grain yield (Table 40 Fig 11)

Grain yield differed significantly among the varieties and maximum yield of 3 00 t ha ^{1} was recorded by Rasi which was on par with Tulasi (2 97 t ha^{-1}) Culture-4 produced the lowest

All pre-sowing seed treatments were on par and improved grain yield significantly over control However the highest yield was obtained from water treatment

4 4 2 10 Straw yield (Table 40 Fig 11)

Varietal variation was not significant regarding straw yield though Tulasi produced the highest

As in the case of grain yield seed treatment increased straw yield over control Among seed treatments water treatment recorded the highest straw yield of 3 58 t ha ^{1} and was on par with triazole treatment

Table 40 Effect of varieties and seed treatments on 1000 grain weight (g) grain and straw yield (t ha^{-1}) and HI

Treatments	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	HI
Varieties				
V_1	30 81	2 65	3 29	0 45
V_2	25 67	3 00	3 18	0 49
V_3	28 06	2 97	3 40	0 47
F	118 10**	12 55**	3 29	8 99**
SE	0 237	0 054	0 062	0 006
CD	0 694	0 158	NS	0 018
Seed treatments				
T_0	27 59	2 43	2 81	0 46
T_1	28 59	3 05	3 58	0 46
T_2	28 41	3 01	3 50	0 46
T_3	28 12	2 99	3 27	0 48
F	2 56	22 26**	23 49	1 33
SE	0 273	0 062	0 072	0 007
CD	NS	0 182	0 211	NS

* Significant at 0 05 level ** Significant at 0 01 level

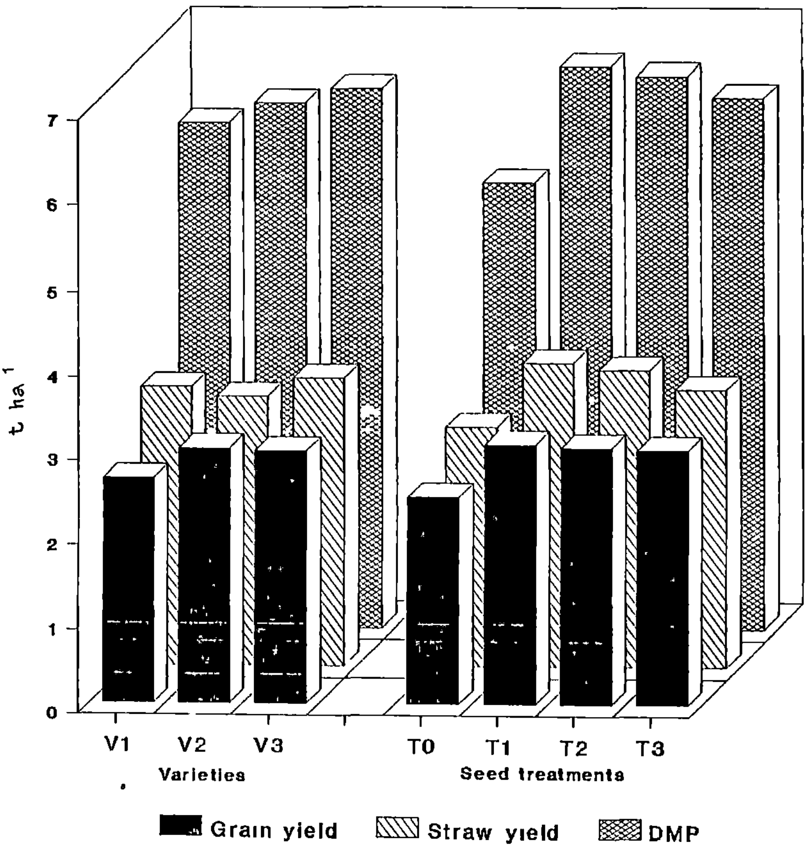

Fig 11 Grain yield, straw yield and DMP (t ha^{-1}) as influenced by varieties and seed treatments

4 4 2 11 Harvest index (Table 40)

The HI differed among varieties Maximum value of 0 49 was recorded by Rasi followed by Tulasi

Seed treatments had no influence on the HI

4 4 3 Physio-chemical parameters (Table 41)

4 4 3 1 Relative water content (RWC)

RWC recorded at flowering did not vary among the varieties Seed treatment methods were on par and recorded higher values over control

4 4 3 2 Total chlorophyll content

Total chlorophyll content at flowering differed among the varieties The highest content was observed in Rasi (2 51 mg g^{1} fresh weight) which was on par with Culture 4

An increase in chlorophyll content was observed due to seed treatment compared to control

4 4 3 3 Chlorophyll a content

The variety Rasi recorded maximum content of chlorophyll a (1 45 mg g^{1} fresh weight) followed by Culture 4 and Tulasi which were on par

Table 41   Effect of varieties and seed treatments on the physio-chemical parameters

Treatments	RWC (%)	Chlorophyll (mg g $^{-1}$ fresh wt) Total	a	b	Proline (µg g^{-1} fresh weight)	Grain protein (%)
Varieties						
V_1	81 01	2 13	1 21	0 92	1 39	6 90
V_2	81 24	2 51	1 45	1 07	1 25	6 96
V_3	81 09	2 02	1 17	0 81	1 54	6 91
F	0 03	4 22*	4 07*	2 52	1 48	0 04
SE	0 682	0 126	0 073	0 071	0 118	0 188
CD	NS	0 370	0 215	NS	NS	NS
Seed treatments						
T_0	78 19	2 06	1 27	0 79	1 39	6 83
T_1	81 49	2 23	1 29	0 94	1 61	7 14
T_2	83 22	2 28	1 22	1 05	1 27	7 02
T_3	81 56	2 30	1 32	0 99	1 31	6 69
F	7 18**	0 55	0 218	1 86	1 22	0 85
SE	0 787	0 146	0 085	0 082	0 137	0 217
CD	2 309	NS	NS	NS	NS	NS

* Significant at 0 05 level   ** Significant at 0 01 level

NS Not significant

Seed treatment showed no significant difference with regard to the content of chlorophyll a compared to control

4 4 3 4 Chlorophyll b content

Neither the varieties nor the seed treatments had a positive influence on the chlorophyll b content

4 4 3 5 Proline content

Proline content did not vary significantly among the varieties and seed treatments

4 4 3 6 Protein content of grains

Varieties seed treatments and their interactions had no significant influence on protein content of grains However the variety Rasi and seed treatment with water recorded higher protein content

4 4 4 <u>Root parameters</u> (Table 42 and 43)

4 4 4 1 Root length

Root length did not vary among the varieties at 20 40 DAS and at harvest though Rasi recorded the highest root length At 60 and 80 DAS varietal difference was observed and Culture 4 recorded the highest root length of 8 60 cm and 7 69 cm respectively This was followed by Rasi and Tulasi both being on par

Seed treatment caused an increase in root length over control at all stages At 40 DAS and 60 DAS all seed treatments were on par and significantly superior to control At 80 DAS and harvest triazole treatment recorded the highest root length followed by water and KCl treatments the latter being on par

4 4 4 2 Root shoot ratio

Root shoot ratio did not vary among the varieties at 20 and 40 DAS and at harvest At 60 DAS Culture 4 had the maximum root shoot ratio of 0 22 which was on par with Tulasi At 80 DAS Culture 4 recorded the highest ratio of 0 23

Changes in root shoot ratio was observed due to seed treatments During early growth stages (20 and 40 DAS) all seed treatments were on par and superior to control Triazole treatment recorded the highest ratio during all observations At 60 DAS the difference in root shoot ratio was not significant among seed treatments and control At advanced stages of crop growth (80 DAS and at harvest) KCl treatment recorded significantly lower ratios

Table 42 Effect of varieties and seed treatments on root length (cm) and root shoot ratio at different intervals

Treatments	Root length (cm)					Root shoot rat o				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Varieties										
V_1	7 01	8 06	8 60	7 69	6 15	0 25	0 32	0 22	0 23	0 08
V_2	7 31	8 13	7 13	6 64	6 64	0 25	0 29	0 12	0 08	0 08
V_3	7 10	7 49	6 79	6 35	6 38	0 26	0 32	0 18	0 07	0 07
F	0 25	26	754 20**	5 13*	0 72	0 58	0 76	20 05**	92 84**	0 56
SE	0 309	0 3 1	0 350	0 311	0 290	0 011	0 014	0 012	0 009	0 007
CD	NS	NS	1 028	0 911	NS	NS	NS	0 034	0 027	NS
Seed treatments										
T_0	6 38	6 76	6 32	5 64	4 93	0 20	0 23	0 15	0 12	0 06
T_1	7 48	8 55	7 39	7 06	6 28	0 25	0 31	0 17	0 13	0 08
T_2	7 31	8 10	8 57	8 40	8 29	0 29	0 36	0 20	0 15	0 12
T_3	7 39	8 17	7 75	6 47	6 06	0 27	0 33	0 17	0 10	0 04
F	2 04	4 76*	5 32**	10 45**	17 40**	8 66**	12 01**	2 63	4 27*	19 26**
SE	0 357	0 359	0 405	0 359	0 335	0 013	0 017	0 013	0 011	0 007
CD	NS	1 054	1 187	1 052	0 982	0 037	0 049	NS	0 031	0 023

* S gnificant at 0 05 level ** Sign f cant at 0 01 level NS Not S gnificant

Table 43   Interaction effect of varieties and seed treatments on root shoot ratio at harvest

Varieties	Seed treatments				
	T_0	T_1	T_2	T_3	Mean
V_1	0 04	0 09	0 14	0 04	0 08
V_2	0 09	0 06	0 12	0 04	0 08
V_3	0 06	0 08	0 10	0 03	0 07
Mean	0 06	0 08	0 12	0 04	
F	2 81*				
SE	0 014				
CD	0 040				

* Significant at 0 05 level

Variety seed treatment interactions caused variations in root shoot ratio at harvest stage The three varieties with triazole treatment were observed to be on par and recorded higher ratios than the other combinations

4 4 5 <u>Uptake of major nutrients at harvest</u> (Table 44)

Nutrient uptake at harvest was significantly influenced by varieties Tulasi recorded maximum uptake of major nutrients followed by Rasi and Culture 4 With regard to the uptake of N Tulasi (49 21 kg ha^{-1}) was on par with Rasi (48 93 kg ha^{-1}) P uptake did not vary much among the varieties tested Regarding K uptake Tulasi recorded significantly higher uptake values (104 39 kg ha^{-1})) than the other two varieties

Seed treatments increased nutrient uptake control recording the lowest Water and triazole treatments were on par with regard to the uptake of N and P K uptake values were on par among the seed treatments and superior to control

4 4 6 <u>Soil analysis after the experiment</u> (Table 44)

Available nutrient content of the soil was not influenced by varieties and seed treatments However in plots where hardened seeds were used the content of

Table 44 Effect of varieties and seed treatments on nutrient uptake (kg ha⁻¹) at harvest and available nutrient content of soil (kg ha⁻¹) after the experiment

Treatments	Nutrient uptake at harvest (kg ha⁻¹)			Available nutrient content of soil after the experiment (kg ha⁻¹)		
	N	P	K	N	P	K
Varieties						
V_1	44 90	12 72	76 18	292 46	31 42	140 83
V_2	48 93	13 27	88 29	287 64	30 92	124 17
V_3	49 21	13 75	104 39	294 77	29 42	109 17
F	3 58*	0 71	37 93**	0 10	0 54	3 12
SE	1 273	0 610	2 298	11 255	1 422	8 967
CD	3 735	NS	6 740	NS	NS	NS
Seed treatments						
T_0	39 35	10 11	70 33	309 57	32 67	151 11
T_1	52 04	14 85	98 80	284 52	29 89	117 78
T_2	51 67	15 10	96 39	284 12	30 11	115 56
T_3	47 67	12 92	92 96	288 26	29 67	114 44
F	16 07**	10 71**	24 30**	0 87	0 73	2 90
SE	1 470	0 705	2 654	12 996	1 642	10 354
CD	4 313	2 067	7 783	NS	NS	NS

* Significant at 0 05 level ** Significant at 0 01 level

NS Not significant

available N P and K were comparatively lower than in plots where non treated seeds were grown

4 4 7 <u>Economic analysis</u> (Table 45 Fig 12)

4 4 7 1 Net income ha $^{-1}$

Tulasi recorded the highest net income and was on par with Rasi Culture 4 gave the lowest net income

Pre sowing seed treatments significantly improved the net income All seed treatments were on par and had higher net income over control The maximum net income of Rs 4594 95 ha $^{-1}$ was registered by water treatment The net income from control was only Rs 1634 95 ha $^{-1}$

4 4 7 2 Benefit cost ratio

Tulasi recorded the highest benefit cost ratio and was on par with Rasi and superior to Culture 4

Seed hardening significantly improved the benefit cost ratio Seed treatment with water recorded the highest ratio (0 44) and was on par with triazole treatment Control plots gave the lowest ratio

Table 45 Effect of varieties and seed treatments on net income (Rs ha^{-1}) and benefit cost ratio

Treatments	Net income (Rs ha^{-1})	Benefit cost ratio
Varieties		
V_1	2845 92	0 27
V_2	4028 63	0 39
V_3	4126 33	0 41
F	10 81**	16 00**
SE	216 777	0 019
CD	635 808	0 056
Seed treatments		
T_0	1634 95	0 18
T_1	4594 95	0 44
T_2	4379 39	0 42
T_3	4058 56	0 39
F	30 07**	29 28**
SE	245 295	0 022
CD	734 167	0 064

Cost of cultivation excluding treatment - Rs 10302 ha^{-1}

Cost of cultivation including treatment - Rs 10427 ha^{-1}

Price of paddy - Rs 3 75 kg^{-1} Price of straw - Re 1 kg^{-1}

* Significant at 0 05 level ** Significant at 0 01 level

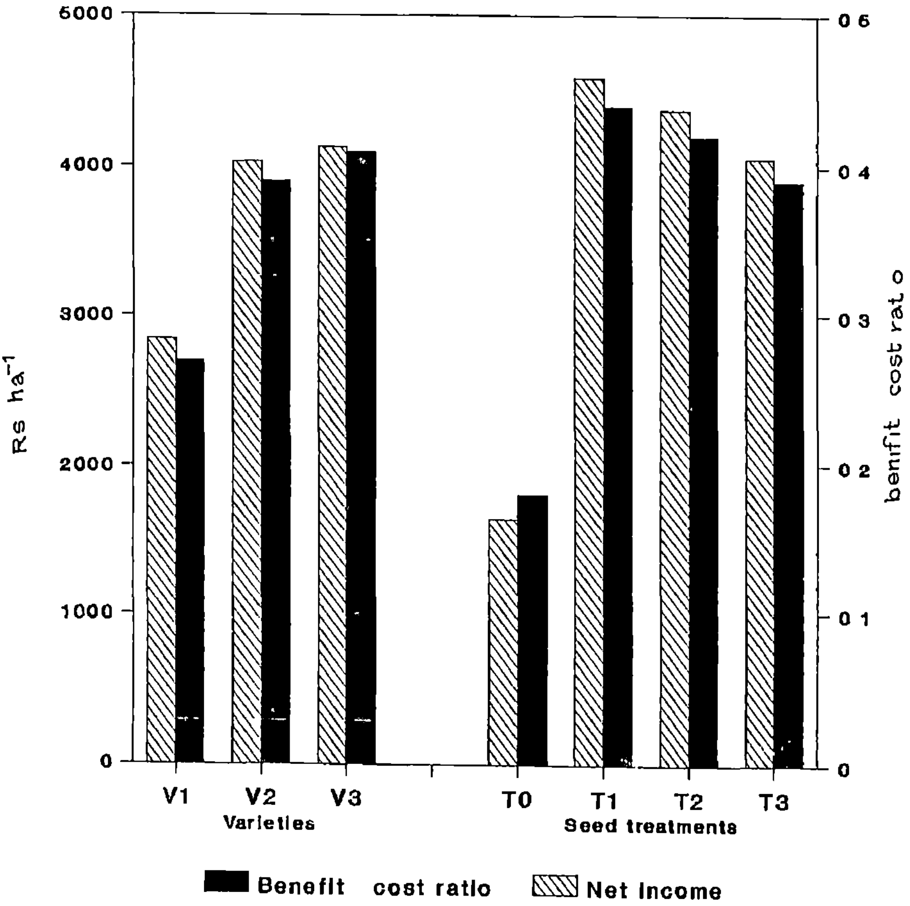

Fig 12 Influence of varieties and seed treatments on net income (Rs ha^{-1}) and benefit cost ratio

Table 46 Effect of varieties and nutrient levels on plant height (cm) at different intervals

T eatments	1991					1992				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Varieties										
V_1	21 57	63 93	83 67	90 71	95 82	28 16	44 60	53 73	65 11	74 06
V_2	25 77	65 80	86 67	91 57	94 97	26 80	47 18	57 27	63 24	72 38
V_3	24 24	75 81	99 84	104 29	106 07	27 96	48 58	65 78	81 34	90 00
V_4	21 4	59 22	89 91	101 03	101 08	23 31	43 71	63 24	81 24	84 11
V_5	24 06	66 80	81 97	88 34	88 34	32 72	49 07	83 09	86 22	86 16
V_6	23 11	61 24	91 49	98 53	98 53	27 67	44 00	63 89	81 36	85 11
F	4 92**	36 01**	14 07**	13 55**	11 38**	3 02**	5 58**	44 085**	76 20**	45 92**
SE	0 787	0 966	1 719	1 745	1 780	0 836	1 009	1 532	1 110	1 046
CD	2 260	2 774	4 936	5 010	5 111	2 401	2 897	4 398	3 187	3 002
Nutr ent levels										
F_1	23 69	67 59	93 04	99 67	101 43	30 55	48 28	68 38	79 51	85 68
F_2	23 35	66 37	89 24	95 13	96 80	26 78	46 02	65 50	75 58	80 71
F_3	22 91	62 45	84 48	92 44	94 17	25 98	44 27	59 62	74 18	79 52
F	0 50	15 44**	12 45**	8 77**	8 53**	17 01**	7 94**	16 97**	12 42**	9 52**
SE	0 557	0 683	1 216	1 234	1 259	0 591	0 714	1 083	0 785	0 739
CD	NS	1 961	3 490	3 543	3 614	1 698	2 048	3 110	2 254	2 123

* S gnificant at 0 05 level   ** S gn ficant at 0 01 level   NS Not s gnif cant

Table 47 Effect of varieties and nutrient levels on tiller number hill ^{1} at different intervals

Treatments	1991					1992				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Varieties										
V_1	2 18	4 67	7 38	7 87	6 63	1 73	6 27	7 48	7 84	7 42
V_2	2 87	6 47	8 38	8 60	7 26	2 22	7 31	8 37	8 59	7 71
V_3	2 47	5 56	7 33	7 20	7 16	2 16	6 80	7 31	6 60	6 22
V_4	1 64	5 08	8 93	8 23	8 13	1 46	7 31	8 60	8 20	8 10
V_5	2 13	4 76	5 00	4 74	4 74	1 10	7 47	7 49	6 99	6 92
V_6	2 42	4 91	9 04	8 46	8 34	1 80	7 04	8 38	8 07	7 96
F	3 55*	5 16**	12 16**	12 36**	12 82**	7 40**	4 61**	6 56**	16 16**	14 77**
SE	0 217	0 297	0 430	0 412	0 362	0 156	0 207	0 222	0 190	0 184
CD	0 623	0 853	1 235	1 182	1 039	0 448	0 593	0 638	0 545	0 529
Nutrient levels										
F_1	2 31	5 63	7 87	7 65	7 27	1 92	7 27	8 21	8 02	7 69
F_2	2 19	5 08	7 95	7 73	7 20	67	7 04	8 02	7 84	7 53
F_3	2 36	5 01	7 19	7 17	6 67	1 65	6 79	7 58	7 29	6 95
F	0 32	2 55	1 90	1 07	1 65	1 87	2 68	4 28*	8 00**	8 88**
SE	0 153	0 210	0 304	0 291	0 256	0 110	0 146	0 157	0 134	0 130
CD	NS	NS	NS	NS	NS	NS	NS	0 451	0 385	0 374

* Significant at 0 05 level ** S gnif cant at 0 01 level NS not s gnif cant

4 5 1 3 Leaf area index (Table 48)

LAI recorded at flowering showed significant variation among varieties during both the years Jaya attained maximum LAI of 6 32 in 1991 and was on par with M 102 During 1992 Culture 4 registered maximum LAI of 5 90 which was on par with M 102 Rasi and Tulasi

In both the years increased nutrient levels improved the LAI and F_1 recorded the highest

4 5 1 4 Dry matter production (Tables 48 and 49)

During 1991 varieties exhibited significant variation in DMP except at 20 DAS At 40 and 60 DAS Ravi accumulated more dry matter than other varieties At 80 DAS Rasi produced maximum dry matter and was on par with Tulasi and M 102 But at harvest stage Jaya was on par with Tulasi and significantly superior to others Ravi had the lowest DMP at harvest

During 1992 DMP was influenced by varieties except at 20 and 40 DAS At 60 DAS Ravi had the highest DMP followed by Tulasi Rasi and M 102 the latter three being on par Rasi had maximum DMP at 80 DAS and harvest stage though it was on par with M 102 at harvest stage

Table 48 Effect of varieties and nutrient levels on LAI and DMP (t ha $^{-1}$)

Treatments	LAI at flowering 1991	LAI at flowering 1992	DMP (t ha $^{-1}$) 1991 20 DAS	1991 40 DAS	1991 60 DAS	1991 80 DAS	1991 Harvest	1992 20 DAS	1992 40 DAS	1992 60 DAS	1992 80 DAS	1992 Harvest
Varieties												
V_1	6 32	4 41	0 15	1 01	2 36	5 06	10 24	0 31	0 57	1 48	2 35	5 97
V_2	5 40	5 90	0 16	0 87	2 37	4 22	8 98	0 30	0 55	1 47	2 29	6 00
V_3	5 94	5 81	0 14	0 90	2 71	8 27	9 47	0 35	0 58	1 66	3 75	6 60
V_4	5 37	5 70	0 16	0 92	3 98	8 47	9 47	0 31	0 57	1 67	5 21	6 72
V_5	5 28	5 09	0 15	2 21	5 17	6 08	6 49	0 32	0 68	3 27	4 17	4 86
V_6	5 45	5 77	0 14	0 95	3 89	8 47	10 02	0 34	0 59	1 90	4 71	6 32
F	2 87*	2 12**	27	95 24**	64 87** •	77 28**	43 72**	1 40	2 47	51 22**	125 88**	32 38**
SE	0 243	0 164	8 473	0 054	0 140	0 215	0 206	1 66	0 030	0 096	0 108	0 118
CD	0 696	0 471	NS	0 154	0 401	0 618	0 590	NS	NS	0 275	0 310	0 339
Nutrient levels												
F_1	6 60	6 05	0 15	1 25	3 65	7 12	10 10	0 35	0 64	2 03	4 11	6 66
F_2	5 54	5 23	0 15	1 54	3 48	6 88	9 24	0 32	0 59	2 02	3 87	6 28
F_3	4 74	4 56	0 14	1 03	3 11	6 29	8 00	0 30	0 54	1 68	3 26	5 30
F	29 73**	41 34**	1 43	8 51**	8 11**	7 86**	53 07**	4 65*	5 01*	8 75**	32 93**	71 14**
SE	0 172	0 116	5 991	0 038	0 099	0 152	0 145	0 112	0 02	0 068	0 076	0 084
CD	0 492	0 333	NS	0 109	0 284	0 437	0 4 7	0 034	0 061	0 194	0 219	0 240

* Significant at 0 05 level ** Significant at 0 01 level NS Not significant

DMP varied significantly at different levels of nutrients during both the years In 1991 F_2 level had maximum DMP at 40 DAS At 60 and 80 DAS F_1 and F_2 levels were on par and at harvest F_1 recorded the highest DMP During 1992 both F_1 and F_2 levels were on par at 20 40 and 60 DAS and after that F_1 became significantly superior to the others

During both the years difference in DMP was observed due to variety-nutrient interactions only at harvest During 1991 Jaya and M-102 at F_1 level and Tulasi at F_2 level were on par and had higher DMP than other combinations DMP was maximum for all varieties except Tulasi at F_1 level while Tulasi responded better at F_2 level During 1992 Rasi and M 102 at F_1 and F_2 levels Culture-4 Tulasi and Jaya at F_1 level were on par and significantly superior to others

4 5 1 5 Dry matter production ha^{-1} day^{1}

(Tables 50 and 51 Fig 13)

The variety Tulasi accumulated maximum dry matter ha^{1} day^{1} during 1991 (102 63 kg ha^{1} day^{1}) and was on par with Rasi In 1992 Rasi had the highest DMP ha^{1} day^{1} and was followed by Tulasi and M 102 the latter two being on par

Table 49 Interaction effect of varieties and nutrient levels on DMP (t ha^{1}) at harvest

Varieties \ Nutrient levels	1991 F$_1$	1991 F$_2$	1991 F$_3$	1991 Mean	1992 F$_1$	1992 F$_2$	1992 F$_3$	1992 Mean
V_1	11 84	10 10	8 78	10 24	6 73	6 18	5 00	5 97
V_2	10 21	9 09	7 64	8 98	6 94	6 08	4 97	6 00
V_3	10 99	9 21	8 22	9 47	7 04	6 70	6 05	6 60
V_4	10 16	9 88	8 37	9 47	7 21	7 24	5 72	6 72
V_5	7 38	6 11	5 99	6 49	5 12	4 87	4 58	4 86
V_6	10 03	11 06	8 98	10 02	6 94	6 58	5 45	6 32
Mean	10 10	9 24	8 00		6 66	6 28	5 30	
F	2 95**				2 19**			
SE	0 356				0 205			
CD	1 022				0 587			

** Significant at 0 01 level

Table 50 Effect of varieties and nutrient levels on DMP ha ^{1} day^{-1} (kg)

Treatments	1991	1992
Varieties		
V_1	85 33	49 75
V_2	74 82	49 98
V_3	90 21	62 84
V_4	97 65	69 31
V_5	74 36	53 96
V_6	102 63	65 19
F	35 85**	58 46**
SE	1 944	1 095
CD	5 581	3 143
Nutrient levels		
F_1	97 54	63 94
F_2	88 22	60 44
F_3	76 75	51 14
F	57 42**	73 10**
SE	1 375	0 774
CD	3 946	2 222

** Significant at 0 01 level

Table 51 Interaction effect of varieties and nutrient levels on DMP ha^{1} day^{1} during 1991

Nutrient levels / Varieties	F_1	F_2	F_3	Mean
V_1	98 63	84 17	73 19	85 33
V_2	85 11	75 72	63 64	74 83
V_3	104 70	87 68	78 26	90 21
V_4	104 78	101 85	86 32	97 65
V_5	88 67	67 89	66 52	74 36
V_6	103 37	111 99	92 54	102 63
Mean	97 54	88 22	76 75	

F	2 73*
SE	9 667
CD	3 367

* Significant at 0 05 level

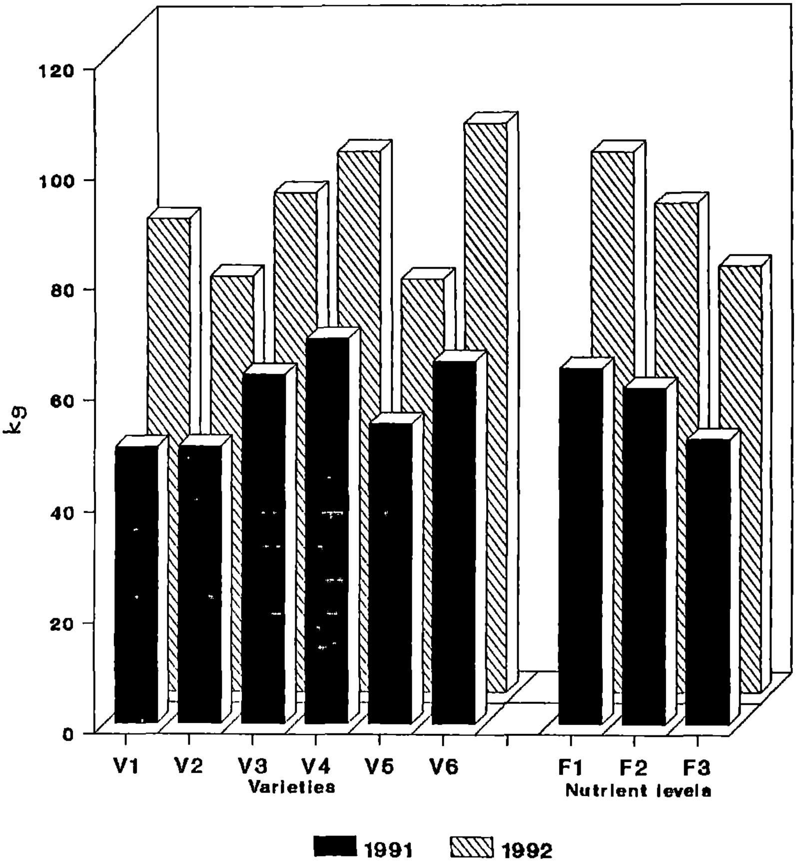

Fig 13 Influence of varieties and nutrient levels of DMP ha^{-1} day^{-1} (kg)

DMP ha ^{1} day ^{1} was significantly higher at F_1 level compared to lower levels

Variety nutrient interactions also influenced this during 1991 Tulasi at F_1 and F_2 levels Rasi and M-102 at F_1 level were on par and had more DMP ha ^{1} day^{-1} than the other combinations

4 5 2 Yield and yield attributes

4 5 2 1 Number of productive tillers hill^{-1} (Table 52)

Varietal difference was observed in the number of productive tillers hill ^{1} during both the years During 1991 Rasi recorded the highest number of productive tillers of 6 41 and was on par with Tulasi and Culture 4 In 1992 also Rasi and Tulasi were on par and recorded significantly higher number of productive tillers than other varieties In both the years M 102 recorded the lowest number of productive tillers hill ^{1} (3 88 and 4 14 respectively)

Nutrient levels had a significant influence on the number of productive tillers hill ^{1} only during the second year when F_1 and F_2 were on par and superior to F_3 level

4 5 2 2 Length of panicle (Table 52)

Varieties differed among themselves in earhead length during 1991 and 1992 The variety M-102 recorded the

Table 52 Effect of varieties and nutrient levels on productive tiller number length (cm) weight (g) and number of grains panicle^{-1}

Treatments	No of productive tillers hill^{-1} 1991	No of productive tillers hill^{-1} 1992	Length of panicle (cm) 1991	Length of panicle (cm) 1992	Wt of panicle (g) 1991	Wt of panicle (g) 1992	No of grains panicle^{-1} 1991	No of grains panicle^{-1} 1992
Varieties								
V_1	5 90	5 22	22 45	20 32	2 74	2 03	116 44	75 00
V_2	5 93	5 13	21 25	19 90	2 46	1 87	112 67	75 22
V_3	3 88	4 14	22 82	20 53	2 87	2 11	129 56	84 44
V_4	6 41	6 30	21 43	17 56	2 47	1 84	100 89	79 33
V_5	4 03	5 67	20 26	19 09	1 93	1 71	81 11	74 00
V_6	6 26	6 59	21 83	18 68	2 64	1 86	98 11	85 11
F	42 89**	21 57**	4 34**	12 94**	12 13**	4 51**	36 20**	8 56**
SE	0 174	0 191	0 439	0 314	0 094	0 068	2 896	1 690
CD	0 499	0 547	1 260	0 901	0 269	0 195	8 027	4 851
Nutrient levels								
F_1	5 56	5 81	21 75	19 65	2 70	2 06	112 72	80 06
F_2	5 38	5 72	21 84	19 84	2 61	2 06	104 94	81 57
F_3	5 27	4 99	21 44	18 55	2 25	1 60	101 72	74 94
F	1 40	11 29**	0 44	9 78**	13 00**	30 35**	8 18**	8 42**
SE	0 123	0 135	0 310	0 222	0 066	0 048	1 977	1 195
CD	NS	0 387	NS	0 637	0 191	0 138	5 676	3 430

* Significant at 0 05 level ** Significant at 0 01 level

maximum earhead length of 22 82 cm and 20 53 cm respectively During 1991 M 102 was on par with Tulasi and Jaya whereas it was on par with Jaya and Culture 4 during 1992

The three nutrient levels produced similar response in this aspect during 1991 and the variation was significant during 1992 only F_1 and F_2 levels were on par and recorded higher earhead lengths than F_3 level

4 5 2 3 Weight of panicle (Table 52)

During both the years varieties exhibited variation with regard to this character and M 102 recorded maximum panicle weight In 1991 M 102 was on par with Jaya and Tulasi whereas it was on par with Jaya during 1992 Ravi had the lowest panicle weight of 1 93 g and 1 71 g respectively during both the years

Panicle weight was significantly influenced by nutrient levels F_1 level recorded maximum panicle weight and was on par with F_2 level during both the years

4 5 2 4 Number of grains panicle ^{1} (Tables 52 and 53)

During 1991 M 102 had maximum number of grains panicle ^{1} followed by Jaya and Culture 4 In 1992 Tulasi registered maximum number of grains panicle^{-1} (85 11) and was on par with M 102 (84 44) During both the years Ravi recorded the lowest grain number of 81 11 and 74 00 respectively

Number of grains panicle^{-1} varied with nutrient levels F_1 level recorded maximum number of grains panicle^{-1} (112 72) during 1991 but it was on par with F_2 level in 1992

Differential responses were observed among varieties at different nutrient levels During 1991 maximum grain number was recorded by M-102 at F_1 level and better results were seen for Jaya and Culture 4 at this nutrient level No significant difference was observed among the three nutrient levels for Rasi Ravi and Tulasi In general F_1 level was found to produce better results in all varieties though the difference was not significantly higher than F_2 level During 1992 maximum grain number panicle ^{1} was observed in M-102 at F_2 level which was on par with Tulasi at F_1 and F_2 levels For all varieties except M 102 the response was similar at F_1 and F_2 levels However no significant difference was observed in Rasi at all the three nutrient levels

4 5 2 5 Number of filled grains panicle^{-1} (Tables 54 and 55)

Varieties exhibited variation on the number of filled grains panicle ^{1} during 1991 and 1992 In 1991

Table 53 Interaction effect of varieties and nutrient

Varieties \ Nutrient levels	1991 F$_1$	F$_2$	F$_3$	Mean
V$_1$	128 33	112 00	109 00	116 44
V$_2$	128 67	106 67	102 67	112 67
V$_3$	142 33	122 67	123 67	129 56
V$_4$	102 00	105 67	95 00	100 89
V$_5$	76 67	85 00	81 67	81 11
V$_6$	98 33	97 67	98 33	98 11
Mean	112 72	104 94	101 72	
F	2 41*			
SE	4 843			
CD	13 903			

* Significant at 0 05 level

levels on number of grains panicle [1]

1992			
F_1	F_2	F_3	Mean
82 00	74 33	68 67	75 00
80 33	77 67	67 67	75 22
76 67	93 67	83 00	84 44
79 00	80 00	79 00	79 33
74 33	75 33	72 33	74 00
88 00	88 33	79 00	85 11
80 06	81 57	74 94	
2 84*			
2 946			
8 401			

Jaya produced the highest number of filled grains panicle^{-1} and was on par with Culture 4 Tulasi recorded maximum number of filled grains and was on par with M-102 during 1992 Ravi produced the lowest number of filled grains panicle^{-1} during both the years

Nutrient levels had a significant influence on the number of filled grains panicle^{-1} In the first year the F_1 level produced more number of filled grains panicle^{-1} than the other two levels whereas it was on par with F_2 level during the second year

Variety - nutrient interactions had a significant effect on the number of filled grains panicle^{-1} During 1991 the varieties Rasi Ravi and Tulasi recorded no significant variation in the number of filled grains at the three nutrient levels Jaya Culture-4 and M 102 recorded highest response at F_1 level which was significantly superior to the other combinations In the second year the response was not the same as that of the first year M 102 at F_2 level produced maximum number of filled grains panicle^{-1} which was on par with Tulasi at F_1 and F_2 levels

4 5 2 6 Number of unfilled grains panicle^{-1} (Table 54)

Varieties showed significant variation on the number of unfilled grains panicle^{-1} only during 1991 though

Table 54 Effect of varieties and nutrient levels on the number of filled and unfilled grains panicle[1] sterility percentage and 1000 grain weight (g)

Treatments	Number of filled grains panicle[1] 1991	Number of filled grains panicle[1] 1992	Number of unfilled grains panicle[1] 1991	Number of unfilled grains panicle[1] 1992	Sterility (%) 1991	Sterility (%) 1992	1000 grain weight (g) 1991	1000 grain weight (g) 1992
Varieties								
V_1	100 44	70 78	16 00	4 22	13 86 (21 63)	5 77 (13 53)	29 40	30 45
V_2	96 22	70 22	16 44	5 00	14 78 (22 30)	6 82 (14 63)	30 64	29 88
V_3	93 56	79 00	23 33	5 44	18 00 (25 02)	6 54 (14 42)	28 77	31 13
V_4	86 78	74 89	14 11	4 44	13 98 (21 92)	5 59 (13 42)	24 32	25 98
V_5	70 00	69 22	11 56	4 78	14 35 (22 12)	6 54 (14 39)	28 15	27 38
V_6	88 00	80 44	11 22	4 67	11 40 (19 53)	5 69 (13 27)	25 77	27 45
F	21 78**	6 84**	15 13**	0 97	5 36**	0 75**	56 88**	20 25**
SE	2 289	1 831	1 140	0 437	0 935	0 605	3 134	4 562
CD	6 571	5 257	3 272	NS	3 893	NS	8 997	13 096
Nutrient levels								
F_1	95 06	76 78	15 72	3 28	13 97 (21 77)	4 13 (11 53)	28 48	29 65
F_2	89 67	77 22	14 44	4 33	13 58 (21 63)	5 35 (13 22)	27 60	29 42
F_3	82 78	68 28	16 17	6 67	15 64 (23 34)	9 00 (17 28)	27 45	27 07
F	14 46**	15 16**	1 23	31 51**	2 83	35 18**	6 34**	19 60**
SE	1 619	1 295	0 806	0 309	0 661	0 428	2 216	3 226
CD	4 647	3 717	NS	0 887	NS	3 581	6 362	9 260

** Significant at 0 01 level NS Not significant

Figures in parentheses are transformed values

Table 55 Interaction effect of varieties and nutrient levels on number of filled grains panicle ^{1}

Varieties \ Nutrient levels	1991				1992			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
V_1	113 33	96 00	92 00	100 44	78 33	70 67	63 33	70 78
V_2	112 67	93 67	82 33	96 22	77 00	72 67	61 00	70 22
V_3	105 67	92 33	82 67	93 56	72 67	88 67	75 67	79 00
V_4	87 00	91 67	81 67	86 78	76 33	75 67	72 67	74 89
V_5	64 67	73 67	71 67	70 00	71 33	71 33	65 00	69 22
V_6	87 00	90 67	86 33	88 00	85 00	84 33	72 00	80 44
Mean	95 06	89 67	82 78		76 78	77 22	68 28	
F	4 10**				2 29*			
SE	3 965				3 172			
CD	11 382				9 105			

* Significant at 0 05 level   ** Significant at 0 01 level

M 102 recorded the maximum number of unfilled grains during both the years In 1991 Culture-4 Jaya and Rasi were on par and followed M-102

At lower nutrient levels the number of unfilled grains increased During the first year the variation was not significant In the second year significant difference was noticed among the three nutrient levels and the lowest level recorded the maximum

4 5 2 7 Sterility percentage (Table 54)

Varietal variation was significant only during the first year All the varieties except Tulasi were on par Tulasi had the lowest percentage of sterile grains

Nutrient levels influenced the percentage of sterile grains only during the second year F_1 registered the lowest value and was on par with F_2

4 5 2 8 Thousand grain weight (Table 54)

Thousand grain weight varied among varieties during 1991 and 1992 In 1991 Culture 4 had the highest 1000 grain weight (30 64 g) which was followed by Jaya and M 102 the latter two being on par During 1992 M 102 registered maximum 1000 grain weight of 31 13 g which was on par with

Jaya and Culture 4 The lowest weight was recorded by Rasi during both the years

Higher nutrient levels significantly increased 1000 grain weight during both the years though F_1 and F_2 levels were on par during the second year

4 5 2 9 Grain yield (Table 56 and 57 Fig 14)

Grain yield showed significant varietal variation during both the years Jaya produced the highest grain yield of 4 70 t ha ^{1} during 1991 followed by Tulasi Culture 4 and Rasi the latter three being on par During 1992 Tulasi recorded maximum grain yield and was on par with M 102 and Rasi Ravi had the lowest grain yield of 2 67 and 2 16 t ha ^{1} during 1991 and 1992 respectively

During the first year the different nutrient levels did not cause any significant variation in grain yield while F_1 and F_2 levels were on par and significantly superior to F_3 during the second year

Variety - nutrient interactions revealed the following results during 1991 Maximum grain yield was recorded by Jaya at F_1 level which was on par with Tulasi at F_2 level The response of Ravi was similar at all nutrient levels The varieties did not show any significant difference in yield between F_2 and F_3 levels However

Culture 4 and M 102 produced the highest grain yield at F_1 level whereas the performance of Tulasi was the best at F_2 level

Pooled analysis of the two year data revealed that maximum grain yield (3 67 t ha^{-1}) was recorded by Jaya and this was on par with Tulasi (3 52 t ha ^{1}) and Rasi (3 34 t ha^{-1}) Ravi recorded the lowest yield

The F_1 and Γ_2 levels of nutrients were observed to be on par and superior to F_3 level with respect to grain yield The variety season interaction was observed to be significant and all varieties recorded higher grain yield during the first year when compared with that of the second year The grain yield recorded by Jaya and Tulasi during the first year were on par and significantly superior to the performance of the other varieties during both the years

4 5 2 10 Straw yield (Table 56 Fig 14)

Difference in straw yield was observed among varieties during 1991 and 1992 In the first year M 102 recorded maximum straw yield of 6 26 t ha ^{1} which was on par with Tulasi During the second year Rasi registered the highest straw yield and was on par with M 102 In both the years the lowest straw yield of 3 82 and 2 70 t ha^{-1} was obtained from Ravi

Table 56 Effect of varieties and nutrient levels on grain and straw yield (t ha ^{1}) and HI

Treatments	Grain yield (t ha ^{1})			Straw yield (t ha ^{1})			HI	
	1991	1992	Pooled	1991	1992	Pooled	1991	1992
Varieties								
V_1	4 70	2 63	3 67	5 48	3 31	4 39	0 46	0 44
V_2	4 02	2 55	3 29	4 96	3 45	4 21	0 45	0 42
V_3	3 21	2 92	3 06	6 26	3 69	4 98	0 34	0 44
V_4	3 84	2 84	3 34	5 36	3 88	4 76	0 41	0 42
V_5	2 67	2 16	2 41	3 82	2 70	3 26	0 42	0 46
V_6	4 11	2 92	3 52	5 91	3 40	4 65	0 41	0 48
F	27 13**	19 27**	14 05**	17 40**	17 05**	50 45**	8 71**	5 25**
SE	0 138	0 067	0 116	0 207	0 098	0 084	0 014	0 010
CD	0 396	0 192	0 334	0 595	0 281	0 243	0 042	0 029
Nutrient levels								
F_1	3 86	2 85	3 35	6 22	3 82	5 02	0 38	0 44
F_2	3 85	2 78	3 31	5 39	3 49	4 44	0 42	0 45
F_3	3 57	2 39	2 98	4 23	2 92	3 67	0 45	0 45
F	2 77	27 43**	6 01**	37 45**	43 32**	123 91**	11 39**	1 13
SE	0 097	0 047	0 082	0 146	0 069	0 060	0 010	0 007
CD	NS	0 136	0 236	0 420	0 199	0 172	0 029	NS

** Significant at 0 01 level

Table 57 Interaction effect of varieties and nutrient levels on grain yield (t ha $^{-1}$) during 1991

Varieties	Nutrient levels Γ_1	Γ_2	Γ_3	Mean
V_1	5 32	4 43	4 35	4 70
V_2	4 31	4 09	3 65	4 02
V_3	3 74	2 96	2 92	3 21
V_4	3 46	4 30	3 76	3 84
V_5	2 64	2 66	2 70	2 67
V_6	3 66	4 64	4 04	4 11
Mean	3 86	3 85	3 57	
F	3 08**			
SE	0 239			
CD	0 685			

** Significant at 0 01 level

Increased levels of nutrients improved straw yield in both the years of study The nutrient level of 100 per cent recommended dose produced maximum yield of straw (6 22 and 3 82 t ha^{-1} in 1991 and 1992 respectively) which was higher than the two lower levels

Varietal variation on straw yield was observed in the pooled analysis results M 102 registered maximum straw yield of 4 98 t ha^{1} which was on par with Rasi (4 76 t ha^{1}) Rasi and Tulasi were also on par and Ravi registered the lowest straw yield

The pooled analysis also revealed that the F_1 nutrient level recorded significantly higher straw yield compared to the other levels

The variety - season and nutrient level - season interactions also influenced straw yield M 102 recorded the highest straw yield during the first year Similarly F_1 level of nutrients recorded maximum straw yield during that year The different varieties and nutrient levels recorded higher straw yield during the first year compared to that of the second year

4 5 2 1 1 Harvest index (Table 56)

HI varied among varieties during both the years of study In 1991 Jaya recorded maximum HI of 0 46 which was

Total chlorophyll content increased with increase in nutrient levels

4 5 3 3 Chlorophyll a content

Chlorophyll a content varied among varieties During 1991 Culture 4 recorded the highest content of chlorophyll a (2 07 mg g^{1} fresh weight) and this was on par with Rasi and Jaya and superior to other varieties In 1992 Rasi recorded the highest content of chlorophyll a (1 34 mg g^{1} fresh weight) which was superior to Jaya and M-102 and on par with the other varieties M-102 had the lowest chlorophyll a content during both the years

During both the years plants with highest nutrient level had maximum content of chlorophyll a In 1991 the three levels differed significantly among themselves In 1992 F_1 level was significantly superior to other lower levels

4 5 3 4 Chlorophyll b content

Varietal variation was not observed in 1991 whereas in 1992 chlorophyll b content differed among the varieties Ravi recorded the highest content of chlorophyll b and was on par with Rasi Culture-4 and M 102

Table 60 Interaction effect of varieties and nutrient levels on N P and K uptake (kg ha^{-1}) at harvest

Nutrient levels	N uptake (1991) (kg ha^{-1})				P uptake (1991) (kg ha^{-1})				K uptake (1992) (kg ha^{-1})			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
Varieties												
V_1	89 94	69 51	59 35	72 93	48 56	36 03	24 20	36 26	91 19	84 73	53 68	76 53
V_2	73 08	64 70	49 65	62 48	35 12	28 50	19 38	27 67	97 95	80 20	48 48	75 54
V_3	68 43	56 34	47 58	57 45	33 38	23 03	19 91	25 44	102 51	82 60	72 83	85 98
V_4	74 00	71 41	52 18	65 86	29 52	26 75	23 88	26 72	103 49	99 33	72 56	91 79
V_5	63 38	44 32	37 88	48 53	24 73	16 74	16 25	19 24	74 95	66 22	61 11	67 43
V_6	68 84	76 83	57 18	67 62	33 41	30 56	23 71	29 23	101 78	90 92	69 70	87 46
Mean	72 94	63 85	50 64		34 12	26 94	21 22		95 31	84 00	63 06	
F	2 29*				2 55*				2 85*			
SE	3 663				2 267				4 184			
CD	10 515				6 508				12 013			

* Significant at 0 05 level

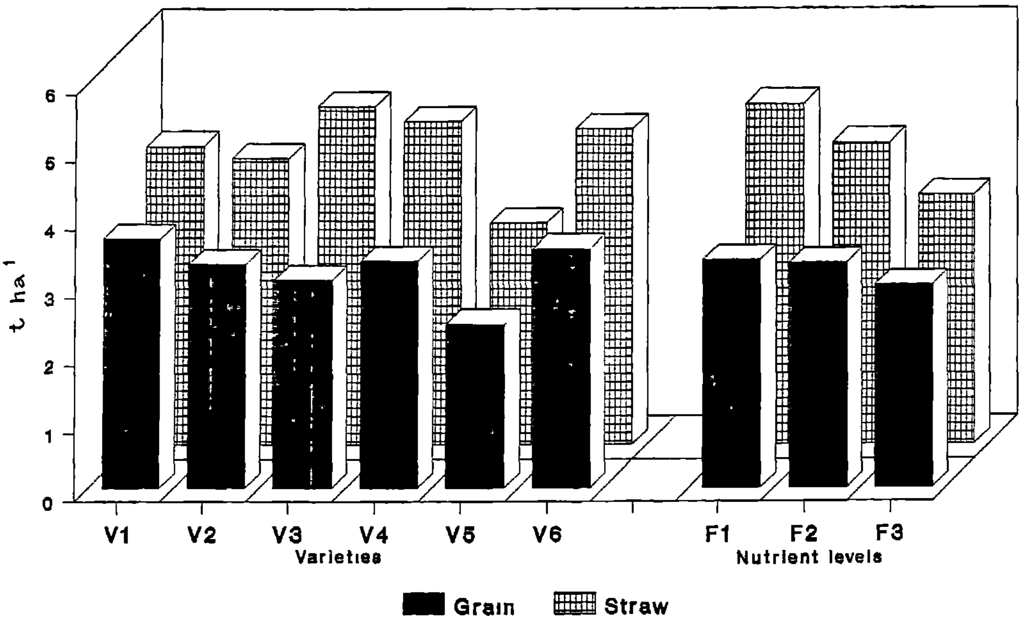

Fig 14 Influence of varieties and nutrient levels on grain and straw yield (pooled data in t ha^{-1})

on par with Culture 4 and Ravi During 1992 Tulasi registered the highest HI of 0 48 and was on par with Ravi

Increased nutrient levels significantly reduced the HI values during 1991 The nutrient level of 50 per cent of recommended dose produced highest HI values while the higher two levels were on par

4 5 3 <u>Physio chemical parameters</u> (Table 58)

4 5 3 1 Relative water content

Observations recorded at flowering revealed that RWC varied among varieties During both the years Tulasi Rasi and Ravi were on par and recorded higher RWC than the other varieties

During 1991 the nutrient levels of 100 and 75 per cent were on par and siperior to 50 per cent in RWC This variation was not significant during 1992

4 5 3 2 Total chlorophyll content

At flowering the total chlorophyll varied among the varieties During 1991 Culture 4 Rasi Tulasi and Jaya were on par and recorded higher content of total chlorophyll than the other two varieties Rasi had the maximum chlorophyll content of 2 37 mg g^{-1} fresh weight during 1992 and was on par with Ravi Culture 4 and Tulasi

Table 58 Effect of varieties and nutrient levels on the physio chemical parameters

Treatments	RWC (%)		Chlo ophyll (mg g [1] fresh weight) Total		a		b		Proline (µg g [1] fresh weight)		Protein (%)	
	1991	1992	991	1992	1991	1992	1991	1992	199	1992	1991	1992
Variet es												
V_1	87 26	77 60	2 63	1 81	1 87	1 04	0 76	0 76	1 00	1 32	6 65	6 12
V_2	84 50	78 82	2 85	2 16	2 07	1 23	0 77	0 93	0 81	1 45	6 54	6 37
V_3	85 65	81 20	2 31	1 91	1 56	1 03	0 74	0 88	0 72	1 69	6 05	6 35
V_4	89 45	88 03	2 75	2 37	1 93	1 34	0 82	1 03	0 90	1 56	6 67	7 29
V_5	88 70	86 40	2 27	2 33	1 72	1 29	0 55	1 04	0 76	1 13	6 62	6 89
V_6	90 86	87 29	2 67	2 12	1 77	1 33	0 90	0 79	1 09	1 43	6 54	6 78
F	3 71**	31 93**	5 01**	2 98*	4 84**	3 36*	2 39	3 17*	1 11	1 29	1 35	10 54**
SE	1 243	0 811	0 106	0 29	0 080	0 076	0 075	0 067	0 138	0 170	0 186	0 134
CD	3 568	2 327	0 304	0 370	0 230	0 218	NS	0 192	NS	NS	NS	0 384
Nutrient levels												
F_1	89 32	83 87	2 92	2 39	2 07	1 37	0 85	1 02	1 14	1 47	7 06	6 95
F_2	88 43	83 05	2 57	2 15	1 80	1 21	0 77	0 94	0 85	1 40	6 64	6 71
F_3	85 45	82 74	2 25	1 81	1 60	1 06	0 65	0 75	0 65	1 42	5 84	6 25
F	5 33**	03**	19 78**	10 36**	17 39**	8 38**	3 73*	8 73**	6 54**	0 09	22 36**	13 88**
SE	0 879	0 573	0 075	0 091	0 057	0 054	0 053	0 047	0 098	0 120	0 132	0 095
CD	2 523	NS	0 215	0 262	0 163	0 154	0 152	0 136	0 281	NS	0 378	0 271

* Significant at 0 05 level ** Significant at 0 01 level NS Not significant

Total chlorophyll content increased with increase in nutrient levels

4 5 3 3 Chlorophyll a content

Chlorophyll a content varied among varieties During 1991 Culture-4 recorded the highest content of chlorophyll a (2 07 mg g ^{1} fresh weight) and this was on par with Rasi and Jaya and superior to other varieties In 1992 Rasi recorded the highest content of chlorophyll a (1 34 mg g^{-1} fresh weight) which was superior to Jaya and M-102 and on par with the other varieties M-102 had the lowest chlorophyll a content during both the years

During both the years plants with highest nutrient level had maximum content of chlorophyll a In 1991 the three levels differed significantly among themselves In 1992 F_1 level was significantly superior to other lower levels

4 5 3 4 Chlorophyll b content

Varietal variation was not observed in 1991 whereas in 1992 chlorophyll b content differed among the varieties Ravi recorded the highest content of chlorophyll b and was on par with Rasi Culture 4 and M-102

During both the years application of different levels of nutrients brought about changes in chlorophyll b content F_1 and F_2 levels were on par and recorded higher content of chlorophyll b than the F_3 level

4 5 3 5 Proline content

Proline content recorded at flowering had no variation among varieties and nutrient levels in both the years However higher nutrient levels showed an increase in proline content Proline content was higher in 1992 than during 1991 though not significant

4 5 3 6 Protein content of grains

Varietal difference was not observed in the protein content of grains during 1991 However Rasi registered the highest content of 6 67 per cent During 1992 Rasi recorded significantly higher protein content than the other varieties followed by Ravi and Tulasi the latter two being on par Protein content significantly increased with increasing nutrient levels in both the years However 100 per cent recommended dose was on par with 75 per cent in 1992

4 5 4 Nutrient uptake at harvest

(Table 59 and 60 Fig 15 and 16)

4 5 4 1 N uptake

N uptake differed among varieties During 1991 Jaya recorded the highest N uptake (72 93 kg ha ^{1}) which was on par with Tulasi During 1992 Rasi Tulasi and M-102 were on par and recorded higher values than the other varieties In both the years Ravi recorded the lowest uptake values of 48 53 and 36 52 kg ha ^{1}

Increased N uptake was observed at higher nutrient levels F_1 recording the highest

During 1991 varieties showed variation in N uptake at different levels of nutrients Jaya at F_1 level recorded the highest uptake This was followed by Culture-4 M-102 Rasi and Tulasi at F_1 level and Tulasi Ras and Jaya at F_2 level which were all on par

4 5 4 2 P uptake

Varieties exhibited variation in P uptake In 1991 Jaya absorbed maximum P from soil followed by Tulasi Culture 4 and Rasi the latter three being on par During 1992 Tulasi registered the highest uptake value and was on par with M-102 and Rasi

Table 59 Effect of varieties and nutrient levels on the uptake of N P and K (kg ha [1]) at harvest

Treatments	N uptake (kg ha [1])		P uptake (kg ha [1])		K uptake (kg ha [1])	
	1991	1992	1991	1992	1991	1992
Varieties						
V_1	72 93	41 22	36 26	12 09	97 92	76 53
V_2	62 48	42 11	27 67	12 23	86 48	75 54
V_3	57 45	46 57	25 44	13 71	95 67	85 98
V_4	65 86	50 19	26 72	12 84	92 54	91 79
V_5	48 53	36 52	19 24	9 15	62 05	67 43
V_6	67 62	47 77	29 23	14 10	95 37	87 46
F	16 42**	14 93**	17 85**	10 95**	9 42**	14 28**
SE	2 115	1 301	1 309	0 531	4 389	2 416
CD	6 071	3 736	3 757	1 526	12 601	6 935
Nutrient levels						
F_1	72 94	51 73	34 12	15 27	114 88	95 31
F_2	63 85	45 37	26 94	12 65	88 20	84 00
F_3	50 64	35 10	21 22	9 14	61 95	63 06
F	52 29**	83 13**	48 79**	66 99**	72 71**	91 75**
SE	1 495	0 920	0 925	0 376	3 104	1 708
CD	4 293	2 642	2 657	1 079	8 910	4 904

** Significant at 0 01 level

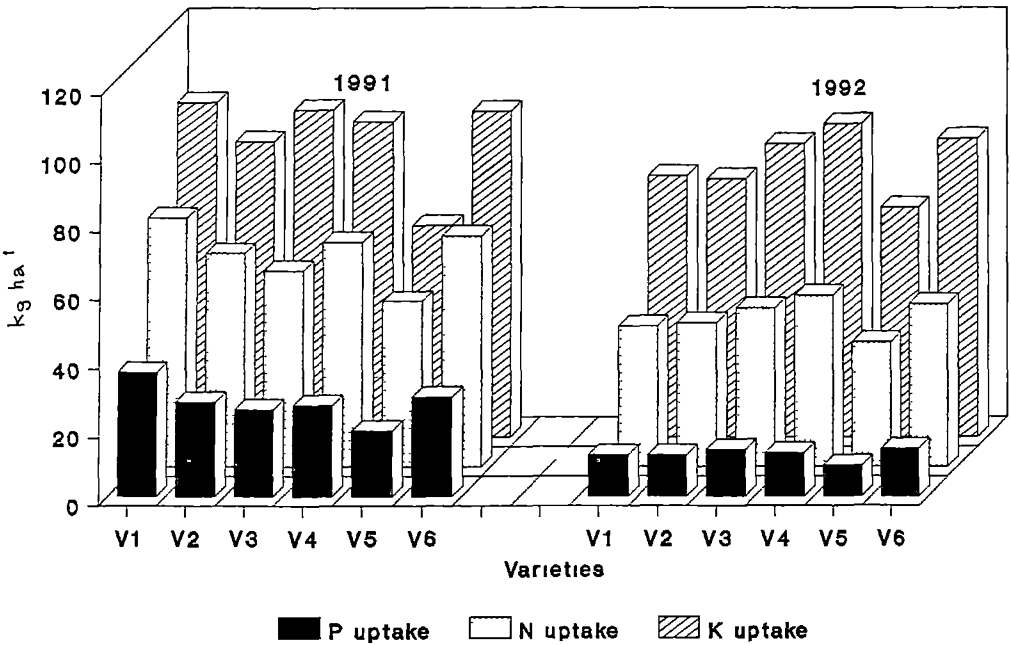

Fig 15 Influence of varieties on the uptake of major nutrients (kg ha^{-1})

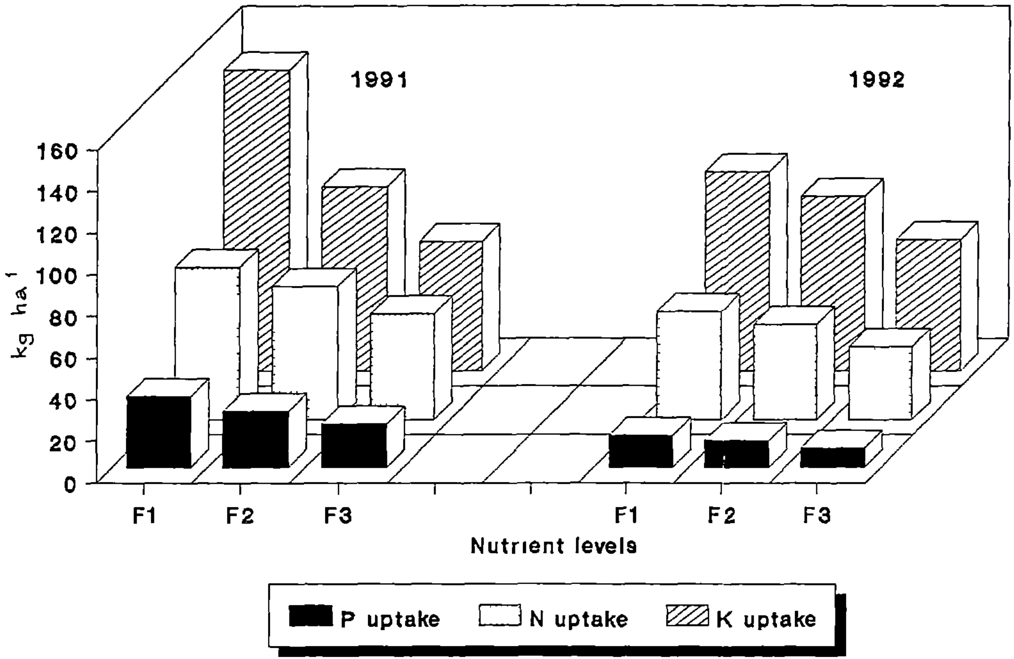

Fig 16 Influence of nutrient levels on the uptake of major nutrients (kg ha^{-1})

During both the years increasing the nutrient level from 50 to 100 per cent of recommended dose increased the uptake of P

As in N uptake variety-nutrient interaction influenced P uptake only during 1991 Jaya with 100 per cent recommended dose had the highest uptake value and Ravi at 50 per cent recommended dose registered the lowest

4 5 4 3 K uptake

Difference was observed among varieties on the uptake of K In 1991 all varieties except Ravi were on par Jaya had the highest uptake value of 97 92 kg ha^{-1} During 1992 Rasi registered the highest uptake (91 79 kg ha^{-1}) and was observed to be on par with Tulasi and M-102

Increase in K uptake was noticed with increase in nutrient levels During 1991 and 1992 F_1 level recorded the highest uptake values of 114 88 and 95 31 kg ha^{-1} respectively and was superior to the other levels

As far as the variety - nutrient interactions were concerned Rasi at F_1 and F_2 levels M 102 Tulasi and Culture-4 at F_1 level were on par and recorded higher uptake values than others during 1992 Ravi at F_3 level had the lowest uptake of K (61 11 kg ha^{-1})

The relationship between nutrient uptake and yield was worked out for the six varieties during 1991 and 1992 using the following linear regression equation

$Y - b_0 + b_1 N + b_2 P + b_3 K$ where

Y = yield

The results are presented in Table 61 During 1991 the R^2 values were significant for Jaya M-102 and Rasi While during 1992 all varieties showed significant R^2 values The highest R^2 value (0 94) was recorded by Rasi during the first year During the second year all varieties had more than 75 per cent R^2 values

Table 61 Summary results of regression analysis of nutrient uptake and yield

Varieties		Equation	F	R^2(%)
Jaya	1991	Y = 2 355615 + 0 0262N + 0 0265P - 0 00543K	8 82*	84 11
	1992	Y = 1 288289 - 0 0033N + 0 0829P + 0 0062K	6 30*	79 07
Culture-4	1991	Y = 2 319146 + 0 0153N + 0 0527P - 0 0082K	4 36	72 34
	1992	Y = 1 060315 + 0 0150N + 0 0554P + 0 0024K	7 61*	82 03
M-102	1991	Y = 1 620447 + 0 0073N + 0 0728P - 0 0072K	5 74*	77 50
	1992	Y = 3 008658 + 0 0247N + 0 0825P - 0 0276K	5 88*	77 93
Rasi	1991	Y = 3 11376 + 0 0457N - 0 0264P - 0 0171K	26 33**	94 05
	1992	Y = 1 567161 - 0 0003N - 0 0008P + 0 0141K	11 49*	87 34
Ravi	1991	Y = 2 748472 0 0100N + 0 0186P + 0 0008K	0 52	23 85
	1992	Y = 0 7741041 + 0 0166N - 0 0013P + 0 0117K	11 68*	87 51
Tulasi	1991	Y = 1 977712 + 0 0470N + 0 0375P - 0 0225K	2 04	55 08
	1992	Y = 1 679592 + 0 0513N + 0 0623P - 0 0238K	5 43*	76 50

* Significant at 0 05 level ** Significant at 0 01 level

4 5 5 Soil analysis after the experiment (Table 62)

Soil samples analysed after the experiment to assess the available nutrient status of the soil revealed the following

4 5 5 1 Available N content in soil

Varietal difference was not seen in the available N content of soil However nutrient level influenced the available N content and the content was higher in plots receiving F_1 level in both the years Fertilizing with 50 per cent recommended dose recorded the lowest content

4 5 5 2 Available P content in soil

Available P content in the soil was not influenced due to varieties

Increased nutrient level enhanced the P content of soil after the experiment During 1991 plots receiving F_1 nutrient level recorded the highest available soil P (48 28 kg ha^{-1}) followed by F_2 and F_3 During 1992 also F_1 level recorded significantly higher soil P value (34 56 kg ha^{-1}) than F_2 and F_3 levels

Table 62 Effect of varieties and nutrient levels on available N P and K content (kg ha ^{1}) of soil after the experiment

Treatments	Available N (kg ha ^{1})		Available P (kg ha ^{1})		Available K (kg ha^{-1})	
	1991	1992	1991	1992	1991	1992
Varieties						
V_1	281 56	284 12	40 67	33 33	110 89	107 22
V_2	264 29	274 69	44 00	30 44	119 44	111 00
V_3	283 82	260 23	44 22	31 78	117 33	117 78
V_4	262 39	257 29	45 44	30 67	122 22	107 33
V_5	258 42	275 55	47 11	30 89	136 11	123 33
V_6	257 03	268 32	42 22	32 22	108 89	114 44
F	1 51	1 24	2 46	0 347	1 93	0 421
SE	9 559	9 083	1 457	1 879	7 003	9 737
CD	NS	NS	NS	NS	NS	NS
Nutrient levels						
F_1	296 11	315 83	48 28	34 56	157 78	138 61
F_2	269 68	261 60	43 61	30 67	109 22	110 28
F_3	237 97	232 68	39 94	29 44	90 44	91 67
F	18 55**	43 19**	16 44**	4 03*	49 23**	11 79**
SE	6 760	6 423	1 030	1 329	4 952	6 885
CD	19 405	18 438	2 957	3 815	14 217	19 767

* Significant at 0 05 level ** Significant at 0 01 level

NS Not significant

4 5 5 3 Available K content in soil

In 1991 and 1992 available K content of soil was not influenced by varieties However plots with Ravi recorded the highest content of available K

Nutrient levels imparted a favourable influence in available K in the soil Plots receiving F_1 nutrient level recorded the highest content of available K after the experiment during both the years During 1992 plots fertilized with 75 and 50 per cent of the recommended dose were on par

4 5 6 <u>Economic analysis</u>

(Tables 63 64 and 65 Fig 17 and 18)

4 5 6 1 Net income ha ^{1}

The net income ha ^{1} differed among varieties During 1991 Jaya recorded the highest net income and was superior to other varieties Tulasi Rasi and Culture 4 were on par and followed Jaya During the second year maximum net income of Rs 4370 39 ha ^{1} was obtained from Culture 4 and it was on par with M 102 Rasi and Tulasi

Nutrient levels had a favourable influence on the net income obtained During both the years the nutrient levels of 100 and 75 per cent of the recommended dose were on par and produced higher net income than 50 per cent

Table 63 Effect of varieties and nutrient levels on net income (Rs ha^{-1}) and benefit cost ratio

Treatments	Net income (Rs ha^{-1})			Benefit cost ratio		
	1991	1992	pooled	1991	1992	pooled
Varieties						
V_1	11632 89	2863 44	7248 17	1 13	0 28	0 70
V_2	8720 67	4370 39	6545 53	0 84	0 42	0 63
V_3	7189 00	4329 22	5759 11	0 70	0 42	0 56
V_4	8766 78	4227 61	6497 20	0 85	0 41	0 63
V_5	2841 78	384 06	1612 92	0 28	0 04	0 16
V_6	9985 67	4059 83	7022 75	0 97	0 39	0 68
F	42 76**	44 68**	20 34**	42 04**	44 23**	67 65**
SE	460 309	234 677	0 045	0 045	0 023	0 025
CD	1321 48	673 724	1320 523	0 129	0 066	0 071
Nutrient levels						
F_1	9157 89	3943 17	6550 53	0 87	0 37	0 62
F_2	8549 94	3950 75	6250 35	0 83	0 38	0 61
F_3	6860 56	2223 36	4541 96	0 68	0 22	0 45
F	13 37**	35 96**	10 77**	9 76**	30 89**	28 73**
SE	325 488	165 942	457 27	0 032	0 016	0 018
CD	934 427	476 395	933 75	0 091	0 047	0 050
Season S_1			8189 46			
S_2			3372 43			
F			159 68			
SE			373 36			
CD			762 404			

Cost of cultivation excluding treatment - Rs 10 302 ha^{-1}
Price of paddy = Rs 3 75 kg^{-1} Price of straw - Re 1 kg^{-1}

Cost of inputs
- Nitrogen = Rs 5 45 kg^{-1}
- Phosphorus = Rs 7 80 kg^{-1}
- Potassium = Rs 3 33 kg^{-1}

** Significant at 0 01 level

Variety nutrient interactions caused variation in net income only during 1991 Jaya with 100 per cent of recommended dose and Tulasi with 75 per cent of recommended dose were on par and had higher net returns over other combinations Ravi with 75 per cent recommended dose registered the lowest net income

Pooled analysis of the two year data revealed that Jaya recorded the maximum net income ha^{-1} and was on par with Tulasi Culture 4 and Rasi Similarly 100 and 75 per cent of the recommended dose were on par

The net income ha^{-1} also varied due to the variety season interaction Jaya recorded maximum net return ha^{-1} and was on par with Tulasi during the first year Tulasi was again on par with Rasi and Culture-4 during the same year All varieties recorded higher net income during the first year compared to second year

4 5 6 2 Benefit cost ratio

Benefit cost ratio varied among varieties during both the years During 1991 Jaya recorded the highest ratio and was followed by Tulasi and Ravi the latter two being on par In 1992 Culture 4 M 102 Rasi and Tulasi were on par and had higher benefit cost ratio than the other two

Table 64   Interaction effect of varieties and nutrient levels on net income (Rs ha -1) during 1991

Varieties	Nutrient levels F1	F2	F3	Mean
V_1	14410 67	10881 33	9606 67	11632 89
V_2	10450 57	9001 33	6710 00	8720 67
V_3	9805 67	6313 00	5448 33	7189 00
V_4	8275 67	10319 67	7705 00	8766 78
V_5	3382 33	2458 00	2685 00	2841 78
V_6	8622 33	12326 33	9008 33	9985 67
Mean	9157 89	8549 94	6860 56	
F	4 04**			
SE	797 279			
CD	2288 870			

** Significant at 0 01 level

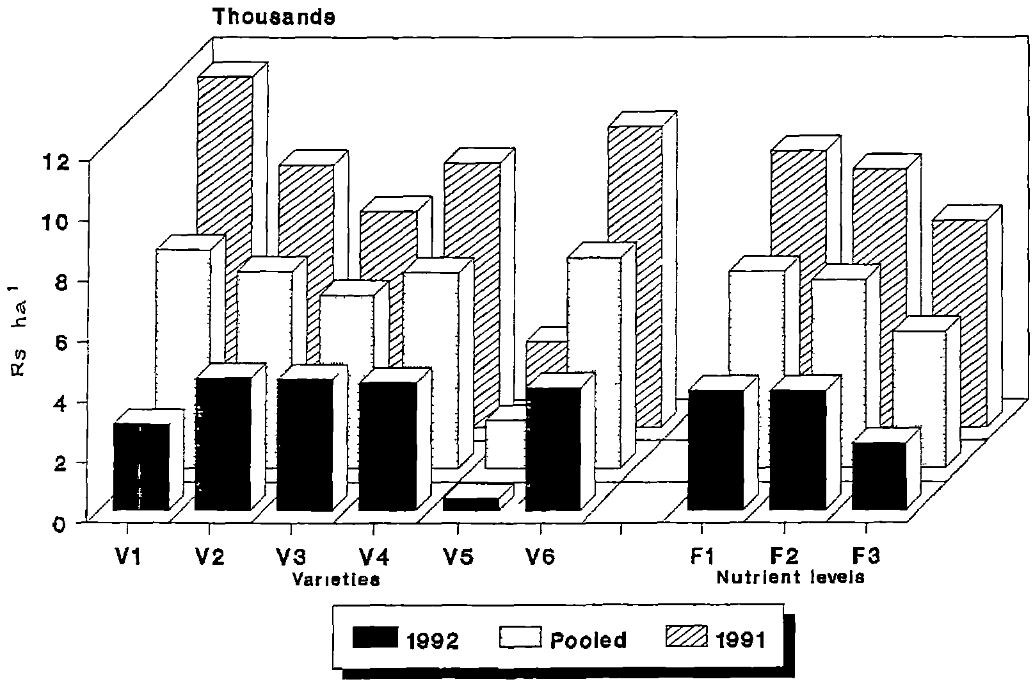

Fig 17 Influence of varieties and nutrient levels on net income (Rs ha^{-1})

Table 65 Interaction effect of varieties and nutrient levels on the benefit cost ratio during 1991

Varieties	Nutrient levels F_1	F_2	F_3	Mean
V_1	1 37	1 06	0 95	1 13
V_2	0 99	0 87	0 67	0 84
V_3	0 93	0 61	0 54	0 70
V_4	0 78	1 00	0 76	0 85
V_5	0 33	0 24	0 27	0 28
V_6	0 82	1 19	0 90	0 97
Mean	0 87	0 83	0 68	

F	3 85**
SE	0 078
CD	0 223

** Significant 0 01 level

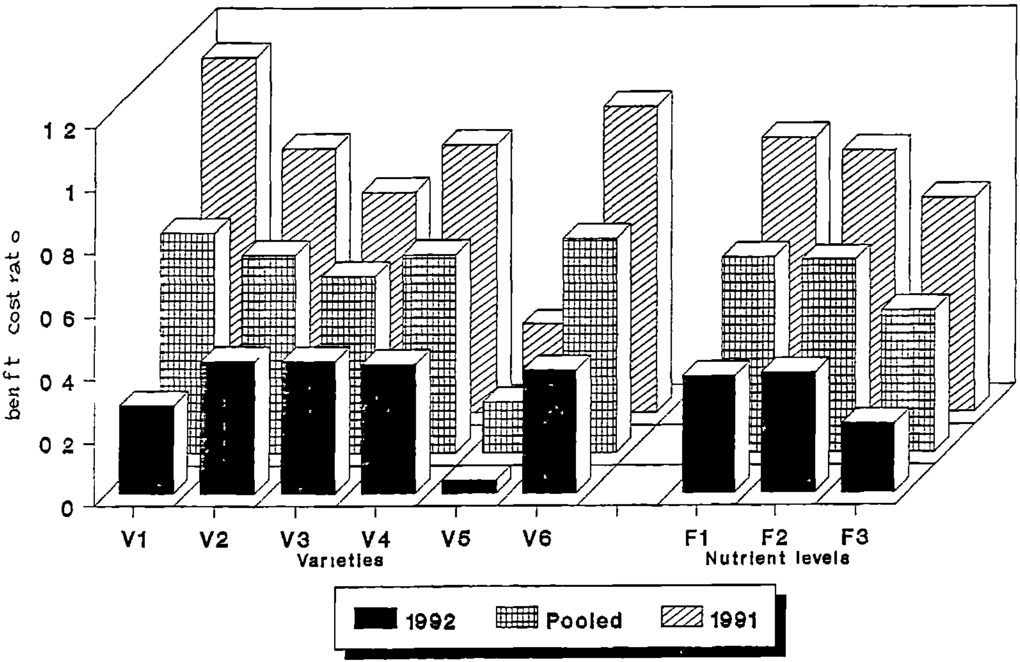

Fig 18 Influence of varieties and nutrient levels on benefit cost ratio

varieties Pooled analysis revealed that Jaya Tulasi Rasi and Culture 4 were on par and superior to M-102 and Ravi

During both the years F_1 and F_2 levels were observed to be on par This was again confirmed by pooled analysis

Among the interactions V_1F_1 and V_6F_2 were on par and superior to the others during the first year Pooled analysis also revealed the same result

4 6 Correlation studies

4 6 1 Experiment 1

(Tables 66 67 68 and 69 Fig 19 and 20)

The results of correlation studies revealed that germination percentage root length and vigour index had significant positive correlations with grain yield

Grain yield was significantly correlated with the yield attributes like number of productive tillers panicle weight 1000 grain weight and number of grains panicle $^{-1}$ Growth characters like plant height tiller number and leaf area also had positive influence on grain yield Among the physio chemical parameters proline accumulation and chlorophyll a content significantly influenced grain yield Root parameters also had significant positive correlation

Table 66 Simple correlation values between grain yield and other important parameters (Experiment 1 b)

Parameters	Correlation values with grain yield
Germination %	0 3790**
Root length	0 4583**
Shoot length	-0 0195
Vigour index	0 3677**
Plant height	0 7531**
Tiller number	0 5603**
Total biomass production	-0 0552
Leaf area hill^{-1}	0 8525**
No of productive tillers	0 5595**
Panicle length	0 1967
Panicle weight	0 4792**
No of grains panicle ^{1}	0 5228**
No of filled grains panicle^{-1}	0 1357
No of unfilled grains panicle^{-1}	-0 1826
1000 grain weight	0 4756**
RWC (%)	0 1141
Total chlorophyll	0 0028
Chlorophyll a	0 3159**
Chlorophyll b	0 1062
Proline	0 5553**
Stomatal frequency	-0 1934
Stomatal index	0 1375
Root weight	0 4625**
Root length	0 6521**
Root volume	0 4059**
Root spread	0 1631
Root shoot ratio	0 9139**
N uptake	0 6669**
P uptake	0 7241**
K uptake	0 3895

** Significant at 0 01 level

with yield and among the parameters root shoot ratio had the highest correlation value (0 9139) followed by root length (0 6521)

Results of the subsequent field experiment indicated that grain yield was highly correlated with the number of productive tillers number of filled grains panicle^{-1} total DMP and N P and K uptake Among the physio chemical parameters highest correlation with grain yield was by RWC In the case of straw yield also total tiller count DMP RWC N P and K uptake showed significant positive correlation Root length showed higher correlation values with grain and straw yield than root shoot ratio

Direct and indirect effect of drought parameters on grain yield

The parameters showing significant positive correlation with grain yield viz chlorophyll a proline root weight root length root volume and root shoot ratio were identified and the cause and effect relationship of yield with these parameters were investigated by applying path analysis The results presented in Table 68 revealed that root shoot ratio had maximum direct influence (1 3253) on grain yield This parameter also had the highest correlation value with grain yield (0 9139) Among the other parameters chlorophyll a and root volume had positive

Table 67 Simple correlation values of important parameters with grain and straw yield (Experiment 1 c)

Parameters	Correlation values with grain yield	Correlation values with straw yield
Plant height	0 4447**	0 2082
Tiller number	0 2312	0 5697**
D M P	0 8885**	0 9000**
D M P ha 1 day 1	0 8681**	0 5923**
LAI	0 2927	0 09664
Number of productive tillers	0 8025**	0 5311**
Panicle weight	0 5025**	0 4786**
Panicle length	0 4800**	0 5761**
Number of grains panicle 1	0 6049**	0 6082**
Number of filled grains panicle^{-1}	0 6635**	0 6540**
Number of unfilled grains panicle^{-1}	0 5613	0 4791
Sterility (%)	-0 6498	-0 5889
1000 grain weight	0 2195	0 3130
Grain yield	1 0000	0 6009**
Straw yield	0 6009**	1 0000
Total chlorophyll	0 2673**	-0 0566
Chlorophyll a	0 1345	-0 1983
Chlorophyll b	0 3319**	0 0992
Proline	0 0511	0 0612
RWC	0 4965**	0 5759**
Protein content of grains	0 1349	0 2296
N uptake	0 7808**	0 7766**
P uptake	0 7054**	0 7054**
K uptake	0 8007**	0 7153**
Root length	0 3206**	0 4839**
Root shoot ratio	0 0631	0 3600

** Significant at 0 01 level

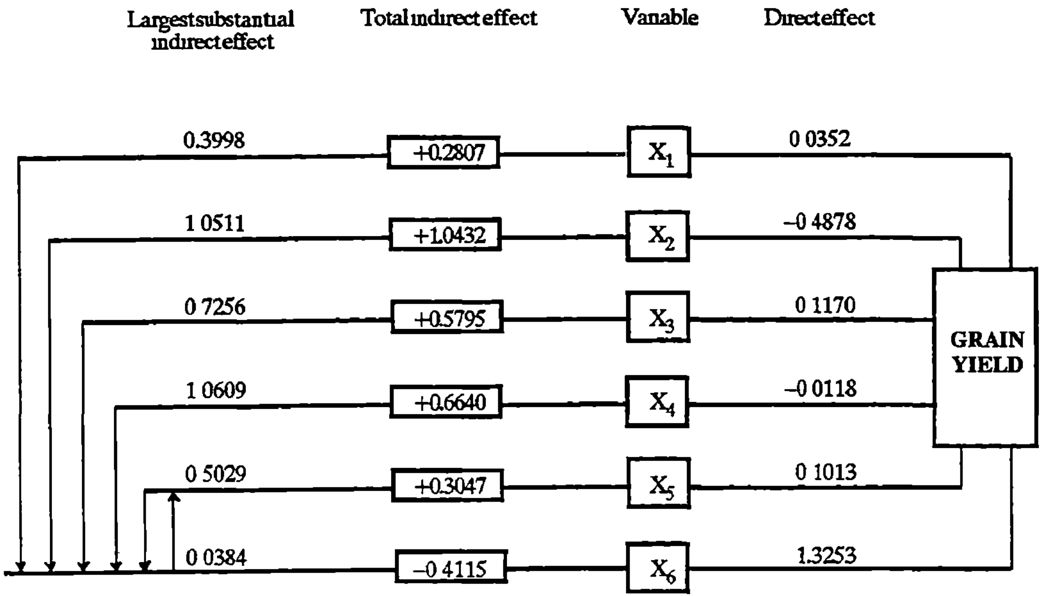

Fig. 19 Path analysis of drought parameters on grain yield

Table 68 Direct and indirect effect of drought parameters on grain yield

Variable		Direct effect	Indirect effect +	Indirect effect −	Total correlation	Maximum indirect effect +	Maximum indirect effect −
Chlorophyll a	X_1	0 0352	0 4037	0 123	0 3159**	0 3998(X_6)	0 0829(X_2)
Proline	X_2	-0 4878	1 0928	0 0496	0 5553**	1 0511(X_6)	0 0406(X_3)
Root weight	X_3	0 1170	0 7567	0 1772	0 4625**	0 7256(X_6)	0 1694(X_2)
Root length	X_4	-0 0118	1 1116	0 4476	0 6521**	1 0609(X_6)	0 3705(X_2)
Root volume	X_5	0 1013	0 5043	0 1996	0 4059**	0 5029(X_6)	0 1717(X_2)
Root shoot ratio	X_6	1 3253	0 049	0 4605	0 9139	0 0384(X_5)	0 3869(X_2)

Residue - 0 26

Table 69 Direct and indirect effect of drought parameters on straw yield

Variable		Direct effect	Indirect effect +	Indirect effect −	Total correlation	Maximum indirect effect +	Maximum indirect effect −
Proline	X_1	0 2945	0 1233	0 1823	0 2356**	0 1056(X_4)	0 1182(X_5)
Root length	X_2	0 0595	0 3565	0 1059	0 1910	0 2237(X_1)	0 0701(X_5)
Root weight	X_3	0 0544	0 1746	0 0517	0 0684	0 1023(X_1)	0 0392(X_2)
Root volume	X_4	0 3000	0 1122	0 0625	0 3497**	0 1037(X_1)	0 0288(X_5)
Root spread	X_5	0 1335	0 3357	0 0364	0 1658	0 2609(X_1)	0 0313(X_2)
Root shoot ratio	X_6	0 0224	0 3474	0 1370	0 2328**	0 2336(X_1)	0 0596(X_5)

Residue 0 93

** Significant at 0 01 level

direct effect while others had negative direct effect Root length followed by proline accumulation had maximum indirect influence on grain yield through root shoot ratio Root length had negative direct effect on grain yield though it had a high correlation value of 0 6521

The residue of the analysis was only 26 per cent

Direct and indirect effect of drought parameters on straw yield

Though path analysis was done using the parameters showing positive correlation with straw yield it was observed that the parameters could influence straw yield only up to seven per cent Among the parameters proline accumulation root volume and root shoot ratio had positive direct effect Maximum indirect influence on straw yield through proline accumulation was due to root length followed by root spread

4 6 2 Experiment 2 (Table 70)

Significant positive correlations between grain yield and number of productive tillers panicle weight number of grains panicle ^{1} number of filled grains panicle ^{1} DMP N P and K uptake were observed during both

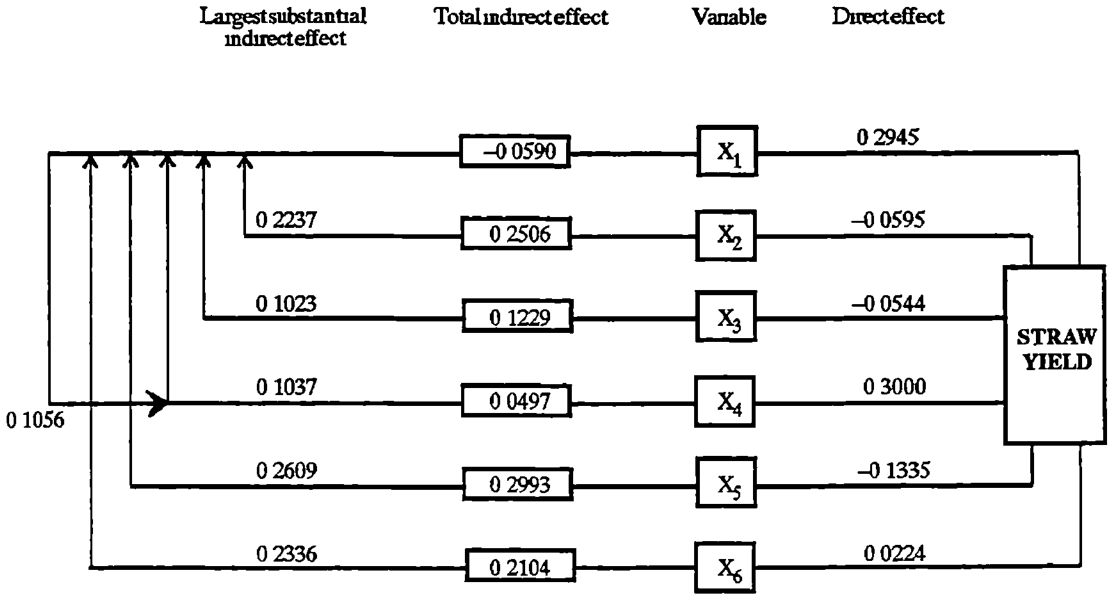

Fig. 20 Path analysis of drought parameters on straw yield

Table 70 Simple correlation values of important parameters with grain and straw yield (Experiment 2)

Parameters	Correlation values with grain yield 1991	grain yield 1992	straw yield 1991	straw yield 1992
Plant height at harvest	0 1833	0 2360*	0 6417**	0 2010
Tiller count at harvest	0 3435**	0 2121	0 5248**	0 3462**
DMP	0 7212**	0 8786**	0 8827**	0 9542**
DMP ha^{-1} day ^{1}	0 3943**	0 7319**	0 8385**	0 7584**
Number of productive tillers	0 6174**	0 2885**	0 2226*	0 2308*
Panicle length	0 3827**	0 1730	0 4387**	0 1872
Panicle weight	0 5341**	0 5396**	0 6198**	0 5206**
1000 grain weight	0 0722	0 2839**	0 0511	0 2619*
Number of grains panicle ^{1}	0 4465**	0 6676**	0 5234**	0 4159**
Number of filled grains panicle^{-1}	0 6960**	0 7046**	0 5143**	0 4971**
Number of unfilled grains panicle ^{1}	0 0169	0 3716	0 2366*	0 4879
Straw yield	0 3135**	0 6995**	1 0000	1 0000
Grain yield	1 0000	1 0000	0 3135**	0 6995**
N uptake	0 6888**	0 7980**	0 6887**	0 8551**
P uptake	0 7173**	0 7850**	0 6251**	0 7814**
K uptake	0 3473**	0 7758**	0 8496**	0 8806**
Soil N	0 1891	0 2422*	0 4738**	0 5000**
Soil P	0 0418	0 2562*	0 2628*	0 1977
Soil K	0 0768	0 2084	0 3386**	0 3379**

* Significant at 0 05 level ** Significant at 0 01 level

the years Similarly tiller count DMP N P and K uptake showed significant positive correlation with straw yield during both the years

Among the yield attributes maximum correlation was recorded between the number of filled grains and grain yield followed by the total number of grains panicle^{-1} and panicle weight Productive tiller number hill^{-1} had significant positive correlation with grain yield during both the years though the correlation coefficient was higher during the first year

DISCUSSION

5 DISCUSSION

With a view to find ways and means to enhance rice production from rainfed areas the present investigation was undertaken to identify a suitable rice variety for Southern Kerala to assess the nutrient level for maximum production and to evaluate the effect of seed hardening methods under such conditions

5 1 Experiment 1

5 1 1 Germination studies

Pre-sowing seed hardening with different concentrations of KCl water triazole NaH_2PO_4 and cowdung extract significantly improved the germination percentage Seed hardening induces early emergence of seeds (Keller and Black 1968) possibly due to longer embryos resulting from cell division during hardening The hardened seed is able to imbibe more water for germination thus enhancing the germination percentage Improvement in germination could be attributed to the reduction in time lag for pre germinative metabolic activity which it had already undergone during the hardening process as reported by Bradford (1986) Similar results were also reported by Urs et al (1970) Singh and Chatterjee (1980) and Kamalam Joseph and Rajappan Nair (1989)

Among the treatments water and KCl treatments recorded higher germination percentage than the others Similar effect of water in increasing germination percentage was reported by Urs et al (1970) and Chatterjee (1982)

The results also revealed that lower concentrations of KCl ie 0 5 to 4 0 per cent recorded greater germination percentage than the higher concentrations tried The germination percentage from 0 5 to 4 0 per cent were on par A number of researchers have advocated the use of low concentration of K salts for treating seeds of cereals like wheat and their recommendation ranged from 0 5 to 3 0 per cent (Alexander and Misra 1972 and Paul et al 1992) The lower germination percentage at higher concentrations may be attributed to the toxic effects of the salts at these levels on the physiological and biochemical processes within the cell (Paul et al 1992)

It was also observed that the varieties Culture-4 and M-102 were on par and superior to Rasi Ravi Tulasi and Jaya in germination percentage though all the varieties had more than 80 per cent germination Kamalam Joseph and Rajappan Nair (1989) also reported such varietal variation in rice This could be attributed to the variation in the inherent potential of varieties in inducing early seed germination when subjected to seed treatment

Among the Variety - seed treatment interactions all varieties treated with water and KCl recorded higher germination percentage and were on par with Jaya treated with cowdung and Culture-4 treated with triazole. The favourable effect of KCl and water treatment of seed resulted in higher germination percentage. Kamalam Joseph and Rajappan Nair (1989) attributed the beneficial effect of cowdung extract treatment in increasing seed germination to the presence of physiologically active substances in it

Regarding root length though KCl concentration of 2 0 2 5 and 3 0 percentages recorded comparatively better root lengths other higher concentrations reduced root length significantly The shoot length was increased by seed treatment at all concentrations of KCl Germination study of pot culture trial also revealed significant improvement in root and shoot length of germinating seeds by seed treatment The physiological advancement of seeds during seed hardening

As in the case of germination percentage, seedling length varied among varieties and Culture 4 recorded the maximum

Root and shoot length were also influenced by variety - seed treatment interaction The inherent potential of Culture-4 along with the beneficial effect of KCl treatment resulted in increased root length of this combination Similarly Culture 4 and M 102 with cowdung treatment and Tulasi with cowdung and water treatments were on par with other varieties treated with KCl and recorded higher shoot length

Vigour index was significantly improved by seed treatment Use of KCl at 2 50 per cent concentration was found to be the best This was due to the high germination percentage and seedling length recorded at this concentration Among the different solutions used for seed hardening water recorded the highest vigour index due to better seedling length and among the varieties Culture-4 had the highest vigour index resulting from the higher germination percentage and seedling length Basu et al (1974) reported that seed hardening increased germinability and vigour of upland rice in the early stages Singh and Chatterjee (1981) also observed similar results by water hardening

Triazole treatment recorded reduced root and shoot length and vigour index compared to control Triazole compounds have been found to inhibit shoot growth although the dosage required may vary between species and cultivars (Fletcher and Hofstra 1988) The reduced seedling growth resulted in lower vigour index values

The highest germination percentage and seedling length recorded by Culture-4 with water treatment enhanced the vigour index and made this variety - seed treatment combination superior to the others

5 1 2 Growth and growth characters

Growth characters like plant height tiller number leaf area and biomass production varied among varieties At harvest stage M 102 recorded maximum plant height and Culture-4 recorded maximum tiller number M-102 being a mutant of Ptb 28 has some characters of the parent variety like tall stature and moderate tiller number The drought tolerant variety Tulasi followed M 102 in plant height and Culture-4 in tiller number At 50 per cent available water Ravi and Rasi recorded the highest leaf area thereby indicating their ability to perform better than other varieties under low soil mositure conditions The better tiller number of Culture 4 resulted in higher biomass production

The growth characters were the lowest for Jaya Moreover its performance was extremely poor at 50 per cent available water This indicated that though Jaya performed well in situations of moisture sufficiency (Harbir Singh et al 1985) its performance was poor under reduced moisture levels and among the six varieties Jaya was the most susceptible under moisture stress conditions

In the subsequent field experiment with Rasi Tulasi and Culture 4 Tulasi and Rasi recorded higher plant height tiller number and LAI than Culture 4 This was mainly due to the rainfall pattern during the cropping period Most of the rainfall was received during the early crop growth period Rasi and Tulasi being short duration varieties could make the best use of available rainfall whereas the medium duration variety Culture 4 was affected by lower levels of soil moisture from 70 DAS The intermittent rains after 70 DAS might not have been sufficient to meet the crop requirement at critical stages especially at flowering and milk stages The better crop growth and yield of Tulasi resulted in higher DMP

Deshmukh et al (1988) Mishra et al (1988) and Sharma and Reddy (1991) also reported that the growth characters of rainfed rice varieties varied depending on the availability of rainfall

Seed treatment resulted in significant improvement of growth characters viz plant height tiller number and leaf area both in pot and field trials This could be accounted by the well developed root system of the treated plants that improved the foraging ability of the plant which in turn increased the RWC and nutrient uptake and improved the growth characters of treated seeds This improvement in growth characters resulted in increased DMP Similar results were also reported by Narayanasamy (1985) Chockalingam (1986) Jose Mathew (1989) and Paul and Choudhury (1991)

Water treatment recorded the highest value for all these growth parameters Devika (1983) observed increased tiller production and LAI of dry sown rice raised after water treatment Triazole treatment recorded lower plant height in pot studies Triazole compounds alone or in combination with KCl were reported to reduce plant height in wheat (Fletcher and Hofstra 1990) But in the field experiment such reduction in plant height was not registered by the triazole treatment

Rice being a semi aquatic plant is favoured by submerged conditions Soil moisture regime of 100 per cent available water produced taller plants with more number of tillers and more leaf area resulting in higher biomass production Drastic reduction in vegetative growth characters was observed in plants maintained at 50 per cent available water Similar reduction in plant height and dry matter due to moisture stress was roported by Agarwal et al (1985)

Moisture stress during the vegetative phase of the crop resulted in reduced plant height tiller number and leaf area and this might be due to the coincidence of maximum physiological activity and morphological advancement of the plant during this period (Sahu and Rao 1974) Similar results were also reported by Boyer and Pherson (1976) O Toole and Baldia (1982) noticed that among the growth characters leaf area expansion was more sensitive to moisture stress as observed in the present study

The results revealed that though continuous submergence was not maintained plants put forth satisfactory growth at 100 per cent available water with seed treatment while they failed to produce normal growth at 50 per cent available water even with seed treatment

Variety - moisture and seed treatment - moisture interactions had significant influence on vegetative growth characters M 102 and Ravi recorded maximum plant height at 100 per cent available water regime whereas Culture-4 had the maximum tiller number at the same moisture regime The increased plant height of M-102 at 100 per cent resulted in maximum leaf area for this variety The complimentary effect of water treatment and increased water availability at 100 per cent regime resulted in improved vegetative growth characters of this combination

5 1 3 Yield and yield attributes

The results of the pot culture study revealed significant varietal variation in yield attributes and yield of rice Among the varieties M 102 produced longer panicles with the maximum weight However the number of productive tillers was significantly lower for this variety which resulted in reduced grain yields Though this variety had favourable root characters as Passioura (1983) observed the increased cost for root growth and its maintenance represented clear diversion of assimilates which might have decreased the yield potential

Culture 4 Rasi and Tulasi recorded higher number of productive tillers with more number of filled grains and low sterility percentage These varieties also had good biomass production and better nutrient uptake values which resulted favourably on yield attributes and yield In the field trial Rasi and Tulasi performed better than Culture-4 with higher number of productive tillers and more mumber of filled grains panicle ^{1} The growth attributes of Culture 4 were lesser compared to Rasi and Tulasi under field conditions This resulted in reduced nutrient uptake which in turn adversely affected the yield attributes and yield

Straw yield was maximum for M 102 in pot study This was due to the higher vegetative growth as evident from increased plant height and leaf area than the others On the other hand varietal variation was not significant in the field trial

The different seed treatments improved the yield attributes and yield both in pot culture and field trial Increased number of panicles (Ramanathan 1980 Singh and Chatterjee 1980 and Kundu and Biswas 1985) and percentage of filled grains (Singh and Chatterjee 1981 Devika 1983 and Chockalingam 1986) were also reported due to seed hardening Seed hardening decreased the severity of moisture stress as observed by high RWC Moreover the better root growth of the hardened plants enabled increased absorption of available water and nutrients which contributed to increased growth photosynthesis and yield Among the seed treatments water KCl and triazole increased the yield attributes and yield in pot culture Field trial with these three had given yield increase to the tune of 26 24 and 23 per cent respectively This yield increase was due to increased panicle number panicle weight increased number of filled grains 1000 grain weight and low sterility percentage Similar increase in yield attributes and yield of rice by pre-sowing soaking with KCl (Peeran and Natanasabapathy 1980) and water (Chatterjee 1982 and Devika 1983) were also reported Yield increase of about eight per cent over control was reported in hybrid rice by Tang et al (1991) by triazole seed treatment

Significant improvement in straw yield by seed treatment was observed in pot culture and field trial Water KCl and triazole treatments resulted in 27 25 and 16 per cent increase in straw yield in field conditions This was due to increase in vegetative growth characters like plant height tiller number and LAI This result was in agreement with the findings of Narayanasamy (1985) and Jose Mathew (1989)

The plants maintained at 50 per cent available water regime failed to produce any grain yield Even in pots maintained at 100 per cent level flowering was delayed by 27 days Senewiratne and Mikkelsen (1961) attributed delayed rate of elongation of the culm in unflooded treatment as the reason for late flowering Several authors (Heenan and Thompson 1984 and Vahl and Gomez 1984) recorded similar results Plants maintained at 50 per cent available water had high soil moisture tension throughout the growth stage which might have restricted the development of reproductive phase in the crop Extreme reduction in tiller number and leaf area due to moisture stress could have led to permanent strain in rice crop as observed by Cruz and O Toole (1984) Ekanayake et al (1989) reported that the time course of panicle exertion showed an inhibitory effect due to low panicle water status and spikelet opening was completely inhibited at water potentials below 0 18 MPa and -2 30 MPa in IR-8 In the present study though some panicles were produced at 50 per cent moisture regime they failed to emerge out completely and were sterile The deleterious effect of water deficit on spikelet opening (Ekanayake et al , 1989) and spikelet water loss might have resulted in spikelet sterility Thus these results revealed that the rice varieties tried in the present study could perform well with seed treatment at 100 per cent available water but could not grow normally and produce grain yield at lower moisture regime

Striking difference was observed in straw yield between the two moisture regimes The stunted growth poor tiller production and extremely low leaf area resulted in reduced straw yield at 50 per cent available water The importance of optimum soil moisture for vigorous growth of rice seedlings had also been emphasized by Amaral and Santos (1983) Singh and Singh (1983) and Hanviriyapant et al (1987)

Variety seed treatment interactions showed significant variation among themselves on yield attributes and yield M 102 and Culture 4 with KCl triazole and water treatments were on par and recorded higher 1000 grain weight than the other combinations Similarly Culture-4 with water KCl and triazole treatment and M 102 Rasi and Tulasi with water treatment recorded higher grain yield than the others Straw yield was maximum for M 102 with water treatment and Culture 4 with water KCl NaH_2PO_4 and cowdung treatments

5 1 4 <u>Root characters and root _ shoot ratio</u>

In pot culture studies the root parameters recorded at harvest stage revealed significant varietal variation Jaya recorded maximum root weight and spread with the lowest root length whereas M 102 being an upland variety had the ability to produce a deep root system Basu Raychaudhuri and Das Gupta (1981) recorded the presence of predominantly long dense and deep roots for upland drought tolerant types Better root length of upland rice cultivars was reported by Gomathinayagam and Soundarapandian (1987)

In the subsequent field trial Rasi recorded the highest root length at 20 and 40 DAS whereas at 60 and 80 DAS Culture 4 recorded maximum root length Rasi being a drought tolerant variety had better root length Since it was of short duration the root growth of Rasi was better than Culture 4 in early stages Culture 4 has 120 days duration So its early growth was comparatively poor and maximum root length was recorded at 60 and 80 DAS By that time Rasi had entered the ~~dough~~ reproductive stage The varietal variation was not significant at harvest stage Haque et al (1992) recorded varietal difference in the root traits of rice

Improvement in root characters by seed hardening was observed in pot culture and field study The primary changes occurring in physio chemical properties of the cytoplasm due to pre-sowing seed hardening determined a series of changes including a more efficient root system (Genkel and Badanova 1959) Similar results were also recorded by Singh and Chatterjee (1981) and Jose Mathew (1989) Among the seed treatments water KCl and triazole treatments were observed to be better than the others in improving the root characters Singh and Chatterjee (1981) observed greater root mass of rice by seed treatment with water Chockalingam (1986) reported increased root length in summer rice by pre-sowing seed hardening with one per cent KCl Improvement in root growth at lower concentration of triazole was recorded by Fletcher and Hofstra (1988) In the field trial at harvest stage triazole treatment recorded significantly higher root length than KCl and water treated plants though all were superior to control

The moisture regime of 100 per cent available water recorded increased values for all root traits viz root length root weight root spread and root volume The pots kept at 50 per cent available water had more mechanical resistance to root proliferation which might have restricted root growth to the surface layer (Klepper 1991) This resulted in lower root length root weight and root volume at 50 per cent available water than at 100 per cent

Heenan and Thompson (1984) observed reduced root proliferation under intermittent irrigation compared to flooded plants Moreover stress could lead to several physiological and biochemical changes which are directly and indirectly related to root generation For instance the stress induced changes in the level of endogenous growth hormones and or carbohydrate could result in a differential rooting pattern (Hsiao 1973) At 100 per cent moisture regime the roots were deeper and had more weight and volume Availability of sufficient water and aerated soil condition under this unflooded phase favoured better root growth Pradhan et al (1973) recorded highest root length in unsaturated soil Katare and Upadhyay (1981) observed longest roots at field capacity and shortest under continuous submergence

The complimentary effect of seed treatment with the varietal character resulted in significant variety-seed treatment interaction in root characters Regarding root volume Jaya Culture 4 Rasi and M 102 with KCl treatment recorded the highest value and this in turn resulted in the highest root weight of these combinations Similarly these varieties recorded highest root weight with water and NaH_2PO_4 treatments M-102 with water and triazole treatments recorded the highest root length

At 50 per cent available water the root parameters of Jaya were the least while the varieties Tulasi and Rasi performed better than the other varieties in terms of root characters This could be attributed to the better ability of these varieties to produce better root characters under low moisture conditions

Root shoot ratio varied among varieties and Jaya recorded the highest ratio followed by Ravi Rasi and Tulasi The small crown and short stature of Jaya resulted in lower shoot weight than other varieties which in turn increased the root shoot ratio of Jaya The drought tolerant varieties (Ravi Rasi and Tulasi) had better foliage development than Jaya and had good root characters This enabled them to record comparatively better root shoot ratio than M 102 and Culture 4 Though M 102 and Culture-4 had better shoot growth and root length they had poor root spread and root weight which resulted in lower root shoot ratio compared to the others

In the field trial the varieties had no significant influence on the root shoot ratio at early and harvest stages Culture-4 recorded significantly higher root shoot ratio at 60 and 80 DAS At these two stages the shoot growth of Rasi and Tulasi reached its peak due to its short duration Culture-4 being a medium duration variety had attained maximum shoot growth after 60 DAS which resulted in higher root shoot ratio at 60 and 80 DAS than the others At harvest stage varietal difference was not significant

In pot culture root shoot ratio recorded at harvest stage was significantly increased by seed treatment and all treatments were on par and superior to control Though not significant at all stages root shoot ratio showed an increasing trend in hardened plants in the field trial This was due to the increased contribution of roots towards total dry matter revealing the effect of seed hardening on root proliferation which in turn increased the root weight Similar results were also recorded by Narayanaswamy (1985) Fletcher and Hofstra (1988) and Jose Mathew (1989)

The root shoot ratio was less at 100 per cent available water though the root growth was good This was mainly due to the proportionate increase in shoot growth in the higher moisture regime Reduction in shoot growth and shoot weight at the lower moisture regime increased the root shoot ratio O Toole and Baldia (1982) found that shoot dry weight was significantly reduced when soil moisture content fell below field capacity Jose Mathew (1989) recorded a decrease in root shoot ratio of rice due to late flooding

Among variety-seed treatment interactions Jaya treated with triazole water and cowdung recorded the highest root shoot ratio The short crown of Jaya with its increased root weight resulting from seed treatment caused an increase in root shoot ratio Similar increase in root shoot ratio by triazole treatment was reported in wheat by Fletcher and Hofstra (1988)

5 1 5 Physio chemical parameters

The physio chemical parameters viz chlorophyll content RWC proline content stomatal index stomatal frequency and grain protein differed among varieties seed treatments and moisture regimes M 102 recorded the highest values for total chlorophyll chlorophyll a and chlorophyll b followed by Tulasi This could be attributed to its inherent genetic potential Chlorophyll synthesis is a varietal character and such varietal variation was reported by Nayak et al (1974) M-102 recorded the highest chlorophyll content both at 50 and 100 per cent available water In a healthy plant the unit of synthesis of chlorophyll was however taking place and this was not altered much by soil moisture (Jayabal 1971) In the subsequent field trial Rasi recorded higher chlorophyll content than the others This could be attributed to the increased N uptake by the variety The favourable influence of N in increasing the chlorophyll content was established by Tisdale et al (1985) In all the varieties chlorophyll a content was higher than b Jayabal (1971) also reported similar results

Seed treatment resulted in increased chlorophyll synthesis This was due to the improvement in nutrient uptake by the treated plants Among the different seed treatments cowdung treatment recorded the maximum content of chlorophyll followed by triazole treatment The presence of micro and secondary nutrients in the cowdung extract might have improved the chlorophyll synthesis In the field trial also seed treatments showed a tendency for increased chlorophyll content Increase in chlorophyll synthesis in triazole treated plants was reported by Fletcher and Hofstra (1990) This increase was mediated through the effect of triazole compounds on cytokinins which stimulated chlorophyll synthesis (Izumi et al 1988)

Chlorophyll content was more at 100 per cent available water than at 50 per cent The increased N uptake by the plants at 100 per cent available water increased chlorophyll synthesis (Tisdale et al 1985)

Among the interactions cowdung treatment at 100 per cent moisture regime and M-102 at the same moisture regime recorded the highest values

RWC varied among varieties in pot culture The drought tolerant varieties maintained higher RWC showing their relative ability to maintain leaf turgor at lower levels of moisture Ramakrishnayya and Murty (1991b) reported varietal variation in RWC in upland rice In the field trial such variation was not observed

Hardened plants ma ntained higher RWC than control both in pot and field study This could be due to the better ability of hardened seeds to hold water against dehydrating forces since the adapted protoplasm did not become rigid and brittle as quickly as in the unadapted plants (Levitt 1956) The development of better root system by the hardened plants enabled better moisture absorption from the soil which in turn increased the RWC This result was in agreement with the findings of Singh and Chatterjee (1981) Jose Mathew (1989)

Among the seed treatments triazole treatment recorded maximum value and was on par with KCl and water Similar results were also reported in wheat by triazole treatment (Fletcher et al 1988) They attributed this due to the reduction in transpiration rate due to partial closure of stomata and increased stomatal diffusive resistance

Soil moisture stress of 50 per cent available water caused significant reduction in RWC Lesser availability of soil moisture and poor development of root system reduced water uptake and resulted in lower RWC Moreover the available soil water was not sufficient to maintain better water relations in plant Nayak et al (1982) and Ramakrishnayya and Murty (1991 a) also obtained a decrease in RWC with increase in moisture stress

Though RWC was lower at 50 per cent available water the percentage reduction was comparatively lower in KCl and triazole treatments than the other treatments This indicated the ability of KCl and triazole treatments to hold water better than the others under stress

Among the interactions the variety Rasi at 100 per cent level and triazole treatment at the same level recorded maximum RWC Among variety seed treatment combinations Rasi with water and Jaya and Culture-4 with triazole treatments were on par and had higher RWC than the other combinations

Proline content showed varietal variation only in pot studies The upland and drought tolerant varieties viz M 102 and Tulasi recorded more proline content than the others This indicated their better ability to withstand moisture stress by increased proline synthesis The accumulation of proline may act as a protective mechanism against moisture stress (Tyankova 1967) Singh et al (1972) and Dingkuhn et al (1991) also observed varietal variation in proline accumulation under moisture stress

The results also revealed that pre-sowing hardening resulted in an increase in proline accumulation The stimulation of proline synthesis from glutamic acid (Barnett and Naylor 1966 and Boggess et al 1976) might have been improved by seed hardening which increased the leaf proline and drought resistance Nilima and Malik (1983) reported similar increase in leaf proline in hardened pigeonpea plants Fletcher and Hofstra (1988) observed increased proline content for osmotic adjustment in triazole treated wheat

Soil moisture stress had direct influence on proline accumulation Stressed plants had more proline content than those maintained at 100 per cent available water The main reason for proline accumulation in water stressed plants is due to the synthesis of free proline from glutamic acid (Stewart et al 1977) This increased level of proline in plants under stress protected several enzymes against the inactivating effects of heat (Paleg et al 1981) Positive correlation between proline accumulation and various indices of drought resistance in rice was reported by O Toole and Chang (1979)

However variation among varieties and seed treatments were not observed in field conditions where continuous moisture stress was not experienced Both water stagnation and drying was experienced in the field Hence on removal of moisture stress the accumulated proline was reconverted to glutamic acid and other soluble compounds which might have resulted in no variation in proline accumulation (Karamanos et al 1983)

Though all varieties had more proline accumulation at 50 per cent available water M 102 recorded the maximum

Stomatal index and frequency inherent genetic characters varied among varieties Jaya M-102 and Tulasi recorded higher values for both these parameters Misken et al (1972) studied the inheritance of stomatal frequency in barley lines and observed that the lines differ in this character and those lines having low stomatal frequency had high stomatal resistance and transpired less water

Seed treatment with different chemicals resulted in reduction in stomatal frequency and index Since stomatal number was an inherent character the improvement in growth by seed treatment resulted in reduced number unit ^{1} area Among the different treatments tried KCl and triazole treatments had the lowest frequency and index values Variation in stomatal characters by pre sowing seed hardening with triazole was reported by Santhakumari and Fletcher (1987)

Reduced soil moisture caused an increase in stomatal frequency The influence of moisture stress in increasing stomatal number was reported by Cook (1943)

Varieties showed variation in protein content of grains The drought tolerant varieties Rasi Tulasi and Ravi recorded significantly higher protein content than the others in pot culture In the field trial also Rasi recorded the highest value though varietal variation was not significant Variation in protein content among varieties was reported by De Datta and Beachell (1972) Singh and Modgal (1978) and Jayapragasam et al (1988)

Pre sowing seed treatment increased the protein content of grains The increased N uptake by the hardened plants improved the protein content of grains

5 1 6 Nutrient uptake

Nutrient uptake showed varietal variation In pot culture Culture 4 had the maximum uptake followed by Tulasi whereas in field trial Tulasi recorded maximum uptake values This was due to the better rainfall availability during the early crop growth which enabled the short duration variety Tulasi to absorb more nutrients from soil Culture 4 being of medium duration was affected by poor rainfall towards the later growth stages resulting in reduced nutrient uptake

Seed treatment improved nutrient uptake both in pot and field trial The development of an efficient root system by the treated plants enabled them to absorb more water and nutrients from soil Similar increase in nutrient uptake by seed treatment was also reported by Chockalingam (1986) and Jose Mathew (1989)

Difference in nutrient uptake between the two moisture regimes was highly significant 100 per cent recording the maximum Increased moisture levels enhanced the root growth and solubility of nutrients which in turn reported by Tagasaia (1982) in pearl millet Ichwantoari et al (1989) reported that N uptake was sensitive to drought

Among the interactions Culture 4 at 100 per cent level recorded the highest nutrient uptake At 50 per cent moisture regime the varietal variation was significant only for N uptake where all varieties except Jaya were on par Similarly water treatment at 100 per cent level recorded the highest nutrient uptake though it was on par with KCl treatment in N uptake and with KCl and triazole treatment in K uptake

5 1 7 Economics

The better performance of the varieties Rasi and Tulasi in terms of grain and straw yields resulted in high net income and benefit cost ratio compared to Culture-4

Seed hardening also increased the grain and straw yields which in turn increased the net income and benefit cost ratio Seed hardening could be identified as a procedure for increased returns in rainfed rice Simple adoption of this inexpensive method was observed to increase the net income by Rs 2 700 ha $^{-1}$ Similar results were also reported by Jose Mathew (1989)

5 2 Experiment 2

5 2 1 Growth and growth characters

During the first year M 102 recorded the maximum plant height throughout the growth period and at harvest stage during the second year Good rainfall received during the crop growth period in first year resulted in better vegetative growth characters of all varieties

In both the years Tulasi and Rasi recorded higher tiller number and were on par with Culture-4 in the second year Ravi and M-102 had the lowest tiller count in both the years M-102 being a mutant of Ptb-28 had the characters of the parent variety like tall plant with low tillering habit This was observed in the results recorded

LAI also showed variation among varieties In 1991 Jaya with its higher leaf number and M-102 with its long leaves recorded the highest LAI while in 1992 M-102 and Culture 4 had the highest LAI The increased tiller number of Culture-4 resulted in high LAI values

Deshmukh et al (1988) and Sharma and Reddy (1991) observed varietal variation with regard to vegetative growth characters of rainfed lowland rice

The highest nutrient level recorded maximum values for vegetative growth characters during both the years

However 100 and 75 per cent levels were on par for tiller count at harvest during 1992 This indicated that 75 per cent level itself was adequate for better tiller production in rainfed condition The positive influence of N P and K in increasing plant height might be due to their combined influence in cell division and cell elongation (Vaijayanthi 1986) An adequate supply of N was reported to increase plant height and deficiency resulted in stunted growth of rice plant (Roy et al 1980) Significant influence of N in enhancing the plant height in rice was established by Sushamakumari (1981) Sobhana (1983) and Surendran (1985) Increase in plant height due to increased application of P (Choudhury et al 1978) and K (Vijayan and Sreedharan 1972) was also reported According to De Datta and [illegible] (1981) N increased height and tiller number P encouraged active tillering and root development and K increased P response and favoured tillering in rice Similarly Uexkull (1976) propounded that tillering in rice was strongly influenced by genetic factors and by the N and P levels in soil K being an element favouring protein production of plants might have exerted some influence on growth and tiller production N application increased LAI due to its influence on increased tiller number and leaf size (Uexkull 1976) Increase in plant height and tiller number might have contributed to a corresponding increase in the number of leaves which in turn might have influenced LAI

Deshmukh et al (1988) also observed increase in growth characters like plant height and tiller number for early duration rainfed rice when the NPK level was increased from 20 15 10 to 80 60 40 kg ha^{-1}

5 2 2 Dry matter production

Inconsistent varietal variation was observed in DMP Ravi recorded higher dry matter yields at 40 and 60 DAS than the others during both the years At harvest stage Jaya and Tulasi recorded higher DMP during the first year while Rasi and M-102 were on par and superior to others during the second year Ravi was the shortest duration variety and its growth rate during the early stages was more resulting in higher dry matter yield during that period The medium duration varieties recorded higher dry matter during later stages of growth The higher LAI and nutrient uptake of Jaya due to favourable rainfall pattern helped it to accumulate more dry matter during the first year During the second year Rasi and M-102 had better grain and straw yields due to better N and K uptake which resulted in higher dry matter accumulation Moreover these varieties on account of their shorter growing period were able to complete their growth during earlier periods of water availability in the second year and hence were less affected by moisture stress at later stages The shortest duration variety Ravi had the lowest DMP

DMP was significantly improved by increasing the nutrient levels from 50 to 100 per cent Increased N P and K supply improved the overall growth like plant height and number of tillers of rice plant and hence the DMP Fageria et al (1990) also reported improvement in DMP in rainfed rice with increase in levels of K

During both the years variety-nutrient interactions were significant in DMP at harvest stage Jaya and M 102 at 100 per cent and Tulasi at 75 per cent levels were on par and recorded higher DMP than the other combinations This was due to the higher grain yield of Jaya at 100 per cent and Tulasi at 75 per cent level and increased straw yield of M-102 at 100 per cent level During the second year Rasi and M 102 at 100 and 75 per cent Culture-4 Tulasi and Jaya at 100 per cent level were on par and had higher DMP than the others

Though total DMP was the highest for Jaya during the first year DMP day ^{1} was maximum for Tulasi and Rasi Their better yielding ability and short duration enabled them to produce more dry matter ha ^{1} day ^{1} Similarly increased nutrient levels enhanced the ability of plants to grow well and thus accumulate more dry matter on day^{-1} basis

5 2 3 Yield and yield attributes

Among the varieties Tulasi and Rasi recorded the highest number of productive tillers in both the years and Culture 4 in the first year alone The lowest number of productive tillers was observed in M 102 in both the years though it recorded better growth characters

For other yield attributes like panicle length and weight the highest value was recorded by M 102 followed by Jaya The long panicles and bold grains of these varieties resulted in increased panicle weight Similarly Culture 4 had the highest 1000 grain weight

In the first year Jaya recorded the highest grain yield followed by Tulasi Culture 4 and Rasi The better rainfall during the cropping period enabled Jaya to fully express its yield potential During the second year two weeks delay in sowing due to the late receipt of pre-monsoon showers and heavy rainfall immediately after sowing retarded the growth and growth attributes of the crop resulting in lesser grain yield Moreover the medium duration varieties like Jaya and Culture 4 were adversely affected by reduced rainfall during the later growth stages especially at flowering and milk stages resulting in lesser grain yield than the short duration varieties except Ravi Nallathambi and Robinson (1992) also reported similar yield reduction in rice varieties when soil moisture stress was experienced during the late vegetative phase and milk stage Ravi recorded the lowest grain yield consistently during both the years

Pooled analysis of yield data revealed that Jaya Tulasi and Rasi were on par and superior to others This could be attributed to the high number of productive tillers greater number of grains panicle^{1} low sterility percentage of Rasi and Tulasi and increased earhead length and panicle weight of Jaya Deshmukh et al (1988) Mishra et al (1988) Dubey et al (1991) and Sharma and Reddy (1991) reported varietal variation in yield of rainfed rice

From the results it could be inferred that Jaya Tulasi and Rasi are the best varieties for rainfed lowland conditions of South Kerala The better performance of Jaya under different moisture regimes was also reported by Harbir Singh et al (1985) Similarly Jaya and Rasi performed well in Karnataka under rainfed conditions (Hanagodimath et al 1989)

As regards nutrients the different levels had no influence on yield attributes like number of productive tiller and length of earhead during first year whereas 100 and 75 per cent levels were on par during the second year In both the years panicle weight showed no variation between

100 and 75 per cent levels though an increasing trend was observed Deshmukh et al (1988) observed increase in panicle weight with increase in nutrient levels in rainfed rice

Considering the number of grains and filled grains panicle ^{1} 100 per cent level was superior to the others in the first year while 100 and 75 per cent levels were on par during the second year Increase in spikelet number with increase in N application was reported by De Datta and Smyth (1981) Favourable influence of P on number of grains panicle ^{1} was reported by Singh and Varma (1971) Sasaki and Wada (1975) and Battacharya and Chatterjee (1978) Uexkull (1982) reported increase in grain number panicle ^{1} with increase in K application Further percentage of filled grains was improved by increasing P levels (Uexkull 1976) Similarly Roy et al (1980) reported that K stimulated build up and translocation of carbohydrates and grain development which increased the number of filled grains Combined application of the major nutrients resulted in favourable response on yield attributes (Deshmukh et al 1988)

The 1000 grain weight increased with increase in nutrient levels during the first year whereas 100 and 75 per cent levels were on par during the second year N increased the size of grains P gave higher food value in addition to promoting good grain developememt and K increased the size and weight of grains This concurred with the findings of De Datta and [illegible] (1981)

The yield attributes like number of grains panicle $^{-1}$ and filled grains were maximum at 100 per cent nutrient level However the yield difference was not significant during the first year as the number of productive tillers did not vary significantly among the nutrient levels In the second year 100 and 75 per cent levels were on par for the yield attributes and hence these two levels were observed to be on par and superior to 50 per cent in yield Pooled analysis also had the same result though an increasing trend was observed at the higher level The beneficial effect of NPK fertilization in increasing grain yield of rice is a well established fact N has a definite role in photosynthesis which is directly related to starch synthesis and yield P influenced grain yield through its effect on root growth which improved nutrient uptake and the role of K is mainly on the manufacture and translocation of starch (Russel 1973) Enhanced grain yield by increasing the nutrient levels in rainfed rice was reported by Deshmukh et al (1988)

From these results it could be summarised that 75 per cent recommended dose was adequate for obtaining good grain yields from rainfed lowland rice Experiments conducted at KAU during 1983 revealed no significant variation on grain yield of dry sown Mashoori rice between 70 45 45 and 50 25 25 kg NPK ha^{-1} (KAU 1984) Similar results were also reported from AICARP studies This might be due to the loss of nutrients either by leaching during periods of excess rainfall or by denitrification during alternate wetting and drying as commonly experienced in rainfed conditions

Variety-nutrient interactions significantly influenced the yield attributes and yield during the first year For yield attributes like number of grains and filled grains $panicle^{-1}$ it was observed that medium duration varieties Jaya Culture-4 and M-102 responded well at 100 per cent level For the short duration varieties Rasi Tulasi and Ravi 75 per cent was sufficient Under conditions of ample water availability as experienced during the first year the medium duration variety Jaya exhibited better yield at the highest nutrient level whereas for the short duration variety Tulasi 75 per cent was adequate The variation between Jaya at 100 per cent level and Tulasi at 75 per cent level was not significant with regard to the yield attributes and yield Tyagi and Agarwal (1989) also reported increased grain yield of Jaya with continuous submergence or by alternate wetting or drying under high N levels

The straw yield also exhibited significant variation among varieties The pooled analysis revealed that M 102 recorded the highest straw yield This was due to its better vegetative growth characters like increased plant height LAI and DMP Similarly the enhanced straw yield at 100 per cent level could be attributed to the increased plant height and tiller production at this level Many workers have reported the beneficial effect of N (Bhatti et al 1982 and Mishra et al 1988) P (Singh and Prakash 1979 and Rastogi et al 1981) and K (Singh et al 1976 and Singh and Prakash 1979) in increasing the straw yield of rice

Harvest index varied among varieties and nutrient levels During the first year significant reduction in HI was observed for M 102 due to its better vegetative growth characters and higher straw yield This indicated that M-102 used greater proportion of nutrients for vegetative growth than for grain production Since the grain yield of Jaya was the highest it had the maximum HI In the second year the varieties did not show variation in HI though Tulasi and Ravi showed an increasing trend Varietal variation in HI during wet season was reported by De Datta (1981)

Higher nutrient levels reduced the HI in both the years though the variation was not significant between 100 and 75 per cent levels in the second year The good vegetative growth and increased straw yield during first year reduced the HI In the second year the straw yield was lesser than that of the first year and the variation in grain yield between 100 and 75 per cent levels was not significant So the HI values at these two levels were on par and superior to 50 per cent level Decrease in HI for rice with increase in NPK levels was reported by Sobhana (1983) and Surendran (1985)

5 2 4 Physio chemical parameters

Chlorophyll content varied among varieties The increased N uptake by Culture-4 Jaya Tulasi and Rasi resulted in increased chlorophyll synthesis by these varieties during first year while in the second year all these varieties except Jaya were on par and had higher chlorophyll content This was due to the reduced growth and N uptake by Jaya In all varieties the content of chlorophyll a was higher than that of b and varietal variation was also observed in chlorophyll a and b contents Jaybal (1971) also obtained similar results

During both the years the highest nutrient level produced the maximum chlorophyll content Increased N uptake at this level stimulated improved chlorophyll synthesis

The water relations of plant as measured by RWC showed significant variation among varieties The drought tolerant varieties like Rasi Tulasi and Ravi recorded higher RWC values showing their ability to absorb and hold water in a better way than the traditional varieties Ramakrishnayya and Murthy (1991 a) also reported varietal variation in RWC of upland rice

Nutrient levels also had significant influence on RWC The RWC was significantly increased due to increased N uptake at 100 and 75 per cent levels Experiments on corn revealed that plants supplied with high N were capable of extracting more water from the soil profile and the leaves of such plants were less affected by water stress (Bennet et al 1986) Radin and Boyer (1982) found that low N strongly decreased the hydraulic conductivity in sunflower plants thereby increasing the water deficit in the expanding leaf blades Increase in P levels improved the root growth which in turn increased the water uptake and RWC Similarly, the osmo regulatory role of K improved RWC in leaves at higher K levels (Tisdale et al 1985)

Proline content was unaffected by varieties and nutrient levels during both the years However its content was higher in the second year than that of first year This could be due to the low rainfall and reduced moisture availability towards the reproductive phase in the second year which in turn increased proline accumulation at flowering

Protein content of grains varied among varieties though variation was not significant in the first year In both the years Rasi recorded the highest value Such varietal variation in protein content of rice was reported by Singh and Modgal (1978) and Jayapragasam et al (1988)

The protein content of grains varied with different levels of N P and K The highest level recorded the maximum protein content This could be due to the enhanced N uptake at higher nutrient levels It is well established that N is the most important constituent of protein Even though the kind of protein formed is largely influenced by genetic factors the amount of protein is governed by environmental factors especially nitrogen supply (Tisdale et al 1985)

5 2 5 Nutrient uptake

During the first year availability of sufficient moisture during the cropping period enabled better uptake of nutrients by the different varieties and Jaya recorded maximum uptake value However during the second year the early rain enabled the short duration varieties like Rasi Tulasi and M-102 to have higher nutrient uptake and growth compared to the medium duration varieties The low levels of soil moisture towards the reproductive stage resulted in reduced nutrient uptake and yield of the medium duration varieties Varietal variation in nutrient uptake of rice under rainfed conditions was reported by Ram et al (1985) Mohankumar and Singh (1984) emphasized the positive relationship between nutrient uptake and yield The summary results of regression analysis between yield and nutrient uptake confirmed that variation existed among varieties on nutrient uptake and yield

The uptake of N P and K increased with increase in nutrient levels This could be attributed to the combined effect of higher content of these elements in plant parts and the increase in DMP at higher fertilizer levels in all growth stages Moreover increased nutrient levels resulted in increased root growth and consequently better absorption of nutrients followed by rapid translocation induced by K Munda (1989) observed higher N and P uptake with increase in N levels

5 2 6 <u>Soil analysis after the experiment</u>

When compared with the initial soil nutrient levels the available nutrient content of soil did not show noticeable depletion after the experiment The varietal variation was not significant In both the years 100 per cent nutrient level recorded higher available nutrient content than the lower levels indicating that at lower levels depletion of nutrients in the soil was more

5 2 7 Economics of rainfed cultivation

During 1991 the favourable moisture regime enabled Jaya to produce more grain yield thereby increasing the net income ha^{-1} and benefit cost ratio In 1992 the higher grain and straw yields of Culture 4 M-102 Rasi and Tulasi resulted in higher economic returns Pooled analysis of the two year data revealed that the net income and benefit cost ratio could be increased under rainfed conditions by selecting varieties like Jaya Tulasi Rasi and Culture 4

Among the nutrient levels 100 and 75 per cent were observed to be on par indicating that 75 per cent was sufficient to get higher net income ha^{-1} and benefit cost ratio Pradhan and Das (1990) reported additional gain from fertilizer application due to additional grain production

During the first year it was observed that Jaya at 100 per cent and Tulasi at 75 per cent level were on par and superior to the others This indicated that under favourable soil moisture conditions the performance of Jaya was the best at 100 per cent recommended nutrient dose Under the same conditions 75 per cent of the recommended dose was sufficient for Tulasi to produce net income and benefit cost ratio comparable to Jaya

5 3 Correlation studies

The results of correlation studies revealed that germination percentage root length and vigour index of germinating seedlings had significant positive correlation with grain yield in pot culture study Vigorous early growth enabled seedlings to survive better under conditions of low moisture and thus ensuring better grain yield Turner and Nicholas (1988) also observed improvement in rice yield as a result of vigorous early growth in upland rice

Similarly the yield attributes like number of productive tillers panicle weight and number of filled grains panicle ^{1} showed significant correlation with yield of treated seeds both in pot and field studies Among the drought parameters recorded in pot culture root shoot ratio recorded the highest correlation (0 9139) followed by root length Singh and Chatterjee (1981) observed that grain yield was significantly correlated with deep roots and root shoot ratio Similar positive correlation between grain yield and root shoot ratio was also reported by Gomathinayagam and Soundarapandian (1987) In the subsequent field experiment significant correlation of root shoot ratio with yield was observed only in early stages The corresponding increase in shoot weight at later stages of crop growth resulted in negative correlation values

The path analysis conducted to study the cause and effect relationship of drought parameters on yield revealed that 74 per cent variation in grain yield could be attributed due to the influence of chlorophyll a proline root weight root length root volume and root shoot ratio Among the parameters root shoot ratio had maximum direct effect on grain yield The importance of root shoot ratio in influencing the grain yield of drought resistant varieties was reported by O Toole and Moya (1981) and Gomathinayagam and Soundarapandian (1987) The other parameters influenced grain yield indirectly through root shoot ratio Root length followed root shoot ratio in correlation values (0 6521) though its direct effect is negative This high correlation value was obtained mainly through its high indirect influence (1 0609) on grain yield Significant positive correlation between rice yield and root length and root shoot ratio was reported by Singh and Chatterjee (1981) Based on the influence of root shoot ratio on grain yield the suitability of varieties for moisture stress situation could be listed as follows Jaya > Ravi > Rasi > Tulasi > M 102 > Culture-4 However it was observed that the shoot weight of Jaya was extremely low under low moisture regime and the higher root shoot ratio was attributed to the very low shoot growth Moreover the grain yield of Jaya and Ravi were lower than Rasi Tulasi and Culture-4 at 100 per cent available water Hence the ideal varieties suited for stress conditions were Rasi and Tulasi mainly due to their higher root shoot ratio and better grain yield

Similarly among the seed treatments the grain yield and root shoot ratio were the highest for KCl water and triazole treatments Hence varieties like Rasi and Tulasi with water KCl or triazole treatment could perform well under rainfed conditions where moisture stress was likely to occur during the crop growth period

Correlation studies of experiment 2 revealed that among the parameters yield attributes and nutrient uptake had significant positive correlation with grain yield Similar results were also reported by Mohankumar and Singh (1984) and Vaijayanthi (1986)

The results of the present study revealed that under conditions of low moisture availability Rasi and Tulasi could give consistently better yields than the other varieties Under conditions of assured rainfall early sown Jaya was found to perform well So also under rainfed conditions the difference in yield between 100 and 75 per cent recommended doses of nutrients were not significant Hence in lands with medium fertility status 75 per cent of the recommended N P and K level ie 67 5 33 75 33 75 kg ha^{1} was sufficient to realise higher grain yields The study also revealed the favourable influence of seed priming in inducing stress tolerance and increasing grain yield in rainfed rice Seed treatment being an inexpensive method could be recommended for dry sown rice where moisture stress was likely to occur

6 SUMMARY

Two field experiments were conducted at the Cropping Systems Research Centre Karamana and one pot culture trial at the College of Agriculture Vellayani during 1991 and 1992 to determine the best seed hardening technique to select a suitable rice variety and to ascertain a proper nutrient level for maximum rice production in the rainfed wetlands of Southern Kerala

In the study experiment 1 included a pot culture study with six varieties viz Jaya Culture 4 M 102 Rasi Ravi and Tulasi and six methods of seed hardening viz water triazole NaH_2PO_4 KCl cowdung extract treatments and a control in two moisture regimes The significant results of the study were tested in the field

Experiment 2 included these six varieties and three nutrient levels viz 100 75 and 50 per cent of the recommended nutrient dose for medium duration varieties (90 45 45 kg N P_2O_5 and K_2O ha ^{1}) This was conducted as a factorial experiment in RBD during the first crop season of 1991 and 1992 The findings of the study are summarised as given here under

1 Among the different concentrations of KCl tested for seed hardening 2 50 per cent was found to be the best

2 From the pot culture study it was observed that M-102 recorded maximum plant height while Culture 4 registered the highest tiller number and biomass Seed hardening improved the growth characters in most cases and water treatment recorded the highest plant height tiller number and biomass Increasing the moisture regime from 50 to 100 per cent available water improved the growth characters and biomass production

3 The varieties Culture 4 and Tulasi were superior to the others in productive tiller number while M-102 had the highest panicle length panicle weight and number of grains panicle^{1} Seed treatment with water KCl and triazole increased all the yield attributes Culture-4 and water treatment recorded the highest grain and straw yields Plants at 100 per cent moisture regime produced more yield of straw than those at 50 per cent level

4 Varieties seed treatments and moisture levels had differential response on physio chemical parameters RWC was maximum for Rasi triazole treatment and 100 per cent moisture regime M 102 and cowdung extract treatment had higher chlorophyll content whereas proline content was maximum at the lower moisture regime and in hardened plants

5 The variety Jaya recorded the highest root weight and root shoot ratio while M-102 had the longest roots Seed hardening improved the root parameters

6 Correlation and path analysis studies revealed that the root shoot ratio had maximum correlation and direct effect on grain yield and other drought parameters indirectly influenced grain yield through root shoot ratio

7 In the subsequent field trial Tulasi and Rasi recorded significantly higher plant height and LAI while Culture-4 registered maximum tiller number Seed hardening improved most of the growth characters

8 The varieties Rasi and Tulasi were superior to Culture-4 in DMP resulting in higher number of productive tillers grain yield and net income All seed hardening methods increased DMP yield attributes and grain yield over control and increased net income by about Rs 2700 ha^{-1}

9 Physio-chemical parameters like RWC and chlorophyll content were improved by pre sowing seed treatments whereas the same had no influence on proline content

10 The variety Rasi recorded the highest root length Improvement in root length was observed due to seed treatment Root shoot ratio was the highest for triazole treatment

11 Results of experiment 2 revealed that M 102 recorded the highest plant height during both the years while Tulasi and Rasi had higher tiller number LAI was maximum for Jaya during 1991 and for Culture 4 during 1992 Jaya registered the highest DMP during 1991 Tulasi Rasi and M-102 were on par and superior to the others in DMP during 1992 Increased nutrient levels improved the growth characters and DMP

12 Productive tiller number was higher for Rasi and Tulasi than the others and M-102 had the highest panicle length and panicle weight The difference between 100 and 75 per cent nutrient levels was not significant on yield attributes indicating that the latter was sufficient for rainfed conditions

13 Pooled analysis results revealed that varieties Jaya Tulasi and Rasi performed better under rainfed conditions Regarding straw yield M 102 and Rasi were superior to the other varieties and increased nutrient levels enhanced the straw yield

14 The drought tolerant varieties recorded higher RWC than the others RWC and chlorophyll content increased with increase in nutrient levels Proline content was unaffected by varieties and nutrient levels

15 Nutrient uptake was the highest for Jaya during 1991 while Tulasi Rasi and M 102 recorded higher uptake values than the others during 1992 The linear relationship between nutrient uptake and grain yield was significant for all the varieties during 1992

16 Available nutrient content of the soil after the experiment was not influenced by varieties However fertilizing with higher nutrient level increased the residual nutrient content of the soil

17 The variety Jaya registered the highest net income and benefit cost ratio and was on par with Tualsi Rasi and Culture 4 Among the nutrient levels 75 per cent recommended dose was sufficient to obtain high net income and benefit cost ratio under rainfed conditions

18 There was significant positive correlation between grain yield and the number of productive tillers panicle weight number of grains and filled grains panicle^{-1} and N P and K uptake during both the years

From the results it could be concluded that the varieties Jaya Rasi and Tulasi were ideal for rainfed wetlands 75 per cent of the recommended dose of nutrients was sufficient to realize better grain yield in rainfed rice However under conditions of ample water availability throughout the crop growth period the performance of Jaya was the best with 100 per cent recommended dose Rasi and Tulasi gave consistently good performance in both the years with 75 per cent of the recommended dose Similarly seed priming could be recommended as an effective tool in inducing stress tolerance in rainfed rice

Future line of work

The scope of this experimentation may further be extended to cover other aspects like optimum sowing time appropriate weed control measures use of different chemicals and mulching materials under rainfed conditions The same experiment may be repeated as a whole in different agro-climatic conditions to obtain location specific package of recommendations

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* Originals not seen

APPENDICES

APPENDIX

Average values of weather parameters during the cropping period and previous five years average

Standard weeks	Temperature (°C) Maximum			Temperature (°C) Minimum			Relative humidity (%)			Rainfall (mm)			Evaporation (mm)		
	1991	1992	5 years mean	1991	1992	5 years mean	1991	1992	5 years mean	1991	1992	5 years mean	1991	1992	5 years mean
18	33 33	33 83	33 38	25 83	24 67	25 59	76 00	80 50	79 59		26	16 96	5 30	5 00	5 46
19	34 57	33 14	33 38	26 29	25 14	25 83	77 43	82 29	78 76	5	44	11 00	5 01	4 51	5 04
20	33 43	29 71	32 84	25 57	24 00	25 44	82 57	89 43	78 41	82	119	56 64	4 50	2 97	4 22
21	33 29	32 00	32 02	25 71	25 71	24 84	82 00	81 29	82 17		1	33 00	4 21	4 23	4 67
22	31 71	32 71	31 22	25 00	25 00	24 59	90 30	84 14	83 97	134	47	55 26	3 67	3 66	3 82
23	28 86	28 71	29 74	24 00	23 14	23 70	96 29	94 29	84 67	286	404	132 40	4 30	2 69	3 41
24	29 71	30 00	29 73	23 43	24 29	23 44	95 57	89 86	85 01	177	63	91 00	4 03	3 29	3 26
25	29 29	30 57	29 86	23 71	25 00	24 07	93 71	90 00	84 46	153	58	66 92	4 37	2 71	3 45
26	28 57	30 71	29 80	23 00	24 43	23 57	95 00	88 71	85 94	131	9	80 74	3 94	4 21	3 51
27	30 43	30 14	30 19	23 71	23 57	23 42	89 14	87 14	80 97	110	41	68 72	3 53	3 17	3 35
28	27 86	29 57	30 65	23 00	22 57	23 34	94 14	86 71	84 85	96	24	48 86	3 10	3 43	3 68
29	30 43	28 86	30 70	23 57	22 86	23 41	89 71	89 29	83 57	16	60	54 28	3 34	2 14	3 92
30	30 00	29 14	29 83	24 00	23 00	23 55	92 14	89 57	82 97	51	104	21 80	3 96	3 34	3 98
31	29 57	28 57	30 21	23 29	22 42	23 61	91 71	92 71	81 16	84	41	18 84	3 33	3 29	3 60
32	29 86	29 00	29 86	23 29	23 43	23 22	87 86	93 29	80 71	20	31	17 20	3 06	3 46	3 59
33	28 57	29 71	29 15	22 57	23 86	23 09	87 29	91 00	84 19	49	17	49 18	3 50	3 44	3 54
34	30 43	30 71	30 12	23 14	23 71	23 45	85 00	82 43	80 90	8	1	31 54	3 71	4 50	3 74
35	30 00	28 71	30 49	22 86	23 29	22 93	87 00	92 43	81 34	13	43	18 82	3 63	3 14	3 94
36	31 43	29 43	30 99	23 14	23 43	23 38	81 14	91 29	78 16	0	41	40 00	4 43	2 74	4 37
37	31 86	29 86	31 28	23 86	23 71	23 77	83 00	87 29	81 19	1	12	31 50	5 21	3 39	3 79
38	32 00	31 71	30 42	23 86	23 86	23 61	82 57	78 85	79 46	0	2	55 56	4 24	4 43	4 00
39	32 14	30 59	30 54	24 29	23 43	23 63	82 57	86 29	81 93	0	38	33 08	4 50	2 31	3 91

AGRONOMIC EVALUATION OF RICE CULTIVARS FOR RAINFED CONDITIONS OF KERALA

BY

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ABSTRACT OF A THESIS
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ABSTRACT

Two field experiments were conducted at the Cropping Systems Research Centre Karamana and one pot culture trial at the College of Agriculture Vellayani during 1991 and 1992 to select a suitable rice variety and nutrient level required for maximum rice production in the rainfed wetlands of Southern Kerala The influence of seed hardening in inducing stress tolerance was also studied

In the study experiment 1 included a pot culture trial with six varieties viz Jaya Culture 4 M 102 Rasi Ravi and Tulasi and six methods of seed hardening viz water triazole NaH_2PO_4 KCl cowdung extract treatments and a control in two moisture regimes The significant results of the study were tested in the field

Experiment 2 included these six varieties and three nutrient levels viz 100 75 and 50 per cent of recommended dose for medium duration varieties (90 45 45 kg N P_2O_5 and K_2O) and was conducted as a factorial experiment in RBD during the first crop season of 1991 and 1992

The results of the germination study revealed that KCl concentration of 2 50 per cent was ideal for seed hardening Seed hardening improved germination of all the varieties and water treatment registered the highest vigour

index values In pot culture Culture 4 with water treatment registered the highest biomass production grain and straw yields The variety Jaya had the highest root weight and root shoot ratio Among the seed treatments water KCl and triazole treatments favourably influenced the yield attributes yield root parameters and root shoot ratio Increasing the moisture regime from 50 to 100 per cent available water enhanced the growth characters RWC chlorophyll and decreased the proline content

The subsequent field trial with the highest grain yielding varieties and seed treatments confirmed the superiority of Rasi and Tulasi for increased grain yield net income and benefit cost ratio The different seed treatments also had favourable influence on the above characters

The results of experiment 2 revealed that M 102 recorded the highest plant height during both the years while Tulasi and Rasi had higher tiller number The varieties M 102 and Rasi registered higher straw yield than the others Increased nutrient levels improved growth characters and straw yield

Pooled analysis of grain yield revealed that the varieties Jaya Rasi and Tulasi were good yielders and 75 per cent of the recommended nutrient level was sufficient to obtain high grain yield under rainfed conditions Increased RWC values were observed in the drought tolerant varieties Ravi Tulasi and Rasi and at increased nutrient levels Proline content was unaffected by varieties and nutrient levels

The variety Jaya registered the highest uptake of major nutrients during 1991 while Tulasi Rasi and M 102 had higher uptake than the others during 1992 The highest nutrient level recorded the maximum uptake during both the years Among the varieties Jaya Tulasi Culture 4 and Rasi recorded high net income and benefit cost ratio Among the nutrient levels the variation between 100 and 75 per cent recommended nutrient dose was not significant with regard to net income and benefit cost ratio

Under rainfed conditions 75 per cent of the recommended nutrient dose was sufficent for the varieties Jaya Rasi and Tulasi to obtain commensurate yield net income and benefit cost ratio Moreover the yield and economic returns could be increased by resorting to seed hardening methods