

**DEVELOPMENT OF WATER STRESS TOLERANT RICE
(*Oryza sativa* L.) GENOTYPES BY INDUCTION
RESPONSE TECHNIQUE**

Thesis submitted in part fulfilment of the requirements for the
Degree of DOCTOR OF PHILOSOPHY in CROP PHYSIOLOGY
to the Tamil Nadu Agricultural University, Coimbatore.

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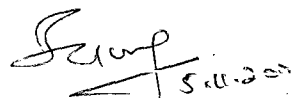
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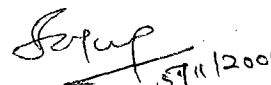
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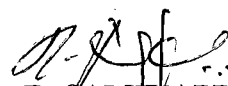
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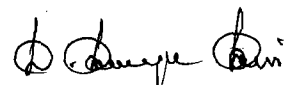
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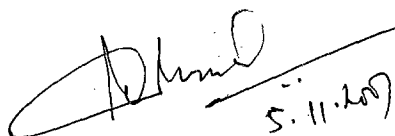
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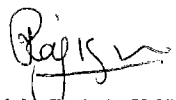
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ABBREVIATIONS USED

%	-	per cent
μ	-	micro
AAO	-	Ascorbic Acid oxidase
AC	-	Absolute control
AOS	-	Active oxygen species
ASM	-	Available soil moisture
CAT	-	Catalase
CD	-	Critical difference
CGR	-	Crop Growth Rate
cm	-	centimeter
d	-	days
DAS	-	Days after sowing
E	-	Transpiration rate
F.W.	-	Fresh weight
FCRD	-	Factorial completely randomised design
Fl	-	Flowering
g	-	gram
GDS	-	Growth During Stress
GEI	-	Growth at the End of Induction
GDR	-	Growth During Recovery
H ₂ O ₂	-	Hydrogen peroxide
ha	-	hectare
HI	-	Harvest index
IN	:	Induced
kDa	-	Kilo dalton
kg	-	kilogram
LA	-	Leaf Area
LAD	-	Leaf Area Duration

LAI	-	Leaf Area Index
LEA	-	Late embryogenesis abundant
m	-	meter
M	-	Molar
m. mhos	-	millimhos
mg	-	milligram
ml	-	milli litre
MPa	-	Mega pascal
NAR	-	Net Assimilation Rate
NBT	-	Nitro blue tetrazolium
NI	-	Non induced
NO ₂	-	Nitrite
NOR	-	Norungan
NOT	-	Nootripattu
NRase	-	Nitrate Reductase
PI	-	Panicle Initiation
POX	-	Peroxidase
RGR	-	Relative Growth Rate
RWC	-	Relative water content
SDS-PAGE	-	Sodium dodecyl sulphate - polyacrylamide gel electrophoresis
SLA	-	Specific Leaf Area
SLW	-	Specific Leaf weight
SOD	-	Superoxide dismutase
TDMP	-	Total Dry Matter Production
TEMED	-	N, N, N ¹ , N ¹ , - tetramethyl ethylene diamine
TI	-	Tillering
TP	-	Transplanting
VAR	-	Varapukudanchan

Abstract

ABSTRACT

DEVELOPMENT OF WATER STRESS TOLERANT RICE (*Oryza sativa* L.) GENOTYPES BY INDUCTION RESPONSE TECHNIQUE

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Investigations were carried out in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore-3 during the year 1998-2001 to understand the physiological and biochemical basis of water stress tolerance in rice through Induction Response Technique and to identify the associated characters.

The optimum dose for induction of water stress tolerance (sublethal) and lethal were fixed as -0.5 MPa and -1.0 MPa respectively through laboratory studies. Among the fifteen genotypes screened for water stress tolerance through Induction Response Technique, four genotypes namely Norungan, Nootripattu, Varapukudanchan and PMK 2 were found to be tolerant whereas CO 37 was found to be susceptible. The induced tolerant genotypes recorded longer shoot and root length and dry matter when compared to the non induced genotypes as well as the susceptible variety CO 37.

In the pot culture study, tolerant genotypes such as Norungan, Nootripattu, Varapukudanchan, PMK 2 and susceptible genotype CO 37 were evaluated for their growth attributes, morphological, physiological and biochemical characters besides yield and yield components.

Among the five genotypes, the land race Norungan recorded the highest plant height, root length and root volume followed by PMK 2 and Nootripattu. The water stress tolerant variety PMK 2 recorded significantly higher number of leaves, largest leaf area and growth attributes such as LAI, LAD, SLA, SLW, NAR, CGR and RGR significantly than other genotypes.

The chlorophyll content was comparatively higher in leaves of induced genotype of PMK 2 followed by Norungan and Nootripattu than other treatments besides recording high soluble protein, enhanced activity of enzymes *viz.*, nitrate reductase, catalase, peroxidase and superoxide dismutase.

Total sugars, reducing sugars, starch, proline, total phenols, ascorbic acid and RWC were also comparatively higher in the induced PMK 2 genotype than the non induced ones. Ascorbic acid oxidase enzyme activity was high in susceptible variety CO 37 indicating low level of ascorbic acid.

Tolerant variety PMK 2 recorded the highest TDMP after induction treatment followed by Norungan and Nootripattu. Among the genotypes, PMK 2 induced seedling recorded a less reduction in yield followed by Norungan under water stress condition (75% ASM and 50% ASM).

The tolerant genotypes, PMK 2 and Norungan along with susceptible variety CO 37 were subjected to SDS-PAGE analysis, which revealed that stress shock proteins were synthesized and accumulated during induction response period. These protein accumulated more in PMK 2 than others. Catalase and peroxidase isoforms were also more in PMK 2 than other genotypes. The above said desirable characters might be responsible for the high water stress tolerance and a significant increase in the yield of induced plant than the non induced ones. This Induction Response Technique appears to be a simple and viable technology for increasing the water stress tolerance of rice.

Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) has been the companion of human kind for more than 8000 years and provides staple food to 2.4 billion people. By the middle of the next century this number is likely to increase to 4.6 billion. Asia, the origin of rice, is the dominant producer with 520 million tonnes of rice constituting 91 per cent of the world's harvest. However, with the increase in population at the rate of 100 million per year, Asia would require more than 760 million tonnes of rice by 2020 A.D. In India, rice is the most important crop and plays a major role in the food security of the country. India tops the list in terms of area constituting 28 per cent of world's rice (Ram and Vyas, 1997). During 1999 – 2000, India produced 89.5 million tonnes of rice (Anonymous, 2001).

Half of the world's 148 million hectares of rice is grown under rainfed condition. Yet this area accounts for only one quarter of rice production (David, 1991) due to its low yield, which ranges from 0.5 to 2.0 tonnes per hectare. Nearly two third of upland rice area is in Asia (Arrandean, 1995). In India, rainfed rice accounts for more than fifty per cent of the total rice area (Siddiq, 1996). Upland rice occupies the major portion of the total rice land and is grown as a rainfed crop. Studies on the constraints to rice yield has confirmed that water deficit is the most serious factor limiting production particularly under rainfed conditions (Barker and Herdt, 1982; Widawsky and O'Toole, 1990). Therefore, there is a need to develop new technologies and varieties suitable for drought prone areas.

Rice germplasm particularly among those adapted to dryland conditions have such a remarkable rich diversity that a continuous spectrum of genotypes differing in their physiological mechanisms can be found and is available for genetic manipulation (Chang *et al.*, 1982). The understanding into the physiological basis of such variation could assist in identifying traits that increase yield in water deficit environments. In most of the breeding programmes, the genetic improvement for adaptation to drought condition were addressed through the conventional approach which involve selection for yield. Selecting rice genotypes with better adaptation to water stress would increase the productivity of rainfed rice. Consequently, there have been many suggestions that improvement in yield could be achieved by identifying physiological traits which could be included in a set of selection criteria (O'Toole and Chang, 1979; O'Tolle, 1982; Ludlow and Muchow, 1990).

Several physiological and biochemical responses of plants to stress like maintenance of protein synthesis (Bewley, 1981), membrane integrity (Dhindsa and Bewley, 1977), Osmotic adjustment (Yancey *et al.*, 1982) and proline accumulation (Stewart and Lee, 1979) were found to be relevant in stress tolerance. In addition to these plant responses to stress, synthesis of stress shock proteins has drawn attention in the last two decades.

Stress shock proteins (SSP)/stress proteins synthesized in response to several abiotic stresses are induced during non lethal induction stresses, which impart tolerance to a subsequent lethal stress. This phenomenon is often referred to as acquired tolerance (Vierling, 1991). In response to the induction treatment, plants

synthesize a wide range of stress proteins ranging from 15 to 90 kDa (Lindquist and Craig, 1988). Many of these proteins are common to different abiotic stresses.

Though the exact role of these proteins is not clear, evidences from several reports reveal that stress proteins provide protection to the organism to otherwise lethal stress (Howarth, 1990). Since, a correlation exists between the synthesis of stress proteins and acquired tolerance in many systems, stress proteins are claimed to be involved in stress tolerance. However, variation in stress protein synthesis of induced systems between stress tolerance and susceptible species is inconclusive. Therefore, the relevance of stress proteins in stress tolerance is still a controversy.

At the molecular level, one of the most extensively characterized stress responses in higher plants is the synthesis of stress shock proteins (SSPs). These proteins are synthesized under a variety of stresses such as high temperature (Key Lin and Chen, 1981; Sachs and Ho, 1986; Lindquist and Craig, 1988), desiccation (Chandler *et al.*, 1988; Bray, 1988), salinity (Singh *et al.*, 1985; Ramagopal, 1987; Esaka *et al.*, 1992), heavy metals (Lin, Roberts and Key, 1984; Howarth, 1990), chilling (Tseng and Li, 1991) and anoxia (Czarnecka *et al.*, 1984). Many of these proteins are suggested to protect the cell against the adverse effects of stress. These proteins are shown to be synthesized when the organism is exposed to a mild non-lethal level of stress often referred to as an induction stress. The ability of induced systems to tolerate severe levels of stress signifies the importance of stress proteins. Thermosensitive mutants that do not synthesize stress proteins when subjected to mild stress do not survive severe stress.

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More information need to be generated on physiological, biochemical and molecular mechanism of stress tolerance. Therefore the present work has been proposed with the following objectives:

- 1) To study the physiological, biochemical and molecular mechanisms of water stress tolerance in rice through induction response technique (IRT).
- 2) To identify parameters closely related to water stress tolerance.
- 3) To develop / identify suitable water stress tolerant genotypes in rice.

Review of Literature

Chapter II

REVIEW OF LITERATURE

Upland rice is grown under rainfed conditions in well drained soil (Pande *et al.*, 1994), where the average yield is low. Water deficit is one of the most serious factors limiting production of rice under rainfed conditions (Barker and Herdt, 1982; Widawsky and O'Toole, 1990). Therefore, there is a need to develop new technologies and varieties suitable for drought prone areas. Efforts to incorporate higher levels of drought resistance into rice needs understanding of specific mechanisms involved in specific environmental targets (Fukai and Cooper, 1995). In this chapter, an attempt has been made to illustrate the relationship between induction response technique and water stress tolerant of rice crop. For convenience, the literature surveyed is classified under relevant topics such as seedling growth, induction response, morphological characters, growth attributes, physiological and biochemical parameters, and yield and yield components.

2.1. RICE ECOLOGY AND DROUGHT ENVIRONMENT

Before discussing drought resistance in rainfed rice, an appreciation of the ecological diversity to which rice has been adapted is imperative. Rice, perhaps more than any other crop, has been so intensely exposed to adaptive process that it now occupies an ecological continuum from deep water to the hills.

There are three major rice cultural systems : upland, lowland and deep water (O'Toole and Chang, 1979; IRRI, 1994). Deep water rice areas represent an unique hydrological situation where the crop is sown on dry land and after a period of 4 to 6 weeks, water accumulates to as much as 6 metres depth. Low land rice are

characterised by low bunds and intensive wet tillage is provided to enhance continual submersion till before harvest. Variation in rainfall distribution in these areas produced rather short cycles of drought and flood. On the other hand, upland sites are characterised by aerobic soil on which impounding of water is practically impossible. Crops generally suffer from water deficit besides inadequate nutrition (IRRI, 1994).

Different types of drought may require different approaches in the crop improvement programme. Rice growing environments, where stress is likely to occur can be grouped into two major categories - upland and rainfed lowland. The later may be grouped on the presence or absence of strongly developed hard pans in the soil. Water stress development is generally more severe in upland than in low land areas. Fukai and Cooper (1995) emphasised on the timing and severity of water stress in relation to crop phenology while characterising drought environments in rice. Drought stress at early period of crop growth may severely affect short duration cultivars but late maturing cultivars may have sufficient time to recover (Maurya and O'Toole, 1986). Mild intermittent stress during the period from tillering to flowering may not develop any visible stress symptoms. However, due to reduced leaf area and stomatal closure, dry matter yield may be affected particularly in most sensitive varieties (Boonjung, 1993). Late stress is a common problem for late maturing cultivars as well as short duration cultivars when planting is delayed due to early drought spell. Reproductive process is greatly affected by late season stress (Fukai and Cooper, 1995).

2.2. CRITICAL GROWTH STAGES OF RICE IN RELATION TO DROUGHT

Water deficit at the vegetative stage appears to be least detrimental to yield (Chang *et al.* 1982, De Datta and Seshu, 1982; Lilley and Fukai, 1994 c;

Boonjung and Fukai, 1996b). The effect may be offset by growth of additional tillers after water deficit ends. Compensation for decreased tiller number is especially feasible in cultivars with long vegetative phase. The obvious exception to this case is when stress is of severe intensity and duration that kill some plants, thus reducing the number of plants per unit area (O'Toole and Chang, 1979).

Water deficit at the reproductive stage is most damaging to rice yield (O'Toole, 1982; Boonjung, 1993; Malabuyoc *et al.*, 1993; Lilley and Fukai, 1994 c). The last 55 to 60 days in rice plant is characterised by the phases panicle initiation, meiotic development of gametes, anthesis - fertilization and grain filling. At these stages water deficit caused irreparable loss of potential yield (Boonjung and Fukai, 1996 b). Namuco and O'Toole (1986) reported that the meiotic (10 to 12 days before anthesis) and anthesis stages were the most sensitive. Stress at panicle initiation reduced spikelet number panicle⁻¹, at the meiotic stage or at anthesis it increased sterility of florets and at the grain filling period it lowered the individual grain weight (O'Toole and Namuco, 1983; Garrity and O'Toole, 1994; Lilley and Fukai, 1994 c; Boonjung and Fukai, 1996 b). Therefore, it is likely that cultivars with different phenology would react differently to a drought depending on the timing of stress (Maurya and O'Toole, 1986).

2.3. DROUGHT TOLERANCE IN RICE

The complexity of the interacting factors related with drought has defined a simplistic and linear relationship of the process or a prediction of events to follow. Under dry land culture, the deep and thick root of traditional upland varieties coupled with thrifty shoot growth enable them to avoid drought. On the other hand, rice genotypes possessing thick and deep roots are frequently deficient in tissue tolerance

or recovery ability (Chang *et al.*, 1972; Chang *et al.*, 1974; De Datta *et al.*, 1975 and O'Toole, 1982). Traditional lowland and many semidwarf varieties are often tolerant to tissue desiccation. However, tolerance and recovery are not necessarily correlated (IRRI, 1971; Chang *et al.*, 1972, 1974).

There are several adaptive mechanisms in rice germplasm that may be exploited to enhance the crops capability to grow, develop and yield during the drought period. The applicability of each type of mechanism, however, must be placed in proper ecological perspective and should not be accepted as a drought resistance *per se*. Because of extreme ecological diversity of rice cultural systems, adaptive mechanisms suited to a particular set of drought conditions may have little or no relevance when considered in an ecologically dissimilar background. There are four basic adaptation mechanisms in rice - drought escape, dehydration avoidance, dehydration tolerance and recovery. Each mechanism may be the result of a number of traits (Sullivan, 1971; Chang *et al.*, 1974; Loresto *et al.*, 1976).

2.3.1. Drought escape

Drought escape completely preclude drought from interacting with the crop growth and yield. The sensitive reproductive stage is photoperiodically controlled to coincide with the peak monsoon season and allow adequate water for the crop to complete grain filling (Oka, 1958; Vergara and Chang, 1976). In areas where rainfall patterns are marginal, short duration cultivars whose life cycle can adapt to the short time of assured rainfall often escape drought (Krishnamurthy *et al.*, 1971).

2.3.2. Dehydration avoidance

This is a mechanism for avoiding low plant water status during the drought period through uptake of soil moisture to meet evaporative demand and control of water loss. Dense and deep rooting habit have more water extraction capability

through increasing soil-water-root interface. (Chang and Vergara, 1975). As the deep root to shoot ratio increases, the visual score in field drought screening shift towards the resistant rating (Ekanayake *et al.*, 1985a). Root thickness of rice has also been positively correlated with drought resistance in screening upland fields (Krupp *et al.*, 1972).

As drought progresses moisture absorption is lagging behind moisture loss of the plant. Adaptive mechanisms of the shoot that help plants maintain a favourable water balance include stomatal closure, a well developed cuticle and leaf rolling (Fukai and Cooper, 1995). Generally, upland rice cultivars have higher stomatal resistance than lowland adapted rice cultivars under stress (O'Toole and Cruz, 1980). Leaf rolling of rice is perhaps the most universally obvious symptoms of drought. Rolling of leaves indicates a decrease in turgor of the tissues giving the lamina its lateral hydraulic extensibility (O'Toole and Cruz, 1980).

2.3.3. Dehydration tolerance

This is a mechanism by which plants maintain metabolisms even at low water potential. Arrandea (1989) considered translocation of assimilates to be a trait associated with dehydration tolerance in rice. When stress develop during grain filling, dehydration tolerance may allow plants to maintain metabolic activity for a few additional days and hence continue the translocation of stored assimilates to fill grain (Weng *et al.*, 1982). Free radical detoxification, synthesis of methylated metabolic products, accumulation of protective molecules, ion transport, structural and metabolic adjustments, all play important roles in desiccation protection. A variety of biochemical and physiological pathways act in a combinatorial sense to create a tolerant type (Thomas, 1996).

2.3.4. Drought recovery

The capability of rice cultivars to rehydrate after the stress period, is of importance to drought recovery. Recovery of a genotype from drought is related to its ability to retain green leaves during that period. Lines with good leaf retention can supply more assimilates to the developing panicle during subsequent recovery. This in turn results in production of a large number of spikelets (Lilley and Fukai, 1994b).

2.4. PUTATIVE TRAITS FOR IMPROVING DROUGHT RESISTANCE AND SELECTION INDICES

To provide a basis for integrating physiological research with plant breeding objectives, Fuaki and Cooper (1995) defined drought resistance in terms of relative yield of genotypes. A drought resistant genotype will be one which has a higher grain yield than others when all genotypes are exposed to the same level of water stress. Under lowland condition, grain yield under stress was most strongly correlated with visual scoring. Aeroponically studied traits were not correlated with traits of stressed plants in the field. Among the traits studied (Visual scoring, canopy temperature, uprooting force and aeroponically studied traits), visual scoring was found to be most suitable (Ingram *et al.*, 1990). Thangaraj and Sivasubramanian (1990) also reported visual scoring of rice genotypes to be effective in identifying plants with high leaf water status. In rice, a large number of putative traits (morpho-physiological traits) which may affect grain yield under drought conditions have been suggested by O'Toole (1982).

2.5. ROOT SYSTEM

Under upland conditions, rice, maize and sorghum possessed similar root length density and water extraction pattern upto 60 cm depth but below that water extraction by rice was small and this was the main reason for its susceptibility to

water stress when compared to sorghum (Fukai and Inthapan, 1988, Inthapan and Fukai, 1988). The development of rice root system is sensitive to soil water deficit (Boonjung, 1993). O'Toole (1982) suggested three root related adaptive mechanisms for rice. (i) Increased rooting depth, root density, root shoot ratio and root conductance for upland conditions, (ii) Increased root penetration and, (iii) Root osmotic adjustment.

There is large variation among rice lines with high root length density below 30 cm and those lines with deeper root system. Yoshida and Hasegawa (1982) used the ratio of deep root weight to shoot weight as an index for drought avoidance because large deep root system are able to extract more water and small shoots transpire less. They found that the ratio was positively related to field evaluation of drought resistance. They also found that those lines with large deep root to shoot ratio tended to be taller and have less tillers. Lines with small number of well developed tillers have fewer long roots and this results in high root length density at depth.

Puckridge and O'Toole (1981) found that a deep rooting cultivar, Kinandang Patong extracted more water at 40-70 cm depth than the two cultivars IR 20 and IR 36 which were shallow rooted. Similar results were obtained by Mambani and Lal (1983 b and c). Lilley and Fukai (1994 a) also found that under upland conditions, variation in water extraction among four cultivars was directly related to the variation in root length density.

Lines with large root length tend to have high leaf water potential and delayed leaf death during drought (Mambani and Lal, 1983a, Cruz and O'Toole, 1985; Ekanayake *et al.*, 1985a). This favourable plant water status may result in larger grain

yield under limiting water condition (Mambani and Lal, 1983 a), although this is not always observed (Puckridge and O'Toole, 1981). Lilley and Fukai (1994 b) reported that cultivars with the greatest root length performed better than others under mild stress conditions. However, there was no direct relationship between total root length and grain yield when there was only one period of prolonged drought. It is likely that the advantages of large root systems would be greater when there are several drought periods i.e. under intermittent stress (Fukai and Cooper 1995). Further, under lowland paddy, the ability to penetrate hard pan rather than potentially larger root length would be more advantageous. Ingram *et al.* (1990) also reported that there was no relation of grain yield under lowland condition with root characters of rice determined on aeroponically grown plants. Nevertheless under the sandy soil texture, genotypic variation in root length at depth may be expressed and large root length may be a useful character (Fukai and Cooper, 1995).

2.6. SHOOT RELATED TRAITS

O'Toole (1982) suggested three shoot related adaptation mechanisms. (i) accumulation of amino acids or growth regulators, (ii) drought avoidance mechanisms and (iii) osmotic adjustment.

2.6.1. Growth regulators

Little work has been done in rice related to growth regulators and drought resistance. Dingkuhn *et al.* (1991) found genotypic variation in abscisic acid accumulation but the differences were not related to the physiological behaviour of lines under water stress. Davies and Zhang (1991) reported that ABA was the major signal from roots in drying soils, accumulation of which is directly related to drought tolerance.

2.6.2. Avoidance mechanism

Leaf diffusive conductance and leaf rolling are drought avoidance mechanism for which genotypic variation has been well documented (O'Toole and Cruz, 1980). The variation is at least partly due to differences in the ability to extract water from the soil as a result of differences in the root system. This causes maintenance of leaf water status. The lines which maintain high leaf water potential with little leaf rolling have higher leaf conductance under drought (O'Toole and Moya, 1978). However, relationship between leaf rolling and leaf water potential varies among lines possibly because of osmotic adjustment (Turner *et al.*, 1986; Fukai and Inthapan, 1988). Lines with high osmotic adjustment may be able to maintain turgor at low leaf water potential. Osmotic adjustment is known to affect leaf rolling in rice (Hsiao *et al.*, 1984). Dingkuhn *et al.* (1989 a) found a correlation between leaf rolling and water potential suggesting that leaf rolling has a positive effect on maintenance of high water potential. In contrast, Fukai and Cooper (1995) suggested that lines which were able to maintain high leaf water potential have a small degree of leaf rolling. This indicated that leaf rolling is the result of other avoidance mechanisms which in turn resulted in high leaf water potential.

Upland rice have more diffusive resistance (O'Toole and Cruz, 1980). However, stomatal resistance is highly dynamic and responsive to various stimuli. Moreover, environmental factors contributing to drought are variable. As such, stomatal resistance as a general selection criteria for drought tolerance in rice genotypes appear to be remote. Dawn leaf water potential which reflects the varietal differences indicates the capability to rehydrate overnight may be a good indicator of a variety's root development system.

2.6.3. Green leaf retention

Leaf death occurs as a result of severe drought and is easily recognisable in the field. Green leaf retention is often used as a selection criteria for drought resistance in rice (De Datta *et al.*, 1988). Lines with good leaf retention produce higher yield than others in dry environments. Lines with good green leaf retention also recovered best after water stress was relieved (Malabuyoc *et al.*, 1985). Maintenance of green leaf indicate possession of drought avoidance mechanism. Some lines also were able to maintain green leaves at low leaf water potential, which are dehydration tolerant (Handerson *et al.*, 1993). Recovery of a genotype from drought is related to its ability to retain green leaves for supply of assimilates to the developing panicles during subsequent recovery (Lilley and Fukai, 1994 b). There is a genotypic variation in expression of green leaf retention which appears to be a useful character for prolonged drought but it is affected by plant size which complicate its use as a selection criteria for drought resistance.

Boonjung (1993) has shown that leaf death is less sensitive to soil water deficit than leaf elongation and leaf diffusive conductance. This implies that in mild and intermittent stress, plant growth will be affected by reduced leaf expansion and photosynthesis. Fukai and Cooper (1995) found no relationship between leaf conductance and drought score indicating that selection for low drought score may not necessarily select for high leaf conductance under stress conditions.

Ingram *et al.* (1990) found correlation of field drought score and grain yield under rainfed low land condition. Lines with low drought score, however, do not necessarily perform well under dry conditions (Puckridge and O'Toole, 1981). The use of drought score at the seedling stage may be appropriate for drought that develop early in the season such as in direct seeded rice.

2.7. SEEDLING GROWTH

Seedling vigour is important for stand establishment in direct seeded rice. Genotypic differences were highly significant for seedling vigour traits both in green house and field conditions (Redona and Mackill, 1996). Seed germination and seedling emergence were reduced under water stress conditions (Zhang *et al.*, 1996; Jha and Sing, 1997 and Yang *et al.*, 1997). However, the drought tolerant varieties showed better germination and seedling growth under water stress conditions (Goswami and Baruah, 1994, Jha and Singh, 1997).

2.8. INDUCTION RESPONSE

Liu-xiaozhong *et al.* (1997) reported that pretreatment of rice seedling with 0.1% NaCl and placed in 0.3% NaCl produced higher dry weight than those treated with 0.3% NaCl directly; and Na^+ contents were lower, K^+ content in seedlings pretreated with 0.1% NaCl was higher than the treatments with 0.3% NaCl directly.

He and Yu (1995) reported that after pretreatment with 100 mmoles/litre NaCl for 2 days, followed by 200 mmoles/litre NaCl for 4 days, the contents of Na^+ and Cl^- in roots, stems and leaves of tolerant and susceptible genotypes were lower than those of plants treated with 200 mmoles/litre NaCl. Proline content was high in pretreated seedlings compared to seedlings of direct exposure to 200 mmoles/litre NaCl.

Gill and Singh (1988) studied varieties of *Oryza sativa* viz., Jaya (salt tolerant) and Basmati (salt sensitive) for salt tolerance. They found that salinity retarded root and shoot growth and on removal of salt stress the seedlings began to recover. Root and shoot weight decreased with salinity and recovery gap widened with days under stress. Jaya was observed to gain more weight than Basmati and recovery was also

better in Jaya. But seed weight in Jaya decreased more than in Basmati. They have concluded that salinity caused less reduction in endosperm weight due to decreased metabolic mobilization. They attribute Jaya's faster recovery, to higher metabolic utilization from the endosperm.

Several experiments have shown that plant system which are pretreated with a low level of salt stress (**induced** or adapted) can tolerate higher levels of stress and grow better compared to a **non induced** or non adapted system (Uma, 1992; Joseph, 1993, Venugopala Reddy, 1994). On similar lines in studies conducted by Greenway and Munns (1980); Hasegawa *et al.* (1986) with cell suspension of *Nicotiana tobaccum* growing in varying levels of NaCl, it was found that after adaptation to NaCl the growth response to tobacco cells resembled that of halophytic growth behaviour. Dry weight gain on media with low to moderate levels of NaCl was equivalent to or greater than that in medium without salt (Binzel *et al.*, 1985). In addition, the capability of these cells to retain water upon exposure to NaCl also was enhanced through the process of adaptation. Although salt adapted cells were able to grow in higher levels of NaCl than the unadapted cells.

Djanaguiraman (2000) reported that the recovery growth of induced rice seedlings was better over non-induced rice seedlings under salinity.

2.9. MORPHOLOGICAL CHARACTERS

2.9.1. Plant height

In general, moisture stress resulted in reduced plant height and the susceptible lowland types were more sensitive than upland varieties (Basu Raychaudhuri and Das Gupta, 1981), Vijayalakshmi and Nagarajan (1994) observed marginal reduction

of plant height in tolerant rice varieties with well developed rooting system. Tomar and Prasad (1996) reported that plant height in rice was associated with thick and deep root system.

2.9.2. Root length

Yoshida *et al.* (1982) and Zuno-Altoveros *et al.* (1990) reported that deep root system in rice was correlated with tall plant stature and low tillering. However, deep root system was found to be more related to low tillering habit. Drought resistant cultivars were found to show vigorous root development (Simane *et al.*, 1993; Namuco *et al.*, 1993). Deep root system have the capacity to absorb water from deep horizon (Ingram *et al.*, 1994; Lilley and Fukai, 1994a; Rao and Shrivastav, 1994). Drought tolerant cultivars were characterised by longer and more numerous roots (Gomathynayagam and Soundarapandian, 1987). Roots of upland rice cultivars in light textured upand soils may grow to a depth of 1m or more while roots of lowland rice rarely grow deeper than 40 cm. Desiccation tolerance increased with increasing rooting depth (Gomosta and Haque, 1995).

Water stress reduced mean root length and root shoot ratio (Sorte *et al.*, 1992). Root growth ceased in all cultivars on imposition of water deficit. The cultivars differed in their inherent rooting pattern with total root length ranging from 1.3 to 33.7 km m⁻² but showed no difference in the ability to alter root growth during water deficit (Lilley and Fukai, 1994a). Singh and Patel (1995) however reported that water stress favoured root growth in upland rice. Boonjung and Fukai (1996a) on the other hand, reported that root growth of upland rice was very sensitive to soil water deficit during the early growth stages.

Rao *et al.* (1994) while studying the nature on sustenance and recovery from drought in deep and shallow rooted rice cultivars concluded that a deep rooting system did not have any advantage for recovery from drought. Vijayalakshmi and Nagarajan (1994) compared drought tolerant and drought susceptible rice varieties on the effect of rooting on productivity under different water regimes. They found that drought tolerant variety had better root penetration and distribution under water stress situation and had consistent yield in all situations.

2.9.3. Root volume

Root volume is a reliable index for rooting pattern. Vijayalakshmi and Nagarajan (1994) reported that decreasing water level resulted a reduction in root volume. However, tolerant variety registered more value than susceptible variety. It may be attributed that the root volume increase was mainly due to the proliferation of root at top layer and the roots were thick and dense, where as under water deficit situations even the tolerant types produced slender and long roots to absorb moisture from lower layers.

Sadasivam *et al.* (2000) reported that drought tolerant rice genotypes (land races) showed increasing root length, root thickness and root biomass under water stress conditions.

2.9.4. Leaf number

Leaves in general are considered as an important functional units of plant which contribute to the formation of yield. The lack of cell expansion due to water shortage would be determined by an increased leaf area rather than the number of leaves (Hsiao, 1973). Reduction in total leaf area under water deficits was attributed to the restricted leaf growth and accelerated leaf senescence (Lud low and Muchow, 1990).

2.9.5. Leaf area

Leaf Area Index (LAI) particularly at flowering stage had a specific role in deciding dry matter production and grain yield of rice (Swain *et al.*, 1986). Among the two components of source: number of leaves and individual leaf size, the former had major impact for deciding the LAI in rice (Mohandass, 1989).

During water stress period, the cultivar with a small canopy maintained higher plant water status as compared to a cultivar with large canopy. However, the cultivar with small canopy could not fully recover from stress (Prasertsak and Fukai, 1997). Mitchell *et al.* (1998) also reported that cultivars with large leaf area tended to lose more green leaves during the stress period. They further noted that green leaf area retention after the stress period was the subsequent growth determining factor in rice. Marginal reduction in leaf area under water stress condition was observed in drought tolerant rice varieties (Vijayalakshmi and Nagarajan, 1994). Lilley and Fukai (1994b) reported that susceptible varieties of rice responded to water deficit in terms of rapid decline in leaf elongation and greatest leaf death. Jayabalan *et al.* (1995) and Wang *et al.* (1996) reported a decline in LAI of rice varieties due to moisture stress. Leaf area was reported to be reduced as much as 54.3 per cent in a traditional upland rice variety when subjected to 35 days moisture stress (Chauhan *et al.*, 1996).

Baruah *et al.*, (1998) reported that there was decrease in leaf area per seedling under stress condition in all the rice cultivars.

2.10. GROWTH ATTRIBUTES

2.10.1. Leaf area index (LAI)

LAI, the ratio of leaf area to land area, is an important plant factor as a determinant in determining the drymatter production and hence the crop yield. Chau

and Deshmukh (1989) indicated a LAI of about 4.6 to 6.0 at flowering was sufficient to produce the grain yield of 6 t/ha in rice. Hence it was concluded that an optimum LAI at flowering was in the range of 4.5 to 6.0. Dingkuhn *et al.* (1991) observed a negative relationship between LAI at flowering and grain yield in rice, because high yielding cultivars possess relatively low LAI (4.19) and low yielding cultivars possess relatively high LAI (6.5). Murthy *et al.*, (1992) while associating LAI and Pn rate in rice observed that rice cultivars having high Pn rate and low LAI resulting in low canopy photosynthesis. On the other hand, cultivars with moderate Pn and high LAI recorded high DMP and yield.

Moisture stress induced changes in leaf area was also noticed in leaf area index which varied with different moisture levels duely reflected in biomass yield (Kerby *et al.*, 1990). De Souza *et al.* (1997) observed reduction in LAI due to acceleration of senescence under drought. Jayabalan *et al.* (1995) and Wang *et al.* (1996) reported a decline in LAI of rice varieties due to moisture stress.

2.10.2. Leaf area duration (LAD)

The LAD is the sum of different growth stages mean LAI over time and hence represents time span of active photosynthesis by the leaves. LAD, in general, indicated that drymatter accumulation was a direct function of leaf area (Power *et al.*, 1967). It integrated responses to environmental factors such as photoperiod and temperature which affect the rate and duration of photosynthesis (Wallace *et al.* 1972). Ramanujam (1985) pointed out that maintenance of optimum LAI over a longer period i.e. higher LAD was important for maximising yield in crop plants. In rice positive correlation between LAD during grain filling with grain yield ($r = +0.650$) was observed by Chau and Deshmukh (1989). Gonzalez and Paez (1996) reported that LAD was reduced when water stress occurred during reproductive stage.

2.10.3. Specific leaf area (SLA)

Specific leaf area (SLA) is a measure of leaf thickness which varies with cultivar, leaf position, growth stage and environment (Murata, 1975). These relationships come in handy to explain the degree of growth under each environmental situation in crop plants. The SLA increased markedly during the early part of the vegetative phase. Usha Rani (1979) noted that SLA was inversely related to SLW. The linear relationship between SLA and NAR indicated the association of thicker leaves with higher NAR and vice versa. Leaves formed in summer were generally thicker (Saini and Das, 1979). The relationship between NAR and SLA is largely as a function of existing light condition prevalent at different times during crop growth.

2.10.4. Specific leaf weight (SLW)

Specific leaf weight (SLW) defined as leaf dry weight per unit area has been reported to have a strong positive correlation with leaf photosynthesis in several crops. (Bowes *et al.*, 1972; Delaney and Dobrenz, 1974; Dornhoff and Shibbes, 1976; Lugg and Sinclair, 1979) P_n showed a strong positive association with SLW at post flowering stage. SLW on the other hand, was significantly and positively associated with leaf thickness. Thus, to a large extent, SLW was found to be dependent on the leaf thickness (Lugg and Sinclair, 1980). According to Mehra *et al.* (1987), SLW was an important feature in the storage of photosynthates and its subsequent translocation to the developing seed.

Khan *et al.* (1997) reported that specific leaf weight was seriously decreased by salinity.

2.10.5. Net assimilation rate (NAR)

The Net assimilation rate (NAR) is the net gain in total dry matter per unit leaf area per unit time. Gregory (1917) was the first to suggest the use of this function in

growth analysis. NAR and RGR were considered as important plant traits governing crop growth (Gregory, 1926). He postulated that internal factors largely determined leaf area whereas external factors were primarily responsible for variation in NAR. He evidently showed that NAR for a number of crops grown under uniform conditions was approximately constant. Shibles and Weber (1965) studied the relationship between NAR with increasing leaf area as a parameter of growth. The NAR showed a rapid decrease after anthesis which coincided with the senescence and shedding of leaves (Ojehomon, 1970). Patra *et al.* (1995) pointed out that LAI 50 and 70 days had negative influence on NAR but the relationship was significant only in case of LAI at 50 days. NAR had negative correlation with chlorophyll content but positively correlated with chlorophyll a:b ratio (Naresh Kumar and Singh, 1996).

Dutt and Bal (1988) reported that salt tolerant variety has less reduction in NAR compared to susceptible variety.

2.10.6. Crop growth rate (CGR)

The crop growth rate (CGR) is the product of LAI and NAR expressing the drymass production per unit land area per unit time. The CGR changes with the age of the crop due to gradual changes in photosynthetic efficiency. Ojehomon (1970) employed CGR particularly to study the association with NAR, LA and LAI. CGR generally increased with higher LAI. The CGR for genotypes with longer reproductive phase was less than varieties with shorter reproductive phase. CGR values increased upto 45 days and thereafter declined till maturity. Crop production was determined by the CGR as a function of light interception in crop canopy (Whigham, 1983). Jayabalan *et al.* (1995) reported reduction in crop growth rate of rice cultivars due to moisture stress. Zhang *et al.* (1997) reported greater inhibition of CGR and physiological activities of five rice varieties under water stress condition.

2.10.7. Relative growth rate (RGR)

The RGR is a complex genetically controlled physiological component of yield (Wallace *et al.*, 1972). It is a derivative of the differences in drymatter accumulation and is not related to the yield, although it has relationships with the total drymatter produced (Krishnamurthy *et al.*, 1976) water stress has been reported to reduce the relative growth rate in crop plants (Wallace and Munger, 1965; Seetharani, 1990; Gonzalez and paez, 1996).

2.11. PHYSIOLOGICAL PARAMETERS

Rice crop response to water deficit most often has been reported in terms of plant height, tiller number, leaf area, dry weight of roots and shoots and yield. Few studies however documented the response of rice metabolic processes to water deficit. After accounting for differences in water extraction ability, cultivar deficiency in sensitivity of physiological processes to water deficit were small (Lilley and Fukai, 1994b). Duration of physiological activity was determined to a large extent by the ability of cultivars to extract water. Greater extraction prolonged physiological activity and crop growth.

2.11.1. PIGMENTS

2.11.1.1. Chlorophyll content

Water stress decreased chlorophyll content in rice leaves (Jayabalan *et al.*, 1995; Yang *et al.*, 1995b; Sheela and Alexander, 1996). Increasing intensity of water stress decreased leaf chlorophyll content and tended to increase the chlorophyll a:b ratio (Zhu and Huang, 1994). The chlorophyll content of drought tolerant upland rice varieties were reported to be higher under water deficit conditions (Sheela and Alexander, 1996; Peng *et al.*, 1996).

Baruah *et al.* (1998) reported that total chlorophyll content was decreased under stress condition in all the rice cultivars. Aruna tyagi *et al.* (1999) reported that rice genotypes have lowest values of RWC under water stress.

2.11.1.2. Relative water content

Water deficit reduced water status of leaves in rice plants (Saxena *et al.*, 1996; Sheela and Alexander, 1996). Krishnayya and Murty (1991) and Sorte *et al.* (1993) reported that relative water content of upland rice cultivars decreased with the increase in soil water deficit. Drought resistant varieties showed consistently higher leaf water potential in their tissues than susceptible types under soil moisture deficit (Swamy *et al.*, 1983; Natarajan and Kumaravelu, 1993). Thangaraj and Sivasubramanian (1990) noted a higher relative water content in drought tolerant cultivars than susceptible varieties under stress. Several other authors (Saxena *et al.*, 1996; Sheela and Alexander, 1996; Tomar and Prasad, 1996; Zhang *et al.*, 1997; Jha and Singh, 1997) also reported similar observations. The genotypes maintaining higher relative water content, accumulated solutes and had higher photosynthesis (Krishnayya and Murty, 1991) and higher recovery upon stress relief (Saxena *et al.*, 1996; Jha and Singh, 1997).

2.11.1.3. Leaf gas exchange parameters

The leaf characteristics viz., photosynthetic rate, transpiration rate, stomatal resistance and leaf temperature expressed the significance of various physiological processes along with their impact on biomass production and grain yield (Dey and Rao, 1989). In rice, stomatal conductance showed direct relationship with photosynthesis and grain yield (Dingkuhn *et al.*, 1989a, Murthy *et al.*, 1991). Water stress decreased photosynthesis at both single leaf and plant community level

(Yang *et al.*, 1995a). Leaf rolling increased stomatal resistance at critical leaf water potential between -0.8 to -1.2 MPa. Leaf diffusive resistance was linearly related to leaf water potential (O'Toole and Cruz, 1980; Dingkuhn *et al.*, 1989a). Higher leaf diffusive resistance was observed in upland varieties than in semidwarf varieties. Leaf injury level at 50°C and under moisture stress was also lower in the upland varieties (IRRI, 1973, 1975, O'Toole and Cruz, 1980). Leaf diffusive resistance rose with soil moisture tension and the onset of the reproductive stage. Dingkuhn *et al.* (1989 a) reported that stomatal closure was more sensitive in upland variety during stress. Leaf water deficit restricted gas exchange through leaf rolling and reduced stomatal conductance. There were significant differences in gas diffusion resistance among types and cultivars of rice which in turn decided the diffusion of CO₂ from atmosphere to the active site of carboxylation (Chen *et al.*, 1990). Wang *et al.* (1996) observed decrease of photosynthesis in rice cultivars as soil water potential decreased. Drought resistant cultivars showed less decrease in photosynthesis. Chauhan *et al.* (1996) reported that improved upland cultivar transpired less water during moisture stress while exhibiting higher stomatal resistance. They further noted that stomatal resistance increased with increasing intensity of moisture stress.

2.11.1.4. Leaf water potential (ψ_1)

O'Toole and Moya (1978) monitored leaf water potential of 17 rice genotypes during stress. They observed dawn leaf water potential of -0.3 to -0.9 MPa while midday leaf water potential ranged between -1.6 to -3.0 MPa. Maintenance of higher leaf water potential in a cultivar was due to better root system. However, varieties that adjusted to lower leaf water potential were dehydration tolerant. Upland rice cultivars maintained higher leaf water potential during drought (O'Toole and Cruz, 1980). They also observed linear relationship of leaf diffusive resistance and leaf rolling with leaf

water potential. Ekanayake *et al.* (1989, 1990) also observed higher leaf water potential of drought resistant rice lines. Decline in leaf water potential was most rapid in susceptible varieties and during reproductive stage when stress was imposed (Lilley and Fukai 1994 c).

Working on 28 rice varieties, Dingkuhn *et al.* (1989 b) reported a critical leaf water potential between -0.8 to -1.2 MPa for stomatal closure. Leaf water potential of upland rice varieties decreased with the increase in soil moisture stress (Krishnayya and Murty, 1991; Lilley and Fukai, 1994 c) because of large demand of transpiration water (Boonjung and Fukai, 1996 a).

2.12. BIOCHEMICAL PARAMETERS

2.12.1. Carbohydrate fractions

At low soil water potentials, leaf sucrose and soluble sugar content increased while starch content decreased. Drought resistant rice cultivars showed greater accumulation of sugars and starch than drought susceptible cultivars (Wang *et al.*, 1996; Jha and Singh, 1997). Water stress during meiosis resulted in pollen sterility due to carbohydrate starvation. Reducing and non-reducing sugars accumulated during stress but there was inhibition of starch accumulation (Sheoran and Saini, 1996). Chaturvedi and Ingran (1988) reported that under dry conditions, yield and drought tolerance were associated with storage of carbohydrates in culms and its translocation to seeds. Carbohydrates such as glucose, fructose, sucrose, sorbitol and starch were to be increased with increasing stress symptoms (Schmid and Feucht, 1986).

Though sugar accumulation is not the only way by which plants deal with desiccation, it is considered as an important factor (Bohnert *et al.*, 1995). Soluble sugars accumulate during acquisition of desiccation tolerance (Leprince *et al.*, 1993). Sugars may serve as compatible solute permitting osmotic adjustment along with proline, glycinebetaine and mannitol. Sugars may also stabilise proteins under stress (Crowe *et al.*, 1992). Many carbohydrates have been viewed central to stress protection via osmoprotection and / or compatible solutes. Sucrose concentration has been linked to desiccation tolerance (Koster and Leopold, 1988). Over production of fructans resulted in augmented survival under stress. similarly trehalose was a very effective stabilizing compound during stress (Lippert and Galinsia, 1992).

Jha and Singh (1997) reported that tolerant rice varieties have high total sugar content under water stress condition than susceptible varieties.

2.12.2. Proteins and enzymes

2.12.2.1. Soluble Protein Content

Soluble protein content in rice leaves was reduced due to moisture stress (Jayabalan *et al.*, 1995). Jha and Singh (1997) reported higher protein content of stressed seedlings of tolerant rice cultivars as compared to susceptible cultivars. Protein contents in leaves were found to be correlated with plant growth rate, soil water holding capacity, LAI, tillering and panicle number (Jayabalan *et al.*, 1995).

Jha and Singh (1997) reported that tolerant rice varieties have high soluble protein content under water stress condition than susceptible varieties.

2.12.2.2. Nitrate Reductase Activity

Saxena *et al.* (1996) and Jha and Singh (1997) reported that NRase activity of rice genotypes decreased when plants were subjected to drought. The tolerant types

however maintained NRase activity in their leaves during stress as compared to the susceptible ones and showed higher recovery upon drought relief (Liu *et al.*, 1993, Saxena *et al.*, 1996; Jha and Singh, 1997). Sairam and Dube (1984) reported that stability of NRase activity under moisture stress was positively correlated with enzyme recovery on subsequent irrigation and was closely correlated with the leaf relative water content and yield.

Baruah *et al.* (1998) reported that Nitrate reductase activity was decreased under stress condition in all the rice cultivars.

2.12.2.3. Activated Oxygen Species and Detoxifying Enzymes in Rice Under Water Stress

Activated oxygen species generation under water stress may be responsible for most of the damage to cellular components (Allen, 1995; Willekens *et al.*, 1995). Photooxidation, due to excess excitation energy leads to production of superoxides, peroxides and hydroxyl radicals which are highly reactive and damaging to biological systems reacting quickly with membranes, proteins and DNA which has been linked to degenerative diseases and ageing (Shigenaga *et al.*, 1994).

The importance of over expression of SOD gene in stress tolerance has been demonstrated by Smirnov (1993). Several isoforms of SOD were over expressed in tolerant species upon stress (Bowler *et al.*, 1991). SOD converts oxygen radicals into peroxides, which are then degraded by peroxidases and catalases. Over expression of SOD isoforms can enhance protection of plants under stress (Allen, 1995).

2.12.2.4. Drought stress and SOD activity

The biological significance of SOD as a protective enzyme has been established by Fridovich (1986); Scandalios (1993) and Bowler *et al.* (1992). Increased activity of the enzyme during stress was due to response to the increased

production of oxygen radical formed under stress conditions. Three forms of SOD (Cu/Zn-SOD, Mn-SOD and Fe-SOD) have been identified in plants (Baum and Scandalios, 1979 and 1982). Chloroplastic SOD's are abundant in green leaves while in etiolated and germinating seedlings, cytoplasmic and mitochondrial SOD's prevail (Jackson *et al.*, 1978). Chowdhury and Choudhury (1985) reported a decrease in SOD activity in drought sensitive jute cultivars as compared to tolerant cultivars. Malan *et al.* (1990) found that tolerance to drought was due to high activities of Cu/Zn-SOD in maize. Dellongo *et al.* (1993) compared maize lines for differential sensitivity to drought. The damage was less obvious in tolerant lines having high SOD activity and catalase. Van Rensburg and Kruger (1994) found that SOD activity in tolerant cultivars was 224 per cent higher. Wang *et al.* (1995) reported initial decrease followed by an increase in SOD activity when maize was exposed to water stress. Zhang and Kirkam (1994) however observed an initial increase in the activity of SOD isoforms followed by a decrease, with an increase in magnitude of water stress in wheat, similar observation was reported by Ranjita *et al.* (1994). Zhu and Huang (1994) reported that SOD activity increases with an increase in soil water stress in rice. Dhindsa and Matowe (1981) and Zelitch (1990) reported that the extent of drought **induced** damage to membrane was negated with increasing activities of SOD and catalase in drought tolerant and sensitive mosses.

2.13. AMINO ACIDS

2.13.1. Proline content

Proline an amino acid has been shown to accumulate in plants including rice when subjected to water stress (Mukherjee, 1974, Chu *et al.*, 1976; Huang and Cavalieri, 1979; Boggess and Stewart, 1980; Greenway and Munns, 1980, Singh and Malik, 1985; Sheela and Alexander, 1996; Zhang *et al.*, 1997). Blum and

Ebercon (1976) and Dix *et al.* (1986) proposed that proline may be a store of nitrogen or respiratory substrate to facilitate post stress recovery. Itai and Paleg (1982) suggested several possible functional roles of proline such as cytoplasmic osmoregulations, prevention of enzyme inactivation and stabilization of biopolymer stability. However, some workers have suggested that proline had no adaptive role and was merely a pathological consequence to stress (Hanson *et al.*, 1979; Tully *et al.*, 1979).

Conflicting reports of drought mediated proline accumulation in drought tolerant and drought susceptible rice genotypes were noted. Dingkuhn *et al.* (1991a) determined free proline in seven diverse rice genotypes. They reported 85 - 517 $\mu\text{g g}^{-1}$ and 32-74 $\mu\text{g g}^{-1}$ proline in stressed and control plants respectively. They further reported that proline content was higher in lowland adapted cultivars both under control and stressed plants. Pattern of proline accumulation was found to be similar to that of osmotic adjustment and midday leaf water potential. However, different critical leaf water potential was observed for osmotic adjustment (-1.3 MPa) and proline accumulation (-2.2 MPa). Further, proline accumulated exclusively in cytoplasm whereas osmotically active solutes were located in the vacuoles. They concluded that proline accumulation reflected varietal differences in stress development but not necessarily differences in proline accumulation ability. Liu *et al.* (1993) reported more accumulation of proline in upland drought tolerant varieties during drought. Yang *et al.* (1995a) reported that in drought resistant cultivars of rice, accumulation of proline in leaves under drought began earlier and lasted longer. Zhang *et al.* (1997) also reported rapid accumulation of proline in upland rice varieties as compared to drought susceptible varieties.

Baruah *et al.* (1998) reported that proline content was increased under stress condition in all the rice cultivars.

2.14. OTHER METABOLITES

2.14.1. Phenolics content

Abdallah (1985) reported differential response of cotton genotypes with regard to total phenolics content. They observed reduced total phenols and o-dihydroxyphenol contents of the roots but increased in the leaves of Ashmouni while in cv. Minoufi there was reduction in phenolics in both the roots and leaves under drought. Abdallah (1985) also reported increase in phenol content during flowering stage of cotton under drought. Ashraf *et al.* (1994) reported increased accumulation of total phenols in wheat under drought and the accumulation was more in susceptible genotypes.

2.15. TOTAL DRY MATTER PRODUCTION (TDMP)

Dry matter accumulation in rice cultivars decreased as leaf rolling and crop canopy to air temperature difference increased under moisture stress condition (Turner *et al.*, 1986). Simane *et al.* (1993) reported that the rate of total dry matter accumulation varied in drought resistant and susceptible cultivars. The post-flowering total dry matter was strongly related to grain yield (Murty *et al.*, 1993). Singh and Patel (1995) observed a reduced aerial plant biomass of rice under water deficit condition. Lilley and Fukai (1994b) reported that water stress reduced biomass production in rice varieties and the degree of reduction depended upon the severity of moisture stress. Dry matter yield of rice genotypes were reduced by 11-37 per cent and 30-65 per cent under mild and severe moisture stress respectively (Yang *et al.*, 1995b). Boonjung and Fukai (1996a) also reported similar results.

Chauhan *et al.* (1996) reported that cultivars differed in their ability to produce dry matter under stress. They noted 40.3 per cent and 67.3 per cent reduction in dry matter accumulation due to moisture stress in improved upland and traditional upland varieties respectively.

2.16. YIELD AND YIELD COMPONENTS

Water deficit reduces grain yield of rice (Fussell *et al.*, 1991; Lilley and Fukai, 1994c; Yang *et al.*, 1995b). The yield reduction was associated with reduced panicle number, grain number per panicle and potential grain size. The degree of reduction in yield depends upon the genotype, timing and severity of water deficit. Under upland conditions, tall varieties maintained stable yield under the adverse soil moisture regime and was linearly related to root density at depth of 25 cm (Mambani and Lal, 1983b; Liu *et al.*, 1993). Vijayalakshmi and Nagarajan (1994) reported that tolerant rice varieties having well distributed rooting system had more stable grain yield under drought due to their ability to maintain a high leaf water potential at anthesis. Cruz and O'Toole, 1984; Ekanayake *et al.*, 1989 and 1990; and Jayabalan *et al.* 1995 also reported that reduction in grain yield was less in tolerant varieties under drought.

Maurya and O'Toole (1986) found large genotypic variation in filled grain percentage during dry season. Reduction in the leaf water potential at anthesis caused poor panicle exertion (O'Toole and Namuco, 1983; Cruz and O'Toole, 1984; Ekanayake *et al.*, 1989) and this increased the percentage of sterile spikelet because of pollination abnormalities. Rice genotypes were most sensitive to drought during reproductive stress (Lilley and Fukai, 1994c, Boonjung and Fukai, 1996b). Ingram and Yambao (1988) and Fussell *et al.* (1991) reported that reduction in grain yield was more than 40 per cent when stress was imposed during mid-flowering period.

Lilley and Fukai (1994b) observed grain yield reduction upto 70 per cent due to occurrence of water deficit during reproductive stage.

Water stress at booting and heading to flowering stages reduced number of productive tillers, grain number per plant and 1000 grain weight (Liu *et al.*, 1993). Lilley and Fukai (1994c) and Boonjung and Fukai (1996b) studied the effect of timing and severity of water stress on growth and yield of rice. They found that the effect of water stress was most severe when drought occurred during panicle development. The result was that anthesis was delayed, number of spikelets per panicle was reduced to 60 per cent and the percentage of filled grain was also reduced. When drought occurred during grain filling, the percentage of filled grains decreased to 40 per cent individual grain mass decreased by 20 per cent.

Grain yield, relative grain yield and spikelet fertility were significantly and negatively correlated to the number of days beyond the beginning of stress period that cultivar flowered (Garrity and O'Toole, 1994). The grain yield of rice was reduced by 5-38 per cent under mild water stress while severe water stress reduced grain yield by 25-67 per cent (Yang *et al.*, 1995b).

Harvest index had shown a consistent association with grain yield in rice (Reuben and Katuli, 1990). Water stress reduced harvest index (Singh and Patel, 1995). Genotypes having greater tolerance to water stress recorded higher number of grains and grain weight per panicle, grain yield per plant and harvest index under drought (Saxena *et al.*, 1996).

2.17. SDS - PAGE

2.17.1. Proteins synthesized in response to water stress induction

2.17.1.1. Stress shock proteins (SSPs)

Plants respond to several abiotic stresses by *de novo* synthesis of a set of new proteins generally referred as stress shock proteins (SSPs) or stress proteins, which may have some relevance in stress tolerance. In recent years extensive work has been done to understand the synthesis (gene regulation) and relevance of these proteins as one of the tolerance mechanisms though the results are not conclusive yet.

Synthesis of stress proteins (26 and 43 kDa) was observed in cultured tobacco cells adapted to NaCl and PEG (Singh *et al.*, 1985). A change in the protein synthesis pattern was detected in barley seedlings when subjected to salinity stress with the synthesis of a new set of proteins (Ramagopal, 1987). Two proteins of 26 and 43 kDa were unique to salt adapted tissue.

A 55 kDa polypeptide was found to accumulate in response to salinity in rice and other genotypes. It was shown that this 55 kDa of rice cross reacted with anti *Neurospora crassa* HSP 80 antibodies (Ashwani pareek *et al.*, 1998).

He and Yu (1995) reported that four new proteins of molecular weight of 21.8, 22.5, 40.7 and 53.3 kDa were present in the callus variant treated with 100 mmol/NaCl, and this 53.3 kDa protein was increased by salinity.

Rani and Reddy (1994) reported that during germination and early seedling growth in rice two predominant polypeptides with apparent molecular weight of 70 and 23 kDa, respectively, were induced under salt stress in germinating seeds of

which the 23 kDa has the most abundant. Two other polypeptides with apparent molecular weight of 15 and 26 kDa were specifically induced in shoots of NaCl treated seedlings. The molecular weight of 15 and 26 kDa exhibited a unique property of boiling stability.

It was assumed that these stress proteins, which are synthesised during a mild/non-lethal stress would protect the organisms when subjected to a subsequent lethal stress. The phenomenon of survival at lethal stress with prior treatment is known as acquired stress tolerance (Vierling, 1991)

The tobacco cell cultures could tolerate 2% NaCl stress with a prior 1.2% NaCl treatment for 3 hours followed by 8 hours recovery period (Harrington and Alm, 1988).

A wide range of stress proteins (15-90 kDa) are synthesised in response to induction. But it is not clear whether all the proteins are involved in acquired tolerance. Importance of certain proteins like HSP 70 and HSP 60 is determined (Clarke and Critchley, 1990).

Dure *et al.* (1983) identified seven groups of proteins depending on appearance or disappearance of tolerance were observed only when the seedlings were subjected to a mild induction stress (-0.6 MPa PEG or 200 mM NaCl.)

Eventhough the relevance of SSP's was quite well established the exact role of these proteins in imparting stress tolerance is still obscure. The recent research area is focussed below.

2.17.2. Osmolytes

Kent and Hanson (1992) showed increase in betaine aldehyde dehydrogenase activity from 2 to 4 fold in both leaves and root of sugar beat as the NaCl levels was raised from 0 to 500 mM.

Plants maintain high water potential during water deficit by osmotic adjustment. A reduction in cellular water potential below the external water potential resulting from a decrease in osmotic potential, allows water to move into the cell. This is achieved by the accumulation of compatible solutes such as betaine and proline in the cytoplasm. Genes that encode for steps in the synthesis of these osmolytes have been identified and in some cases, they have been shown to be induced by osmotic stress (Weretilnyk and Hanson 1989; Arakawa *et al.*, 1990).

2.17.3. Channel protein

Homologues of a tonoplast transmembrane channel protein have been identified in *Arabdiopsis* and pea (Guerrero *et al.*, 1990; Yamaguchi - Shinozaki and Shizozaki, 1993), whose mRNA were found to accumulate rapidly following the onset of desiccation.

The above information suggests that this protein forms intercellular junctions between plant cells and functions in the intercellular transport of small molecules or it may be involved in the transport of small molecules across intercellular membranes such as the tonoplast membrane.

2.17.4. Signal transduction

Covarrubias *et al.* (1995) showed the accumulation of 2 basic cell wall proteins (36 and 33 kDa) in bean seedlings and 21 day old plants grown under water limited conditions.

Charles and Ligawinikov (1995) also found a salt inducible gene encoding a putative chimeric proline rich cell wall protein in alfalfa.

2.17.5. Late Embryogenesis abundance (LEA) proteins

When plant tissues experience water loss, a number of metabolic changes occur, including the accumulation of ABA (Zeevaart and Creelman, 1988) and the synthesis of new proteins and RNAs (Skriver and Mundy, 1990). Most of these transcripts encode polypeptides that are closely related to dehydrin like proteins and to LEA proteins which are abundantly induced during embryo maturation in seeds of many higher plants, as well as in water stressed seedlings (Skriver and Mundy, 1990). An important group of stress responsive genes are late embryogeny abundance (lea) genes which were first identified in maturation and desiccation phases of seed development in cotton. Some drought induced proteins are highly hydrophilic and remain soluble after boiling (Close *et al.*, 1989). These proteins (eg: dehydrins) have been suggested to prevent cellular damage during desiccation by binding to macromolecular structures (Dure *et al.*, 1989). Since dehydrins appear during later embryogenesis, they have also been implicated in the acquisition of desiccation tolerance in seeds (Blackman *et al.*, 1991). Dehydrins probably work in conjunction with other substances (eg. specific carbohydrates and other osmolytes) to prevent desiccation injury (Bianchi *et al.*, 1991). Dehydrins, the D-11 subgroup of late embryogenesis abundant (LEA) proteins (Dure *et al.*, 1989) are frequently observed

and more than 65 plant dehydrin sequences are available (Close, 1997). Dehydrins are highly abundant in the desiccation tolerant embryos and accumulate during the periods of water deficit in the vegetative tissue. These proteins display particular structural features such as highly conserved lys-rich domains predicted to be involved in hydrophobic interaction leading to macromolecular stabilization (Close, 1996). Studies have established correlation between drought adaptation and dehydrin accumulation in wheat and Poplar (Labhili *et al.*, 1995; Pelah *et al.*, 1997). Positive correlations were also reported for species tolerant to stresses that have a dehydrative component such as salt stress (Galvez *et al.*, 1993; Moons *et al.*, 1993) and freezing and cold stress (Artlip *et al.*, 1997). Using western blots with the corresponding antibodies, it was found that in *Populus popularis* accumulation of BsPA and sucrose synthase due to water stress and constitutive presence of dehydrin like protein (dsp-16).

Several LEA genes have been characterized based on deduced amino acid sequence, different LEA group of proteins have been identified and their functions postulated. Among the identified groups of LEA proteins, the LEA 2 and LEA 3 groups have been extensively characterized. The LEA 2 group of proteins, also referred to as dehydrins, are characterized by highly conserved sequence, KIKEKLPG in the carboxy terminus (Baker *et al.*, 1988). LEA 2 protein have been predicted to function as chaperons useful for maintaining protein structure and function (Bray, 1993). LEA 3 could counteract the irreversible damaging effects of increasing ionic strength in the cytosol during desiccation by sequestration of ions (Dure, 1993). LEA proteins are expressed under osmotic stress in mesophytic tissues and since they have unique structure and function, these proteins can be expected to play important role in imparting stress tolerance (Chandler and Robertson, 1994).

Ried and Walker Simmons (1993) demonstrated that higher levels of LEA 3 protein accumulated in severely dehydrated wheat seedlings and this was correlated with high levels of desiccation tolerance. Xu *et al.* (1996) have shown the relevance of LEA 3 proteins in imparting tolerance by over expressing HVA 1 gene, coding for LEA 3 protein which conferred a small increase in tolerance to water deficit and in salt tolerance in transgenic rice. Jayaprakash *et al.* (1998) reported that tolerant finger millet genotype exhibited higher expression of RAB 16 A and M3 that code for LEA 2 proteins, than susceptible finger millet genotypes in response to salinity, partial dehydration and abscisic acid.

Bradford and Chandler (1992) reported accumulation of "dehydrin like" proteins in rice seedlings during dehydration which were heat stable and showed sequential similarity to RAB-16 proteins Rao *et al.* (1993) and Reddy *et al.* (1993) studied response of rice cultivars to water stress. Several water stress responsive proteins were identified by SDS-PAGE and one such protein *viz.* the 23 kDa polypeptide was purified. this protein was found to be ABA responsive and immunologically related to RAB-16 family of proteins. This protein was also boiling stable. They suggested that this protein might play role in tolerance to water stress in rice.

2.17.6. Molecular Mechanisms of Dehydration Tolerance

Plant responses to desiccation at molecular level is controlled by genes which express many enzymes of drought induced metabolic path ways and many upregulated genes. Many proteins involved in damage limitation or the removal of toxic metabolites are induced during water deficit. Genes encoding enzymes that detoxify reactive oxygen species are also induced (Ingram and Bartels, 1996).

Aquaporins, transport proteins, ion channels and carriers also play an important role in water deficit avoidance or osmoregulation (Agre *et al.*, 1993).

2.17.6.1. Metabolism

Changes in primary metabolism are a general response to stress in plants. Protease is an important feature of stress metabolism dispensing with redundant proteins and depolarising storage polypeptides, thereby releasing amino acids for new protein synthesis (Guerrero *et al.*, 1990). Enzymes of sugar metabolism are critical in stress tolerance. It has been demonstrated that certain sugars may be central in desiccation tolerance. Enzymes involved in the synthesis of compatible solutes such as S1 - pyrroline; 5 - carboxylate synthetase is involved in proline biosynthesis (Yoshida *et al.*, 1995).

2.17.6.2. Osmotic adjustment

Total water potential can be maintained during mild water stress by osmotic adjustment involving solutes such as sugars and amino acids.

Diverse environmental stress stimulate the synthesis and accumulation of compounds such as polyamines, prolines, glycine-betaine, β -alanine-betaine, choline-o-sulphate, polyols and sucrose (Yancey *et al.*, 1982; Smirnov, 1993). Osmoprotection mechanism provides a barrier against descending water potential (McCue and Hanson, 1990). Compatible solutes such as proline have also been found to be effective hydroxyl scavenger (Smirnov and Cumbers, 1989). Proline protected thylakoids from photo-inhibition (Alia and Mohanty, 1991), impede oxidation and lipid peroxidation (Ahmad *et al.*, 1983).

2.17.6.3. Sugars

Though sugar accumulation is not the only way by which plants deal with desiccation, it is considered as an important factor (Bohnert *et al.*, 1995). Soluble sugars accumulate during acquisition of desiccation tolerance (Leprince *et al.*, 1993). Sugars may serve as compatible solute permitting osmotic adjustment along with proline, glycine betaine and pinnitol. Sugars may also stabilise proteins under stress (Crowe *et al.*, 1992). Many carbohydrates have been viewed central to stress protection via osmoprotection and/or compatible solutes. Sucrose concentration has been linked to desiccation tolerance (Koster and Leopold, 1988). Over production of fructans resulted in augmented survival under stress.

2.17.6.4. Degradation and Repair

Genes encoding proteins with sequence similar to proteases are involved during drought to degrade proteins damaged by the effects of drought irreparably (Guerrero *et al.*, 1990). The residues are modified by deamination, isomerisation or oxidation by upgraded protein repair mechanisms. These proteins involved in repair mechanisms showed similarity to heat shock proteins and are probably chaperonins (Coca *et al.* 1994).

2.17.6.5. Removal of Toxins

Zhang and Kirkam (1994) noted the enzymatic response of ascorbate glutathione cycle under stress. Enzymes such as superoxide dismutase (SOD) which removes toxic intermediates produced during oxygenic metabolism were very important in drought tolerance (Mittler and Zilinskas, 1994). Decreasing leaf water content and stomatal closure resulted in active oxygen species (Sgherri *et al.*, 1993). Increased photorespiration during drought also elevate glycolate oxidase activity

resulting in H_2O_2 production (Mittler and Zilinskas, 1994). As such, genes encoding enzymes such as SOD and ascorbate peroxidase are upregulated for detoxifying the active oxygen species (White and Zilinskas, 1991).

2.18. ISOZYMES

Environmental stress is known to increase the oxygen induced damage to cells, due to the generation of oxygen radicals or due to inhibition of the antioxidant metabolism in plants. (Vinta jagtap and Sujatha Bhargava, 1995).

2.18.1. Drought stress and catalase activity

Dhindsa and Matowe (1981) and Zelitch (1990) reported that the extent of drought induced damage to membrane was negated with increasing activities of SOD and catalase in drought tolerant drought sensitive mosses. A larger decrease in the catalase activity was found in drought sensitive as compared to drought tolerant jute line (Chowdhury and Choudhury, 1985). Zhu and Huang (1994) observed a increased catalase activity during the early stages of drought in rice. In maize it was found to increase initially with drought stress and then decrease rapidly with further increase in stress (Wang *et al.* 1995). Similar results were reported by Zhang and Kirkam (1994) and Ranjita Baisak *et al.* (1994). Fashui *et al.* (1996) reported variation in the catalase activity in wheat seedlings under drought condition.

Variation in the activity of catalase isoforms in wheat was also observed (Badiani *et al.*, 1990). Changes in catalase isozyme patterns were the result of expression of different catalase genes - Class III catalase gene was expressed during stress whereas class I catalase responded to stress negatively. Class II catalase is commonly present in all plants (Willekens *et al.*, 1995).

2.18.2. Drought Stress and Peroxidases

Multiple forms of peroxidase (POX) existed in many plant tissues (Vanhuystee, 1990). Anionic isoforms were localised in cell walls while basic peroxidases in the vacuole (Schloss *et al.*, 1987). Badiani *et al.* (1990) studied the relationship between drought stress and peroxidase activity in wheat. A marked decrease in the activity of POX was found in rice seedlings under moisture stress (Jiang *et al.*, 1991). Under water stress there was a potential increase in the POD activities in wheat (Zhang and Kirkam, 1994), while it decreases in maize (Wang *et al.*, 1995).

Several POX isoforms were found in the extracellular matrix. Ascorbate peroxidases were the most important enzymes for protection against H_2O_2 in the cytosol and chloroplasts (Asada, 1992) particularly in the "Mehler reaction". The O_2^- produced in the "Mehler reaction" will be dismutated to O_2 and H_2O_2 by SOD. Thus, effective scavenging of active oxygen species require concerted action by SOD and APX. Chloroplastic APX occur as a thylakoid associated and stromal isoform (Miyake *et al.*, 1993). Drought stress strongly induce in the transcript levels of cytosolic APX isoform (Mittler and Zilinkas, 1992) mostly to remove the H_2O_2 produced during dismutation of O_2^- by SOD. Jha and Singh (1997) reported that tolerant rice varieties have high peroxidase activity under water stress condition than susceptible varieties. It is assumed that the isozymic banding patterns may act as sensitive markers to discriminate tolerant and susceptible genotypes.

Materials and Methods

Chapter III

MATERIALS AND METHODS

The laboratory and pot culture experiments proposed in the present work were carried out during 1998-2001 in the Department of Crop Physiology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-3. A brief account of the materials used and methodologies followed in the various experiments conducted to achieve the objectives of the study are given below:

3.1. MATERIALS

3.1.1. Physical and chemical properties of soil

The soil properties of the experimental pots were studied and are presented in Table 1.

3.1.2. Weather parameters

Meteorological data pertaining to maximum and minimum temperature, relative humidity, wind velocity, evaporation and total rainfall were collected from the Meteorological Observatory of Tamil Nadu Agricultural University, Coimbatore-3 (Table 2).

3.1.3. Experimental materials

Rice genotypes collected from different sources and which were used for the study are listed in Table 3.

Table 1. Characteristics of wet land soil used for the pot culture experiment

S. No.	Particulars	Values
I.	Mechanical composition	In per cent, on moisture free basis
i.	Clay	38.5
ii.	Silt	19.5
iii.	Fine sand	25.0
iv.	Course sand	17.1
v.	Texture class	Clay loam
II.	Physical properties	
i.	Bulk density (g cc^{-1})	1.33
ii.	Field capacity (%)	29.5
iii.	Permanent wetting point (%)	15.1
iv.	Total porosity (%)	46.6
v.	Infiltration rate (cm day^{-1})	1.5
III.	Chemical properties	
i.	Organic carbon (%)	0.73
ii.	Available nitrogen (kg ha^{-1})	248.0
iii.	Available phosphorus (kg ha^{-1})	15.00
iv.	Available potassium (kg ha^{-1})	550.00
v.	pH (1:2 soil water suspension)	7.80
vi.	EC (dSm^{-1})	0.5

Table 2. Weather data for the cropping period

Standard week	Dates	Mean temperature °C		Mean (%) Relative Humidity		Mean wind velocity	Mean evaporation	Total rainfall
	Year 2000	Max.	Min.	07.22 Hrs.	14.22 Hrs	(Km/h)	(mm/day)	(mm)
31	July 30-5	32.8	22.6	92	53	6.0	5.6	41.4
32	Aug 6-12	30.2	22.8	75	55	21.1	6.5	6.2
33	13-19	31.6	22.1	88	56	7.2	4.8	89.0
34	20-26	28.4	22.8	75	70	25.4	4.9	22.9
35	27-2	29.8	21.8	86	54	17.0	5.2	4.1
36	Sept 3-9	32.3	22.1	85	54	9.3	6.8	-
37	10-16	32.3	22.1	88	59	4.9	5.0	3.6
38	17-23	31.9	22.5	89	60	3.8	3.8	89.6
39	24-30	29.6	22.3	92	70	3.8	3.2	117.2
40	Oct 1-7	29.3	21.4	91	65	4.0	4.5	10.3
41	8-14	30.9	21.6	90	60	3.0	4.1	11.3
42	15-21	31.1	21.7	93	63	2.5	3.9	10.0
43	22-28	31.7	19.4	91	46	3.1	4.5	5.2
44	29-4	30.8	21.2	89	54	2.6	3.3	-
45	Nov 5-11	31.0	21.5	89	48	5.2	4.5	-
46	12-18	30.0	21.4	87	49	6.2	4.3	1.2
47	19-25	28.2	21.8	93	66	4.8	2.4	52.1
48	26-2	29.0	18.0	92	50	3.6	3.7	30.2
49	Dec 3-9	28.9	19.1	88	50	5.1	3.5	-
50	10-16	28.5	15.2	88	35	5.1	4.2	-
51	17-23	28.7	17.3	88	41	5.2	4.2	-
52	24-31	28.6	19.4	87	53	6.4	5.3	14.4
	2001							
1	Jan 1-7	30.0	20.9	91	48	1.1	3.7	-
2	8-14	30.0	19.4	88	43	5.1	4.3	-
3	15-21	30.2	17.8	90	40	7.3	4.5	-
4	22-28	31.2	20.8	81	44	5.6	4.8	-
5	29-4	30.2	21.0	86	50	-	3.7	-
6	Feb 5-11	33.3	17.8	84	32	4.5	4.6	-
7	12-18	33.4	22.7	88	33	5.3	6.1	-
8	19-25	34.9	21.1	87	37	3.8	6.3	-
9	26-4	34.3	20.6	87	33	6.2	7.1	-
10	Mar 5-11	34.7	21.8	74	34	5.3	5.9	-
11	12-18	35.4	21.7	78	33	4.0	6.5	-
12	19-25	36.1	22.9	84	38	4.5	6.9	-
13	26-1	36.2	23.4	83	38	5.5	7.8	-
14	2-8 (AP)	36.1	24.5	79	36	4.9	6.4	-
15	9-15	33.1	22.6	88	50	4.6	5.5	77.7
16	16-22	33.8	23.6	90	46	3.6	5.4	11.8
17	23-29	35.4	23.5	89	38	3.1	4.8	6.5
18	30-6	36.0	24.4	83	40	5.1	5.3	0.5

Table 3. Genotypes used and their sources

S. No.	Variety/land race	Duration (Days)	Source
1.	Norungan	100-110	Agricultural Research Station, TNAU, Paramakudi
2.	Nootripattu	110	"
3.	Varapukudanchan	100-110	"
4.	PMK 1	110-115	"
5.	PMK 2	110-115	"
6.	Co 37	115	Paddy Breeding Station, TNAU, Coimbatore.
7.	IR 20	130-135	"
8.	ADT 36	110	"
9.	ADT 39	120-125	"
10.	ASD 16	110-115	"
11.	ASD 18	105-110	"
12.	TPS 1	110-115	"
13.	TPS 2	125-130	"
14.	TKM 9	100-105	"
15.	TKM 10	135	"

3.2. METHODS

3.2.1. Laboratory Experiment - I

3.2.1.1. Standardization of the lethal dose (Table 4)

A preliminary study for standardization of the critical lethal dose for screening of genotypes was conducted in a completely randomized block design with three genotypes viz., Norungan (a land race adapted to upland condition), PMK 2 (Drought tolerant cultivar) and CO 37 (a water stress susceptible check). In this experiment four water potential treatments (0.00, -0.50, -0.75 and -1.00 MPa) were used. Polyethylene glycol (PEG)-6000 solutions of different water potentials viz., 0.00, -0.50, -0.75 and -1.00 MPa (prepared respectively by dissolving 0.0, 19.6, 23.5 and 28.9 g of PEG 6000 in 100 ml distilled water separately (Hadas, 1976) were used to achieve desired water potential. Distilled water was used as control (0.00 MPa). Two layers of filter paper in each petridish was moistened with the respective solution and fifty surface sterilized seeds were placed. For initial wetting of the filter papers, 5 ml of the solutions were required and 2 ml for every alternate day. Each treatment was replicated eight times.

3.2.2. Laboratory Experiment - II

3.2.2.1. Experimental materials

As per given in Table 3.

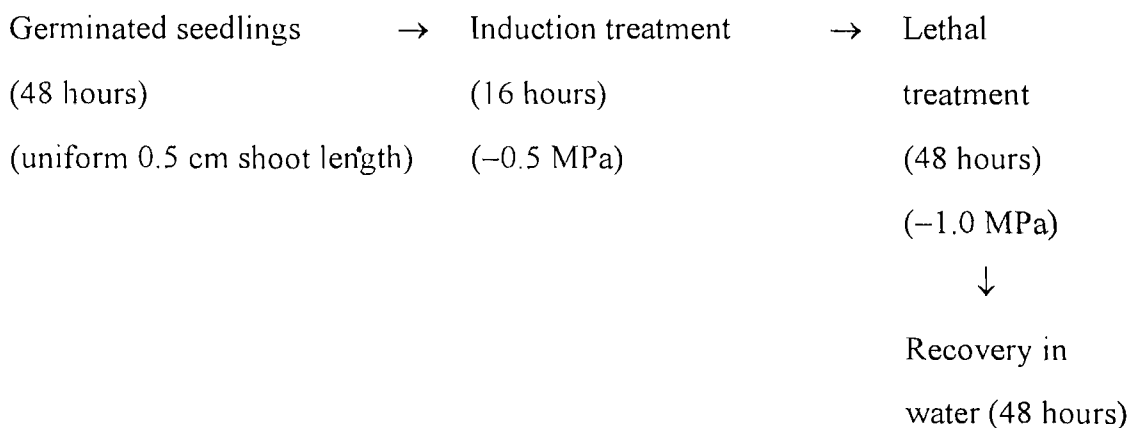
3.2.2.2. Screening for water stress tolerance

Screening of genotypes was carried out at -0.5 MPa as induction dose and -1.0 MPa as lethal dose as reported by Uma *et al.* (1995) and Jayaprakash *et al.* (1998). Two layers of filter paper in each petridish was moistened with distilled water and fifty surface sterilized seeds were placed. It was maintained at

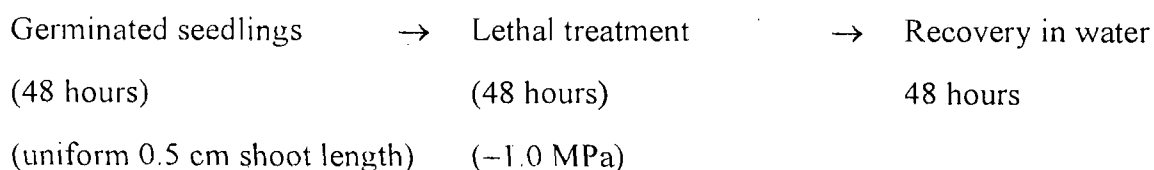
room temperature. After 48 hours of germination, the seedlings were subjected to induction treatment for 16 hours by transferring them to petridish containing induction dose of PEG 6000 solution (-0.5 MPa). Then the seedling were then subjected to lethal stress of 48 hours in -1.0 MPa by transferring them to lethal concentration of PEG 6000. The stress was alleviated by transferring the seedlings to water for 48 hours. Each treatment was replicated five times.

The general protocol followed for induction response is given below:

Induced seedlings



Non-induced seedling



After the completion of protocol, the root length and shoot length were measured at end of induction, end of lethal stress, and end of water recovery. From this data, the growth during stress (GDS), growth during recovery (GDR) and growth during stress and recovery (GDS + GDR) were arrived at.

Growth during stress = Growth at the end of stress – Growth at the end of induction
(GDS)

Growth during recovery = Growth at the end of recovery – Growth at the end of stress
(GDR)

Growth during stress and recovery = Growth during stress + Growth during recovery
(GDS + GDR)

3.2.2.3. Normal method

The same cultivars were used for assessing drought tolerance. Fifty seeds of each cultivars are placed in petridish containing –0.5 MPa (PEG 6000) solution. For each petridish 10 ml of –0.5 MPa PEG 6000 solution was used. Each petridish contains 2 layers of filter paper moistened with –0.5 MPa PEG 6000 solution.

–0.5 MPa solution was used to find out the best germinating cultivars and also for calculating vigour index. Distilled water was used as control (0.00 MPa). Each treatment was replicated five times.

3.2.2.3.1. Germination percentage

Fifty seeds of each rice cultivars were placed in each petridish and the germinability was recorded on seventh day after placing. The number of seeds germinated is expressed as percentage.____

3.2.2.3.2. Seedling shoot length (cm)

The shoot height of the seedlings was measured from five randomized selected seedlings in each replication. On seventh day and the mean was worked out and expressed in cm.

3.2.2.3.3. Seedling root length (cm)

The root length of the seedlings was also measured from five randomly selected seedlings in each replication on seventh days after sowing (DAS) and the mean was worked out and expressed in cm.

3.2.2.3.4. Vigour index (VI)

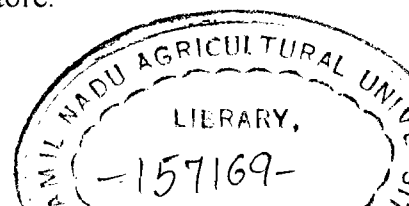
Vigour index was worked out according to Abdul-Baki and Anderson (1970).

$VI = \text{Germination \%} \times (\text{Root length (cm)} + \text{Shoot length (cm)})$.

3.2.3. Pot culture experiment I

Among fifteen rice genotypes evaluated for their germination percentage, vigour index, GDS, GDR and GDS + GDR under laboratory conditions, Norungan, Nootripattu, Varapukudanchan and PMK 2 were identified as water stress tolerant genotypes. Hence, these four genotypes were selected for further evaluation for their morphological characters, growth attributes, physiological and biochemical characteristics in comparison with CO 37 (water stress susceptible genotype) under pot culture condition, to identify parameters closely related to water stress tolerance by induction response technique.

The pot culture experiment was conducted in Glasshouse, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore.



3.2.3.1. Experiment details

Date of sowing (petridish)	:	16.8.2000
Date of seedlings transfer to pots	:	23.8.2000
Design	:	FCRD
No. of factors	:	2
Genotypes/land races (Factor 1)	:	5
		G ₁ – Norungan
		G ₂ – Nootripattu
		G ₃ – Varapukudanchan
		G ₄ – PMK 2
		G ₅ – CO 37
Treatments (Factor 2)	:	7
		T ₁ – Absolute control with 100% ASM
		T ₂ – Absolute control with 75% ASM
		T ₃ – Induced with 75% ASM
		T ₄ – Non-induced with 75% ASM
		T ₅ – Absolute control with 50% ASM
		T ₆ – Induced with 50% ASM
		T ₇ – Non-induced with 50% ASM
Replications	:	Five

The various morphological, growth attributes, physiological and biochemical attributes were estimated at transplanting, tillering, panicle initiation, and flowering. The yield characters were assessed at harvest.

3.2.3.2. Treatment details

It consists of five main treatment (Genotype) and three sub treatment (Levels of water stress). Main treatment was represented as G and sub treatment was represented as T.

G_1T_1	–	Norungan Absolute control 100% ASM
G_1T_2	–	Norungan Absolute control 75% ASM
G_1T_3	–	Norungan Induced 75% ASM
G_1T_4	–	Norungan Non induced 75% ASM
G_1T_5	–	Norungan Absolute control 50% ASM
G_1T_6	–	Norungan Induced 50% ASM
G_1T_7	–	Norungan Non induced 50% ASM
G_2T_1	–	Nootripattu Absolute control 100% ASM
G_2T_2	–	Nootripattu Absolute control 75% ASM
G_2T_3	–	Nootripattu Induced 75% ASM
G_2T_4	–	Nootripattu Non induced 75% ASM
G_2T_5	–	Nootripattu Absolute control 50% ASM
G_2T_6	–	Nootripattu Induced 50% ASM
G_2T_7	–	Nootripattu Non induced 50% ASM
G_3T_1	–	Varapukudanchan Absolute control 100% ASM
G_3T_2	–	Varapukudanchan Absolute control 75% ASM
G_3T_3	–	Varapukudanchan Induced 75% ASM
G_3T_4	–	Varapukudanchan Non induced 75% ASM
G_3T_5	–	Varapukudanchan Absolute control 50% ASM

G ₃ T ₆	–	Varapukudanchan Induced 50% ASM
G ₃ T ₇	–	Varapukudanchan Non induced 50% ASM
G ₄ T ₁	–	PMK 2 Absolute control 100% ASM
G ₄ T ₂	–	PMK 2 Absolute control 75% ASM
G ₄ T ₃	–	PMK 2 Induced 75% ASM
G ₄ T ₄	–	PMK 2 Non induced 75% ASM
G ₄ T ₅	–	PMK 2 Absolute control 50% ASM
G ₄ T ₆	–	PMK 2 Induced 50% ASM
G ₄ T ₇	–	PMK 2 Non induced 50% ASM
G ₅ T ₁	–	CO 37 Absolute control 100% ASM
G ₅ T ₂	–	CO 37 Absolute control 75% ASM
G ₅ T ₃	–	CO 37 Induced 75% ASM
G ₅ T ₄	–	CO 37 Non induced 75% ASM
G ₅ T ₅	–	CO 37 Absolute control 50% ASM
G ₅ T ₆	–	CO 37 Induced 50% ASM
G ₅ T ₇	–	CO 37 Non induced 50% ASM

The treatments were randomized systematically as per statistical norms to minimum the errors.

3.2.3.3. Preparation of pots

Mud pots of sizes 30 cm x 30 cm were used. Soil collected from wetland of the University farm was dried, powdered and mixed with FYM (2:1) and then each pot was filled with 12 kg of soil and watered. The pots were provided with a hole at the bottom to facilitate drainage of excess water. Before transplanting the seedlings,

NPK fertilizers were worked out based on the recommended dose of 120:60:60 kg ha⁻¹ and applied basally in the respective pots. The physical and chemical characteristics of the wetland soil are presented in Table 1.

Induced and non-induced seedlings were transplanted, at one seedling /hill in the pots. Seedlings which are not induced and planted in normal soil was considered as **absolute control** and it received normal water throughout its life cycle. Thinning was done at 10 DAT to maintain a uniform population of four plants in each pot.

3.2.3.4. Determination of Available Soil Moisture (ASM) (Gravimetric method)

Uniform size (30 cm x 30 cm) pots were selected and weighed. Then 12 kg of dried powdered wet land soil mixed with FYM (2:1) were taken into pots. Water is added to the pots. Excess water was drained by holes in the bottom. Then irrigated pots were weighed by balance. The excess weight is the amount of water needed for 100 per cent ASM. Likewise 75 per cent ASM and 50 per cent ASM were determined based on the 100 per cent ASM.

After seedlings transplanted, pots with seedlings were weighed. At same time pots without seedlings were maintained for control (pots + soil + water). The difference between weight of pots with seedlings (pot + soil + water + seedlings) and pots without seedlings (pots + soil + water) is the seedling weight.

Steps

(1) Before seedlings transplanted

1. Weight of the pot = W_1
2. Weight of the pot + soil = W_2

$$3. \text{ Weight of the pot + soil + water} = W_3$$

$$\text{Therefore weight of the water} = W_3 - W_2 = Y$$

'Y' is the amount of water needed for 100 per cent ASM

Likewise 75 per cent ASM and 50 per cent ASM water determined based on the 100 per cent ASM.

(2) After seedling transplanted

$$\text{Weight of the pot + soil + water} = W_3 (\text{control})$$

$$\text{Weight of the pot + soil + water + seedling} = W_4$$

$$\text{Therefore weight of the seedling} = W_4 - W_3 = Z$$

'Z' is the amount of water needed for 100 per cent ASM. Likewise 75 per cent ASM and 50 per cent ASM water determined based on the 100 per cent ASM.

Every day pot weight was taken and the amount of water needed was calculated and irrigated.

The desired level of ASM was maintained by computing the amount of water needed to be applied as given below.

(3) 75% and 50% available soil moisture

For 75 per cent ASM and 50 per cent ASM were maintained by computing the amount of water needed to be applied as given below:

$$75\% \text{ ASM} = W_4 - X$$

$$50\% \text{ ASM} = W_4 - X$$

where,

W_4 = Weight of the pot + soil + water + seedling

X = Weight of the pots with soil, water and seedling at a time 't' prior to bringing the soil to 100 per cent, 75 per cent ASM and 50 per cent ASM.

For 75 per cent and 50 per cent ASM were arrived based on the amount of water needed for 100 per cent ASM. The required amount of water was added by pots by manually.

3.2.4. Morphological characters

3.2.4.1. Plant height (cm)

Height of the plant was measured from the base of the shoot to the longest leaf at different stages and the average was worked out for five plants and expressed in cm.

3.2.4.2. Root length (cm)

Plants were carefully uprooted from the pot with minimum root damage at different stages. These were washed carefully and the distance from the base of the shoot to the longest root was measured and the average was arrived for five plants and expressed in cm.

$$3. \text{ Weight of the pot + soil + water} = W_3$$

$$\text{Therefore weight of the water} = W_3 - W_2 = Y$$

'Y' is the amount of water needed for 100 per cent ASM

Likewise 75 per cent ASM and 50 per cent ASM water determined based on the 100 per cent ASM.

(2) After seedling transplanted

$$\text{Weight of the pot + soil + water} = W_3 \text{ (control)}$$

$$\text{Weight of the pot + soil + water + seedling} = W_4$$

$$\text{Therefore weight of the seedling} = W_4 - W_3 = Z$$

'Z' is the amount of water needed for 100 per cent ASM. Likewise 75 per cent ASM and 50 per cent ASM water determined based on the 100 per cent ASM.

Every day pot weight was taken and the amount of water needed was calculated and irrigated.

The desired level of ASM was maintained by computing the amount of water needed to be applied as given below.

(3) 75% and 50% available soil moisture

For 75 per cent ASM and 50 per cent ASM were maintained by computing the amount of water needed to be applied as given below:

3.2.4.3. Leaf number

Number of leaves was determined by counting the leaves from the base to the tip of the plant at different stages and the average was worked out for five plants and expressed in number.

3.2.4.4. Leaf area (LA) (cm² plant⁻¹)

Leaf area for the whole sampling unit was measured at different stages by using Leaf Area Meter (LICOR Model 3100) and expressed in cm² plant⁻¹.

3.2.4.5. Root volume (CC)

At each stage, washed roots of each plant were used for measuring the root volume by putting them into a measuring cylinder containing water. By measuring the replacement of water or increase in the water column, root volume was assessed and expressed in CC.

3.2.5. Growth attributes

3.2.5.1. Leaf Area Index (LAI)

Leaf area index was determined by using the formula of Williams (1946)

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Ground area occupied per plant}}$$

3.2.5.2. Leaf Area Duration (LAD)

Leaf area duration was determined by using the formula of Power *et al.*, (1967) and expressed in days.

$$LAD = \frac{L_i + (L_{i+1})}{2} (t_2 - t_1)$$

Where.

L_i = LAI at first stage.

$L_i + 1$ = LAI at second stage.

$t_2 - t_1$ = Time interval in days.

3.2.5.3. Specific Leaf Area (SLA)

Employing the formula of Kvet *et al.*, (1971), SLA was calculated by using leaf area and leaf dry weight and expressed in $\text{cm}^2 \text{g}^{-1}$.

$$SLA = \frac{\text{Leaf area per plant}}{\text{Leaf dry weight per plant}}$$

3.2.5.4. Specific Leaf Weight (SLW)

Specific leaf weight was calculated by using the formula of Pearce *et al.*, (1968) and expressed in mg cm^{-2} .

$$SLW = \frac{\text{Leaf dry weight per plant}}{\text{Leaf area per plant}}$$

3.2.5.5. Net Assimilation Rate (NAR)

The method proposed by Gregory *et al.*, (1917) and subsequently modified by Williams (1946) was employed for calculating the NAR and the values were expressed in $\text{mg cm}^{-2} \text{day}^{-1}$.

$$\text{NAR} = \frac{W_2 - W_1}{L_2 - L_1} \times \frac{\text{Loge} L_2 - \text{Loge} L_1}{t_2 - t_1}$$

where,

W_1 and W_2 = Dry weight of whole plant at t_1 and t_2 respectively.

L_1 and L_2 = Leaf area at time intervals of t_1 and t_2 respectively.

t_1 and t_2 = Time in days.

3.2.5.6. Crop Growth Rate (CGR)

The Crop growth rate was estimated by using the formula of Watson (1958) and expressed in $\text{g cm}^{-2} \text{ day}^{-1}$.

$$\text{CGR} = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

where,

W_1 and W_2 = Whole plant dry weights at t_1 and t_2 respectively.

t_1 and t_2 = Time in days

P = Ground area occupied by the plant (m^2)

3.2.5.7. Relative Growth Rate (RGR)

The relative growth rate was calculated by using the formula suggested by Williams (1946) and expressed in $\text{g g}^{-1} \text{ day}^{-1}$.

$$\text{RGR} = \frac{\text{Loge} W_2 - \text{Loge} W_1}{t_2 - t_1}$$

where,

W_1 and W_2 = Whole plant dry weight at t_1 and t_2 respectively.

t_1 and t_2 = Time in days.

3.2.6. Physiological parameters

3.2.6.1. Pigments

3.2.6.1.1. Chlorophyll content

The total chlorophyll was estimated in a fully expanded young leaf at specified phenophases by adopting the procedure of Yoshida *et al.* (1971) and the contents were expressed as mg g^{-1} of fresh weight.

3.2.6.1.2. Relative water content

Leaf samples from the middle 5–6 cm of the youngest fully expanded leaves were taken for recording relative water content. RWC was estimated by Weatherly (1950) method, and expressed in percentage.

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

3.2.6.1.3. Porometer reading

Transpiration rate and leaf diffusive resistance were measured using a steady state porometer (LICOR 1600 Model CI 301 CTD IWC, made in USA) between 10 A.M. to 1.00 P.M. on the respective sampling dates. The measurements were recorded on the top most fully expanded leaf from five plants. The average values were computed and expressed as μ moles of $\text{H}_2\text{O m}^{-2} \text{S}^{-1}$ and μ moles of $\text{CO}_2 \text{m}^{-2} \text{S}^{-1}$ for transpiration rate and leaf diffusive resistance.

3.2.6.1.4. Leaf water potential (ψ_1)

Leaf water potential was measured by using pressure chamber (Soil Moisture Equipment Corp., P.O.Box. 30025, Santa Barabara, CA 93105, U.S.A.) between 11.00 A.M. to 1.00 P.M. on the respective sampling dates and expressed as MPa.

3.2.7. Biochemical parameters

3.2.7.1. Carbohydrate fraction

3.2.7.1.1. Reducing sugars (mg g^{-1} f.w.)

Reducing sugar content was estimated from the ethanol extract following the method described by Somogyi (1952).

3.2.7.1.2. Total sugars (mg g^{-1} f.w.)

Total sugars content was estimated from the ethanol extract of leaf sample by adopting the methods of Somogyi (1952).

3.2.7.1.3. Starch content (mg g^{-1} f.w.)

The method of Hedge and Hofreiter (1962) was adopted to estimate the starch content of the leaves from the extracts in 52 per cent PCA after removing the sugars.

3.2.8. Proteins and enzymes

3.2.8.1. Soluble protein (mg g^{-1} f.w.)

Soluble protein content of leaves was estimated following the method of Lowry *et al.*, (1951).

3.2.8.2. Nitrate reductase activity (μ moles $\text{NO}_2 \text{ g}^{-1} \text{ hr}^{-1}$)

Nitrate reductase activity was estimated as per the method described by Nicholas *et al.*, (1976) and expressed as μ moles $\text{NO}_2 \text{ g}^{-1} \text{ hr}^{-1}$.

3.2.8.3. Catalase activity (μ moles H_2O_2 $100 \text{ mg}^{-1} \text{ min}^{-1}$)

Catalase activity was determined from the change in the absorbance at 240 nm over time of the enzyme extract in 3 ml of H_2O_2 - PO_4 buffer (Luck, 1974) and expressed as (μ moles H_2O_2 $100 \text{ mg}^{-1} \text{ min}^{-1}$).

3.2.8.4. Peroxidase activity ($\mu\text{g hr}^{-1} \text{ g}^{-1}$)

Peroxidase activity ($\mu\text{g hr}^{-1} \text{ g}^{-1}$) was determined by the methods described by Sadasivam and Manickam (1996).

3.2.8.5. Superoxide dismutase activity (enzyme units $\text{mg protein}^{-1} \text{ min}^{-1}$)

Superoxide dismutase activity was determined by using Nitro Blue Tetrazolium (NBT) by the method of Beau Champ and Fridovich (1971) and expressed as (enzyme units $\text{mg protein}^{-1} \text{ min}^{-1}$).

3.2.8.6. Ascorbic acid oxidase activity (enzyme units $\text{min}^{-1} \text{ g}^{-1} \text{ f.w.}$)

The enzyme ascorbic acid oxidase activity was determined by following the method of Oberbacher and Vines (1963) and expressed as enzyme units $\text{min}^{-1} \text{ g}^{-1} \text{ f.w.}$

3.2.9. Amino acids

3.2.9.1. Proline content (μ moles $\text{g}^{-1} \text{ f.w.}$)

Proline content of the leaves was estimated by the method described by Bates *et al.*, (1973).

3.2.10. Other metabolites

3.2.10.1. Phenolics content (mg g^{-1} f.w.)

Phenol content of extract was determined by using the method of Malik and Singh (1980).

3.2.10.2. Ascorbic acid

Ascorbic acid content was volumetrically determined as per the method described by Sadasivam and Manickam (1996).

3.2.11. Total dry matter production (TDMP)

The total dry matter production was calculated by adding the leaf, shoot and root dry weights for all the stages. It is expressed in g plant^{-1}

3.2.12. Yield and yield components

To make an assessment on the relationship between yield and its components, the following parameters were chosen. The details of the method for estimating each character are indicated below.

3.2.12.1. Number of productive tillers plant^{-1}

In each treatment, four plants were selected, labelled and the number of tillers producing panicles at harvest stage were recorded.

3.2.12.2. Length of panicle (cm)

Ten panicles at random were selected from each treatment and length of each panicle was measured in cm scale. The average length of one panicle was arrived at and the values were expressed in cm.

3.2.12.3. Number of grains panicle⁻¹

The panicle collected from sample plants were threshed, cleaned and the total number of grains were counted by grain counters. The average number of grains panicle⁻¹ was worked out.

3.2.12.4. Number of filled grains panicle⁻¹

After harvest, five plants from each treatment were selected and the number of filled grains panicle⁻¹ was counted and the average for five replications was recorded.

3.2.12.5. Number of unfilled grains panicle⁻¹

After harvest, five plants from each treatment were selected, number of unfilled grains panicle⁻¹ was counted and the average for five replications was recorded.

3.2.12.6. Yield of grain and straw plant⁻¹

The grain and straw yield plant⁻¹ from each treatment were recorded after drying and the values were computed and expressed in g plant⁻¹.

3.2.12.7. 1000 grain weight

The grains were dried in oven at $80 \pm 12^{\circ}\text{C}$ for 24 hrs and 1000 grain weight for each treatment (in five replications) was recorded. The average was arrived and expressed in g.

3.2.12.8. Harvest Index (HI)

Harvest index was calculated from the dry weight of grain and dry weight of plant hill⁻¹ at harvest by using the formula and expressed in per cent.

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

3.2.13. Pot culture experiment - II

Among five rice genotypes evaluated for their morphological, growth attributes, physiological, biochemical and yield characters under pot culture condition, Norungan (land race), PMK 2 (variety) were identified as water stress tolerant genotypes. Hence, these genotypes were selected for further evaluation for their protein fraction and isozymes studies in comparison with CO 37, a water stress susceptible genotype.

The pot culture experiment was conducted in the Glasshouse, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore.

3.2.13.1. Experimental details

Date of sowing (petridish)	:	3.1.2001
Date of seedlings transfer to pots	:	10.1.2001
Design	:	FCRD
No. of factors	:	2
Genotypes/land races (factor 1)	:	3
		G ₁ - Norungan
		G ₂ - PMK 2
		G ₃ - CO 37

Treatments (factor 2)	:	7
		T ₁ – Absolute control with 100% ASM
		T ₂ – Absolute control with 75% ASM
		T ₃ – Induced with 75% ASM
		T ₄ – Non-induced with 75% ASM
		T ₅ – Absolute control with 50% ASM
		T ₆ – Induced with 50% ASM
		T ₇ – Non-induced with 50% ASM
Replications	:	eight

The protein fractions and isozymes was done at panicle initiation stage only.

3.2.13.2. Treatment details

The treatments consisted of three main treatment (Genotype) and three sub treatments (levels of water stress). Main treatment were represented as G and subtreatment was represented as T.

G ₁ T ₁	–	Norungan Absolute control 100% ASM
G ₁ T ₂	–	Norungan Absolute control 75% ASM
G ₁ T ₃	–	Norungan Induced 75% ASM
G ₁ T ₄	–	Norungan Non induced 75% ASM
G ₁ T ₅	–	Norungan Absolute control 50% ASM
G ₁ T ₆	–	Norungan Induced 50% ASM
G ₁ T ₇	–	Norungan Non induced 50% ASM
G ₂ T ₁	–	PMK 2 Absolute control 100% ASM
G ₂ T ₂	–	PMK 2 Absolute control 75% ASM

G_2T_3	–	PMK 2 Induced 75% ASM
G_2T_4	–	PMK 2 Non induced 75% ASM
G_2T_5	–	PMK 2 Absolute control 50% ASM
G_2T_6	–	PMK 2 Induced 50% ASM
G_2T_7	–	PMK 2 Non induced 50% ASM
G_3T_1	–	CO 37 Absolute control 100% ASM
G_3T_2	–	CO 37 Absolute control 75% ASM
G_3T_3	–	CO 37 Induced 75% ASM
G_3T_4	–	CO 37 Non induced 75% ASM
G_3T_5	–	CO 37 Absolute control 50% ASM
G_3T_6	–	CO 37 Induced 50% ASM
G_3T_7	–	CO 37 Non induced 50% ASM

The treatments were randomized systematically to minimize errors.

3.2.13.3. Preparation of pots

As given in pot culture experiment I.

3.2.13.4. Determination of available soil moisture (Gravimetric method)

Uniform size (30 cm x 30 cm) pots were selected and weighed. Then 12 kg of dried powdered wet land soil mixed with FYM (2:1) were taken into pots. Water is added to the pots. Excess water was drained by holes in the bottom. Then irrigated pots were weighed by balance. The excess weight is the amount of water needed for 100 per cent ASM. Likewise 75 per cent ASM and 50 per cent ASM were determined based on the 100 per cent ASM.

After seedlings transplanted, pots with seedlings were weighed. At same time pots without seedlings were maintained for control (pots + soil + water). The difference between weight of pots with seedlings (pot + soil + water + seedlings) and pots without seedlings (pots + soil + water) is the seedling weight.

Steps

(1) Before seedlings transplanted

$$1. \text{ Weight of the pot} = W_1$$

$$2. \text{ Weight of the pot + soil} = W_2$$

$$3. \text{ Weight of the pot + soil + water} = W_3$$

$$\text{Therefore weight of the water} = W_3 - W_2 = Y$$

'Y' is the amount of water needed for 100 per cent ASM

Likewise 75 per cent ASM and 50 per cent ASM water determined based on the 100 per cent ASM.

(2) After seedling transplanted

$$\text{Weight of the pot + soil + water} = W_3 (\text{control})$$

$$\text{Weight of the pot + soil + water + seedling} = W_4$$

$$\text{Therefore weight of the seedling} = W_4 - W_3 = Z$$

'Z' is the amount of water needed for 100 per cent ASM. Likewise 75 per cent ASM and 50 per cent ASM water determined based on the 100 per cent ASM.

Every day pot weight was taken and the amount of water needed was calculated and irrigated.

The desired level of ASM was maintained by computing the amount of water needed to be applied as given below.

(3) 75% and 50% available soil moisture

For 75 per cent ASM and 50 per cent ASM were maintained by computing the amount of water needed to be applied as given below:

$$\begin{array}{lcl} 75\% \text{ ASM} & = & W_4 - X \\ 50\% \text{ ASM} & = & W_4 - X \end{array}$$

where,

W_4 = Weight of the pot + soil + water + seedling

X = Weight of the pots with soil, water and seedling at a time 't' prior to bringing the soil to 100 per cent, 75 per cent ASM and 50 per cent ASM.

For 75 per cent and 50 per cent ASM were arrived based on the amount of water needed for 100 per cent ASM. The required amount of water was added by pots by manually.

3.2.14. Protein fraction and isozyme studies

3.2.14.1. SDS-PAGE

When the plants subjected to sublethal levels of stress they acquire capability to withstand ensuing lethal stress levels much better than plants straight away exposed to lethal stress levels. Therefore it is likely that protein/gene expression changes, concomitant with the development of induced tolerance, have a role in the induction of tolerance (Pareek *et al.*, 1995). To testify this hypothesis with reference to water

stress, a study on soluble protein profile with induction of PEG 6000 has been conducted.

3.2.14.1.1. Method of extraction, separation and quantification of stress proteins

Extraction of the soluble protein

A known amount of seedling was taken and ground in 100mM Tris-HCl buffer, pH 7.8. It was centrifuged at 12,000 rpm for 10 minutes at 4°C. The supernatant was used for further analysis.

3.2.14.1.2. Quantitative determination of soluble proteins by coomassie brilliant blue dye binding method

Quantification of soluble proteins by coomassie brilliant blue (CBB) dye binding method was adopted (Bradford, 1976). CBB dye binding method is based on the principle that the CBB G 250 binds to proteins and gives a consistent blue colour. The blue colour was read at 595 nm using Beckman Spectrophotometer, Japan.

3.2.14.1.3. Preparation of Bradford reagent

CBB G 250 (3.0 mg) was dissolved in 1.5 ml of 95 per cent ethanol. To this 3.0 ml of 85 per cent w/v orthophosphoric acid was added. The resulting solution was diluted to a final volume of 30 ml with double distilled water. Reagent was made fresh for quantification.

3.2.14.1.4. Development of standard curve for protein estimation

Different known concentration of BSA were prepared for the development of standard curve. 100 µl of solution each of different concentrations were taken in test tubes in three replications 3.0 ml of the reagent was added and mixed well. The intensity of blue colour developed was read at 595nm using

Beckman Spectrophotometer, Made in Japan, the absorbance was plotted against protein concentrations.

3.2.14.1.5. Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE)

Separation and qualitative analysis of the proteins was done using SDS-PAGE as described by Laemmli (1970). The proteins in the supernatant fractions were precipitated, if the protein concentrations are less, precipitated with cold acetone, kept in -20°C for 30 minutes and centrifuged at 12,000 rpm for 10 minutes at 4°C. The pellet was dried and the traces of acetone was removed by vacuum drying and then taken into Laemmli's SDS-PAGE sample buffer. The proteins with high concentrations were mixed with 2 x SDS sample buffer boiled for 3 minutes and then separated on vertical slab gel.

Stock solutions

- Acrylamide - bis acrylamide (30:0.8, w/w). Prepared by dissolving 30.0g of acrylamide and 0.8 g of bisacrylamide in double distilled water and the volume was made upto 100 ml. The solution was then filtered through Whatman No.1 filter paper and stored at 4°C.
- SDS (10% w/l): 10 g of SDS was dissolved in little distilled water and made upto 100 ml in double distilled water.
- Ammonium persulphate: 100 mg of ammonium persulphate dissolved in 1.0 ml of double distilled water and made fresh just before use.
- TEMED used as supplied.
- Electrophoresis Buffer

a. Stacking gel buffer

0.5 M Tris-HCl (pH 6.8) - 6.0 g of Tris was dissolved in 40 ml of double distilled water and pH was adjusted to 6.8 with HCl and the final volume was made upto 100 ml.

b. Resolving gel buffer

1.5 M Tris-HCl (pH 8.8) - 18.15 g of Tris was dissolved in 40 ml of double distilled water and the pH was adjusted to 8.8 with HCl and the final volume was made upto 100 ml.

c. Electrode buffer

6.0 g of Tris and 14.4 g of glycine and 1.0 g of SDS were dissolved in 800 ml of double distilled water and made upto 1000 ml.

SDS-sample buffer (2 x sample buffer)

Water	=	4.0 ml
0.5 M Tris-HCl (6.8)	=	1.0 ml
Glycerol	=	0.8 ml
10% SDS	=	1.6 ml
Merapta ethanol	=	0.4 ml
Bromophenol blue	=	8.0 mg

Note: For the isozyme studies SDS was excluded from electrode buffer as well as sample buffer.

Receipe for the minislab SDS-polyacrylamide gels

	4% stacking gel	12% resolving gel
Acrylamide-bis acrylamide (30%)	0.65 ml	3.0 ml
Stacking gel buffer (pH 6.8)	1.25 ml	-
Resolving gel buffer (pH 8.8)	-	1.87
SDS 10%	50 μ l	75 μ l
TEMED	5 μ l	5 μ l
Water	3.25 ml	2.5 ml
Ammonium per sulphate	25 μ l	38 μ l

3.2.14.1.6. Preparation of slab gels

The cleaned glass plates wiped with ethanol were assembled keeping the two Teflon spacers of 1.5 mm thickness in between at the two sides and tightened by side screws. The set was made to stand on the casting unit, and 2 per cent agar solution was poured into the casting unit to seal the bottom of the glass plates. Appropriate resolving gel mixture was prepared and TEMED was added just before use. The resolving gel mixture was poured into the space between the glass plates leaving sufficient space at the top for stacking gel. Care was taken to avoid any air bubbles in the gel. After polymerization, the stacking gel mixture was prepared, poured over the resolving gel and comb was placed over it. The assemble was left undisturbed. After the polymerization of stacking gel, the comb was carefully removed and the wells were washed with the reservoir buffer and fixed to the electrophoresis apparatus. Reservoir buffer was added to the tank of the electrophoresis apparatus. Air bubbles from the bottom of the gel were removed for uniform contact between the gel and buffer.

3.2.14.1.7. Enzyme extraction

A quantity of 500 mg of freshly collected leaf samples were cut into small pieces and homogenized in 1 ml of phosphate buffer pH 7.0 in a prechilled pestle and mortar. The homogenate was centrifuged in a refrigerated centrifuge at 15,000 rpm for 15 minutes and the supernatant was used for analysis.

3.2.14.1.8. Sample preparation and sample loading

The proteins were dissolved in appropriate amount of the sample buffer and incubated in a boiling water bath for 3 minutes. After cooling the sample to room temperature, it was centrifuged at 15,000 rpm for 10 minutes to remove the insoluble material. The sample was used either immediately or stored at -20°C and warmed just before use.

The protein sample was carefully loaded into the gel surface using a microsyringe. Equal amount of protein was loaded from all the samples. The electrophoresis was done at constant voltage of 100 v (25 mA). The run was continued until the dye front reached the bottom of the gel. Standard SDS molecular weight markers were used. After the electrophoresis, the gel was removed and developed by coomassie brilliant blue staining method.

3.2.14.1.9. Staining methods

1. Coomassie brilliant blue staining

a. Staining solution

Coomassie brilliant blue R 250	100 mg
Methanol	40 ml
Acetic acid	10 ml
Water	50 ml

b. Destaining solution

Methanol	40 ml
Acetic acid	10 ml
Water	50 ml

Procedure

The gel was carefully removed and immersed in staining solution overnight. The stained gel was transferred to another container with 100 ml of destaining solution. During the destaining the gel was gently shaken to remove the excess stain. The destainer was changed frequently and continued till the background of the gel was colourless. The gels were then photographed or stored in 30 per cent methanol or 7 per cent glacial acetic acid.

3.2.15. Isozymes (peroxidase and catalase)**3.2.15.1. Enzyme extraction**

500 mg of freshly collected leaf samples were cut into small pieces and homogenized in 1 ml of 50 mM potassium phosphate buffer (pH 7.0 for peroxidase and catalase in a prechilled pestle and mortar. The homogenate was centrifuged in a refrigerated centrifuge at 15,000 rpm for 15 minutes and the supernatant was used for analysis.

3.2.15.2. Electrophoresis

Electrophoretic separation of isozymes was achieved with 8 per cent native PAGE, as described by Laemmli (1970) with a slight modifications as per the need.

3.2.15.3. Composition of solutions used for isozymes

The same solution used for SDS-PAGE was used, but SDS was excluded from electrode buffer as well as sample buffer.

3.2.15.4. Casting of gel and running

Casting of gel was done as like that of SDS-PAGE. The whole electrophoresis set was kept into the refrigerator for cooling during the run. Sample solutions diluted with sample buffer were loaded into the sample wells carefully with the help of a micro syringe. The DC power supply was set to a constant current of 25 mA at 100 volts. The run was continued until the dye front reached the bottom of the gel.

Receipe for minigel

	4% stacking gel	8% resolving gel
Acrylamide-bisacrylamide	0.65 ml	2.0 ml
Stacking gel buffer (pH 6.8)	1.25 ml	-
Resolving gel buffer (pH 8.8)	-	1.87 ml
TEMED	5 μ l	5 μ l
APS	25 μ l	25 μ l
Water	3.25 ml	3.6 ml

3.2.15.5. Staining methods

1. Peroxidase

Staining solution

Solution A:	Benzidine	100 mg
	Acetic acid	0.5 ml
	Acetone	0.5 ml

	Ammonium chloride	6% w/v
Solution B:	H ₂ O ₂	30% v/v
Solution C:	Glacial acetic acid	7% v/v

Procedure

The gel was incubated in the dark in solution A. After 30 minutes solution B was added drop by drop till blue coloured bands appeared. The gel was then fixed with solution C and photographed.

2. Catalase

Staining solution

Solution A:	Sodium thiosulphate (60 mM)	30 ml
	H ₂ O ₂ 3%	70 ml
Solution B:	Potassium iodide 50 mM	100 ml
	Glacial acetic acid	0.5 ml

Procedure

The gel was treated with solution A until bubbles appeared on the gel. Solution B was added discarding solution A. Chromophore developed as orange/reddish orange brands.

Nomenclature for isozymes

Vander Berg and Wissman (1982) described the norms for the nomenclature of isozymes. The same norm was followed in this study. The acronyms for peroxidase, and catalase were POX and CAT respectively.

3.2.16. Statistical analysis

The data collected were subjected to statistical analysis in Factorial Completely Randomized Block Design (FCRD) by the method suggested by Panse and Sukhatme (1961).

Experimental Results

Chapter IV

EXPERIMENTAL RESULTS

The aim of the present investigation was to elucidate information on morphological, physiological, biochemical and molecular mechanisms of drought tolerance, identify traits for rapid screening and to study the possibilities of mitigating drought stress through induction response technique. The results are presented in various topics viz., standardization of sublethal and lethal concentration, seedling growth, induction response, morphological characters, growth attributes, physiological parameters, biochemical, total dry matter production, yield and yield components and molecular mechanisms. The study comprised of laboratory and potculture experiment, thereby providing ample scope for making detailed observations. The results were subjected to statistical scrutiny and the data are presented in appropriate tables with suitable figures in the following pages.

4.1 STANDARDIZATION OF SUBLETHAL AND LETHAL DOSE CONCENTRATION (PEG 6000)

The data related to standardization of sublethal and lethal concentrations are given in Table 4. Significant differences were observed in genotypes, treatments and interactions. Among the genotypes, tolerant genotypes namely Norungan and PMK 2 recorded the highest germination percentage (21.5 and 21.5) than susceptible variety CO 37 (11.3). Among the treatments T₁ (0.00 MPa) recorded the highest germination percentage (24.7) followed by T₂ (-0.5 MPa, 19.3) and lowest value was recorded in T₄ (-1.00 MPa, 11.0). From these studies, it was concluded that for rice -0.5 MPa was sublethal and -1.0 MPa was lethal.

4.2 SCREENING OF RICE GENOTYPES FOR WATER STRESS TOLERANCE

4.2.1. Induction response

Survival and subsequent recovery of seedling growth, under lethal stress will be higher when they are pre-treated with a mild non-lethal stress, compared to the untreated seedling. This is often referred to as induction response. This induction response is species specific and the optimum water potential by using PEG 6000 for induction of water stress response for rice was found to be -0.5 MPa (sublethal) whereas the lethal level was at -1.0 MPa.

Assessment of induction responses in rice genotypes

The data relating to assessment of induction responses in rice genotypes are given in Table 5 to 12. Experiment was conducted to examine the induction response of fifteen rice genotypes. Germinated seedlings were subjected to induction stress (16 hours), lethal stress (48 hours) and water recovery (48 hours). The seedlings without induction treatment served as control. In the above rice genotypes the recovery growth of induced seedlings were better over non induced seedlings (control)

Drought tolerant land race, Norungan recorded the highest value of shoot length (4.4 cm) at the end of water recovery, where as its control had only 1.8 cm. Drought susceptible variety CO 37 recorded the lowest value of shoot length (2.1 cm) at the end of water recovery but it was higher than the control (0.3 cm). Norungan recorded the highest value of root length (5.5 cm) at the end of water recovery, where as the control had only 2.5 cm. Susceptible variety CO 37 recorded the lowest value of root growth (2.6 cm) at the end of water recovery but it was higher than the control (0.4 cm).

Table 4: Standardization of the **sublethal** and **lethal** PEG 6000 concentration

GENOTYPE	TREATMENTS				MEAN
	T1 0.00 MPa	T2 -0.50 MPa	T3 -0.75 MPa	T4 -1.00 MPa	
NORUNGAN	25 (5.0)	24.0 (4.9)	22.0 (4.7)	15.0 (3.9)	21.5 (4.7)
PMK 2	25 (5.0)	24.0 (4.9)	22.0 (4.7)	15.0 (3.9)	21.5 (4.7)
CO 37	24 (4.9)	10.0 (3.2)	8.0 (2.9)	3.0 (1.9)	11.3 (4.7)
MEAN	24.7 (5.0)	19.3 (4.4)	17.3 (4.1)	11.0 (3.2)	

Transformed values are given in parentheses.

CD(5%): G:0.07 T:0.06 GxT:0.12

Table 5. Induction response of rice seedlings (Shoot cm)

Genotypes	GDS		GDR		GDS + GDR	
	Induced	Control	Induced	Control	Induced	Control
Norungan	3.7	1.3	4.4	1.8	8.1	3.1
Nootripattu	3.1	1.1	3.7	1.5	6.8	2.6
Varapukudanchan	2.8	0.9	3.3	1.1	6.1	2
PMK ₁	2.5	0.5	2.7	0.7	5.2	1.2
PMK ₂	3.5	1.2	4.0	1.6	7.5	2.8
IR 20	2.4	0.4	2.6	0.6	0.5	0.1
ADT 36	2.3	0.3	2.5	0.3	4.8	0.8
ADT 39	2.4	0.4	2.6	0.6	0.5	0.1
ASD 16	2.3	0.3	2.5	0.5	4.8	0.8
ASD 18	2.3	0.3	2.5	0.5	4.8	0.8
TPS 1	2.2	0.4	2.4	0.4	4.6	0.6
TPS 2	2.2	0.2	2.4	0.4	4.6	0.6
TKM 9	2.1	0.2	2.3	0.3	4.4	0.5
TKM 10	2.1	0.2	2.3	0.3	4.4	0.5
Co 37	1.5	0.2	2.1	0.3	3.6	0.5
CD (0.05%)	0.20	0.20	0.20	0.12	0.20	1.23

GDS : Growth During Stress

GDR : Growth During Recovery

Table 6. Induction response of shoot growth (cm) of Rice seedlings (Germination at the end of induction)

Genotypes	Germination at the end of induction			
	Induced		Control	
	Before	After	Before	After
Norungan	0.50	2.20	-	-
Nootripattu	0.51	1.60	-	-
Varapukudanchan	0.50	1.31	-	-
PMK 1	0.50	1.00	-	-
PKM 2	0.50	2.01	-	-
IR 20	0.50	0.90	-	-
ADT 36	0.51	0.81	-	-
ADT 39	0.51	0.90		
ADT 16	0.51	0.80		
ASD 18	0.50	0.80	-	-
TPS 1	0.50	0.71	-	-
TPS 2	0.50	0.70	-	-
TKM 9	0.51	0.71	-	-
TKM 10	0.50	0.71	-	-
CO 37	0.51	0.10	-	-
CD (0.05%)	0.02	0.42	-	-

Table 7. Induction response of shoot growth (cm) of Rice seedlings (Germination at the end of stress)

Genotypes	Germination at the end of stress			
	Induced		Control	
	Before	After	Before	After
Norungan	2.20	5.90	0.52	1.80
Nootripattu	1.60	4.70	0.50	1.60
Varapukudanchan	1.31	4.10	0.51	1.41
PMK 1	1.00	3.51	0.50	1.00
PKM 2	2.01	5.50	0.51	1.70
IR 20	0.90	3.30	0.50	0.91
ADT 36	0.81	3.10	0.51	0.81
ADT 39	0.90	3.30	0.50	0.91
ADT 16	0.80	3.11	0.50	0.80
ASD 18	0.80	3.10	0.51	0.82
TPS 1	0.71	2.91	0.51	0.70
TPS 2	0.70	2.90	0.51	0.71
TKM 9	0.70	2.91	0.51	0.72
TKM 10	0.71	2.90	0.50	0.70
CO 37	0.10	1.60	0.50	0.61
CD (0.05%)	0.42	0.14	0.02	0.13

Table 8. Induction response of shoot growth (cm) of Rice seedlings (Germination at the end of Recovery)

Genotypes	Germination at the end of recovery			
	Induced		Control	
	Before	After	Before	After
Norungan	5.90	1.30	1.80	3.61
Nootripattu	4.70	8.40	1.60	3.11
Varapukudanchan	4.10	7.41	1.41	2.50
PMK 1	3.51	6.21	1.00	1.70
PKM 2	5.50	9.51	1.70	3.31
IR 20	3.30	5.90	0.91	1.51
ADT 36	3.10	5.62	0.81	1.30
ADT 39	3.30	5.90	0.91	1.51
ADT 16	3.11	5.60	0.80	1.30
ASD 18	3.10	5.60	0.82	1.30
TPS 1	2.91	5.31	0.70	1.10
TPS 2	2.90	5.32	0.71	1.11
TKM 9	2.91	5.31	0.72	1.10
TKM 10	2.90	5.30	0.70	1.11
CO 37	1.60	3.70	0.61	0.81
CD (0.05%)	0.14	0.64	0.13	0.42

Table 9. Induction response of rice seedlings (Root cm)

Genotypes	GDS		GDR		GDS + GDR	
	Induced	Control	Induced	Control	Induced	Control
Norungan	4.5	1.4	5.5	2.5	10.0	3.9
Nootripattu	3.9	1.2	5.0	2.2	8.9	3.4
Varapukudanchan	3.5	1.0	4.5	1.8	8.0	2.8
PMK ₁	3.1	0.5	3.3	0.7	6.4	1.2
PMK ₂	4.4	1.3	5.3	2.4	9.7	3.7
IR 20	3.1	0.5	3.3	0.6	6.4	1.2
ADT 36	3.0	0.5	3.2	0.7	6.2	1.2
ADT 39	3.0	0.5	3.2	0.7	6.2	1.2
ASD 16	2.8	0.4	3.0	0.6	5.8	1.0
ASD 18	2.8	0.4	3.0	0.6	5.8	1.0
TPS 1	2.9	0.5	3.1	0.6	6.0	1.1
TPS 2	2.9	0.5	3.1	0.6	6.0	1.1
TKM 9	2.7	0.4	2.9	0.5	5.6	0.9
TKM 10	2.7	0.4	2.9	0.5	5.6	0.9
Co 37	2.2	0.2	2.6	0.4	4.8	0.6
CD (0.05%)	2.00	0.10	1.20	0.20	1.12	0.08

GDS : Growth During Stress

GDR : Growth During Recovery

Table 10. Induction response of root growth (cm) of Rice seedlings (Germination at the end of induction)

Genotypes	Germination at the end of induction			
	Induced		Control	
	Before	After	Before	After
Norungan	1.40	3.01	-	-
Nootripattu	1.50	2.41	-	-
Varapukudanchan	1.40	2.11	-	-
PMK 1	1.41	1.80	-	-
PKM 2	1.40	2.80	-	-
IR 20	1.00	1.70	-	-
ADT 36	1.02	1.60	-	-
ADT 39	1.01	1.71	-	-
ADT 16	1.01	1.61	-	-
ASD 18	1.00	1.61	-	-
TPS 1	1.11	1.51	-	-
TPS 2	1.12	1.52	-	-
TKM 9	1.02	1.40	-	-
TKM 10	1.00	1.41	-	-
CO 37	0.61	0.80	-	-
CD (0.05%)	0.12	0.16	-	-

Table 11. Induction response of root growth (cm) of Rice seedlings (Germination at the end of stress)

Genotypes	Germination at the end of stress			
	Induced		Control	
	Before	After	Before	After
Norungan	3.01	7.50	1.50	2.90
Nootripattu	2.41	6.31	1.40	2.60
Varapukudanchan	2.11	5.60	1.40	2.40
PMK 1	1.80	4.91	1.41	1.51
PKM 2	2.80	7.20	1.42	2.80
IR 20	1.70	4.81	1.39	1.50
ADT 36	1.60	4.61	1.39	1.50
ADT 39	1.71	4.71	1.38	1.51
ADT 16	1.61	4.41	1.40	1.41
ASD 18	1.61	4.40	1.50	1.41
TPS 1	1.51	4.40	1.50	1.41
TPS 2	1.52	4.40	1.47	1.52
TKM 9	1.40	4.12	1.00	1.40
TKM 10	1.41	4.11	1.01	1.41
CO 37	0.80	3.00	0.60	0.81
CD (0.05%)	0.16	1.18	0.12	0.24

Table 12. Induction response of root growth (cm) of Rice seedlings (Germination at the end of recovery)

Genotypes	Germination at the end of recovery			
	Induced		Control	
	Before	After	Before	After
Norungan	7.50	13.00	2.90	5.40
Nootripattu	6.31	11.30	2.60	4.81
Varapukudanchan	5.60	10.11	2.40	4.21
PMK 1	4.91	8.20	1.51	2.21
PKM 2	7.20	12.51	2.80	5.20
IR 20	4.81	8.10	1.50	2.20
ADT 36	4.61	7.80	1.50	2.21
ADT 39	4.71	7.91	1.51	2.21
ADT 16	4.41	7.40	1.41	2.02
ASD 18	4.40	7.40	1.41	2.00
TPS 1	4.40	7.50	1.50	2.12
TPS 2	4.40	7.51	1.52	2.11
TKM 9	4.12	7.01	1.40	1.90
TKM 10	4.11	7.00	1.41	1.91
CO 37	3.00	5.62	0.81	1.22
CD (0.05%)	1.18	0.82	0.24	0.42

4.2.2. Normal method

The data related to screening of rice genotypes by normal method are given in Table 13 to 16.

4.2.2.1. Germination Percentage

Fifteen genotypes evaluated for their water stress tolerance under in vitro conditions. It was evident that with increase in PEG-6000 concentrations, the germination percentage decreased, irrespective of the genotypes. Among the genotypes, are water stress tolerant genotypes such as Norungan, Nootripattu, Varapukudanchan and PMK 2 recorded the highest germination percentage of 98 per cent compared to the susceptible genotype CO 37 (68%). Significant differences were observed among genotypes, treatments and their interactions.

4.2.2.2. Shoot length

Shoot length decreased due to increase in PEG 6000 concentration. Significant differences in their response were observed in genotypes among the genotypes. Norungan recorded the highest shoot length (8.60 cm) followed by PMK 2 (8.40 cm), and the lowest was recorded by CO 37 (4.00 cm). The tolerant genotypes such as Norungan, Nootripattu, Varapukudanchan, PMK2 were on par. All other genotypes were on par, except susceptible genotype CO 37.

4.2.2.3. Root length

Root length decreased due to increase in PEG 6000 concentration. Significant differences were observed in genotypes. Among the genotypes, Norungan recorded the longest root length (9.40 cm) followed by PMK 2 (9.25 cm), Nootripattu (9.15 cm), Varapukudanchan (9.05 cm) whereas the lowest recorded in CO 37 (4.95 cm). All other genotypes were on par except susceptible genotype CO 37.

Table 13: Effect of water stress on shoot length(cm) of rice seedlings.

GENOTYPE	TREATMENTS		MEAN
	0.00 MPa	-0.50 MPa	
NORUNGAN	9.70	7.50	8.60
NOOTRIPATTU	9.00	7.30	8.15
VARAPUKUDANCHAN	9.20	7.20	8.20
PMK 1	8.90	4.30	6.60
PMK 2	9.50	7.30	8.40
IR 20	8.80	4.30	6.55
ADT 36	8.60	4.10	6.35
ADT 39	8.50	4.10	6.30
ASD 16	8.70	4.30	6.50
ASD 18	8.70	4.20	6.45
TPS 1	8.60	4.10	6.35
TPS 2	8.60	4.00	6.30
TKM 9	8.50	4.00	6.25
TKM 10	8.50	4.10	6.30
CO 37	5.10	2.90	4.00
MEAN	8.59	4.91	6.75

CD(5%): G: NS

T: 97

TxG: NS

Table 14: Effect of water stress on root length(cm) of rice seedlings.

GENOTYPE	TREATMENTS		MEAN
	0.00 MPa	-0.50 MPa	
NORUNGAN	10.50	8.30	9.40
NOOTRIPATTU	10.00	8.30	9.15
VARAPUKUDANCHAN	9.90	8.20	9.05
PMK 1	9.60	5.90	7.75
PMK 2	10.20	8.30	9.25
IR 20	9.50	5.90	7.70
ADT 36	9.50	5.80	7.65
ADT 39	9.40	5.80	7.60
ASD 16	9.50	5.60	7.55
ASD 18	9.50	5.70	7.60
TPS 1	9.40	5.70	7.55
TPS 2	9.40	5.60	7.50
TKM 9	9.30	5.40	7.35
TKM 10	9.30	5.30	7.30
CO 37	6.20	3.70	4.95
MEAN	9.41	6.23	7.82

CD(5%): G: NS

T: 0.94

GxT: NS

Table 15: Effect of water stress on germination percentage of rice seedlings.

GENOTYPE	TREATMENTS		MEAN
	0.00 MPa	-0.50 MPa	
NORUNGAN	100(90.0)	96 (79.5)	98 (84.7)
NOOTRIPATTU	100(90.0)	96(79.5)	98 (84.7)
VARAPUKUDANCHAN	100(90.0)	96(79.5)	98 (84.7)
PMK 1	96(78.8)	80(63.5)	88 (71.2)
PMK 2	100(90.0)	96(79.5)	98 (84.7)
IR 20	96(78.8)	76(60.7)	86 (69.8)
ADT 36	96(79.5)	72(58.1)	84 (68.8)
ADT 39	96(79.5)	72(58.1)	84 (68.8)
ASD 16	96(79.5)	68(55.6)	82 (67.5)
ASD 18	96(79.5)	64(53.1)	80 (66.3)
TPS 1	96(78.6)	64(53.1)	80 (65.8)
TPS 2	96(78.6)	64(53.1)	80 (65.8)
TKM 9	96(78.6)	60(50.8)	78 (64.7)
TKM 10	96(78.8)	60(50.8)	78 (64.8)
CO 37	96(78.8)	40(39.2)	68 (59.0)
MEAN	97.1(81.9)	73.6(60.9)	85.3 (71.4)

Transformed values are given in parentheses.

CD(5%): G:5.81 T: 2.12 GxT: 8.22

Table 16: Effect of water stress on vigour index of rice seedlings.

GENOTYPE	TREATMENTS		MEAN
	0.00 MPa	-0.50 MPa	
NORUNGAN	2020.00	1517.00	1768.50
NOOTRIPATTU	1900.00	1498.00	1699.00
VARAPUKUDANCHAN	1910.00	1478.00	1694.00
PMK 1	1776.00	816.00	1296.00
PMK 2	1970.00	1498.00	1734.00
IR 20	1757.00	775.00	1266.00
ADT 36	1738.00	713.00	1225.50
ADT 39	1718.00	713.00	1215.50
ASD 16	1747.00	673.00	1210.00
ASD 18	1747.00	634.00	1190.50
TPS 1	1728.00	627.00	1177.50
TPS 2	1728.00	614.00	1171.00
TKM 9	1709.00	564.00	1136.50
TKM 10	1709.00	564.00	1136.50
CO 37	1085.00	264.00	674.50
MEAN	1749.47	863.20	1306.33

CD(5%): G:12.50 T: 4.97 GxT: 17.66

4.2.2.4. Vigour Index

Vigour Index was calculated for all the genotypes. Water stress reduced the vigour index as compared to the control. Significant differences were observed in treatments, genotypes and their interactions. Among the genotypes, Norungan recorded the highest vigour index (1768.50) followed by PMK 2 (1734), Nootripattu (1699), Varapukudanchan (1694) and the lowest was recorded in susceptible genotype CO 37 (674.50).

4.3. MORPHOLOGICAL CHARACTERS

4.3.1. Plant height

The data relating to plant height are given in Table 17, 18 and Fig. 1. Plant height decreased with increase in water stress. Significant differences were observed among the genotypes, treatments, stages, G x T, G x S and T x S. Among the genotypes Norungan recorded the maximum plant height (62.82 cm), followed by PMK 2 (60.93 cm), Nootripattu (58.68 cm), Varapukudanchan (55.61 cm) and the minimum in CO 37 (40.50 cm).

Among the treatments T₁ (AC 100% ASM) recorded maximum plant height (85.70 cm), and the minimum in T₇ (50 % non induced, 39.05 cm). The induced seedlings have shown maximum plant height, when it was compared with non induced seedlings under 75 and 50 per cent ASM. Significant increase in plant height was noticed from transplanting stage to flowering stage.

4.3.2. Root length

The influence of various treatments on root length is given in Table 19, 20 and Fig. 2. Significant differences were observed among the genotypes, treatments and

Table17: Effect of water stress on plant height(cm) in induced and non induced rice genotypes

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	35.00	32.00	30.00	34.00	20.00	30.20
T2-AC 75% ASM	20.00	18.00	15.00	19.00	11.00	16.60
T3- 75% INDUCED	23.00	20.00	18.00	22.00	14.00	19.40
T4- 75% NON INDUCED	16.00	13.00	11.00	14.00	9.000	12.60
T5- AC 50% ASM	15.00	12.00	10.00	13.00	10.00	12.00
T6- 50% INDUCED	17.00	14.00	12.00	15.00	11.00	13.80
T7- 50 % NON INDUCED	11.00	9.00	8.00	10.00	7.000	9.00
Mean	19.60	17.10	14.90	18.10	11.70	
	TILLERING STAGE					
T1-AC 100%ASM	85.00	81.00	78.0	83.00	55.00	76.40
T2-AC 75% ASM	60.00	55.00	51.0	58.00	30.00	50.80
T3- 75% INDUCED	65.00	60.00	57.0	63.00	35.00	56.00
T4- 75% NON INDUCED	49.00	45.00	42.0	47.00	33.00	43.20
T5- AC 50% ASM	47.00	43.00	40.0	45.00	32.00	41.40
T6- 50% INDUCED	52.00	48.00	45.0	50.00	37.00	46.40
T7- 50 % NON INDUCED	42.00	38.00	35.0	40.00	27.00	36.40
Mean	57.1	52.90	49.7	55.10	35.60	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	115.00	110.00	107.0	113.00	76.00	104.00
T2-AC 75% ASM	89.00	84.00	80.0	87.00	50.00	78.00
T3- 75% INDUCED	95.00	90.00	86.0	93.00	56.00	84.00
T4- 75% NON INDUCED	61.00	57.00	53.0	60.00	43.00	54.80
T5- AC 50% ASM	60.00	55.00	52.0	58.00	41.00	53.20
T6- 50% INDUCED	65.00	60.00	57.0	63.00	47.00	58.40
T7- 50 % NON INDUCED	55.00	50.00	47.0	53.00	35.00	48.00
Mean	77.10	72.30	68.9	75.30	49.60	
	FLOWERING STAGE					
T1-AC 100%ASM	145.00	140.0	138.0	143.00	95.00	132.20
T2-AC 75% ASM	115.00	110.0	105.0	112.00	70.00	102.40
T3- 75% INDUCED	120.00	116.0	110.0	118.00	75.00	107.80
T4- 75% NON INDUCED	77.00	70.0	66.0	74.00	55.00	68.40
T5- AC 50% ASM	75.00	71.0	68.0	73.00	54.00	68.20
T6- 50% INDUCED	80.00	76.0	73.0	78.00	60.00	73.40
T7- 50 % NON INDUCED	70.00	66.0	63.0	68.00	47.00	62.80
Mean	97.40	92.7	89.0	95.10	65.10	

CD(5%): G:1.02 T:1.20 S:0.91 GxT: 2.69 GxS: 2.03 TxS: 2.40 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan

NOT: Nootripattu, VAR: Varapukudanchan.

Table18: Effect of water stress on plant height(cm) in induced and non induced rice genotypes (GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	95.00	90.75	88.25	93.25	61.25	85.70
T2-AC 75% ASM	71.00	66.75	62.75	69.00	40.25	61.95
T3- 75% INDUCED	75.75	71.50	67.75	74.00	45.00	66.80
T4- 75% NON INDUCED	50.75	46.25	43.00	48.75	35.00	44.75
T5- AC 50% ASM	49.25	45.25	42.50	47.25	34.25	43.70
T6- 50% INDUCED	53.50	49.50	46.75	51.50	38.75	48.00
T7- 50 % NON INDUCED	44.50	40.75	38.25	42.75	29.00	39.05
G-Mean	62.82	58.68	55.61	60.93	40.50	

CD(5%): G:1.02 T: 1.20 GxT:2.68

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 1. Effect of water stress on plant height (cm) in induced and non induced rice genotypes

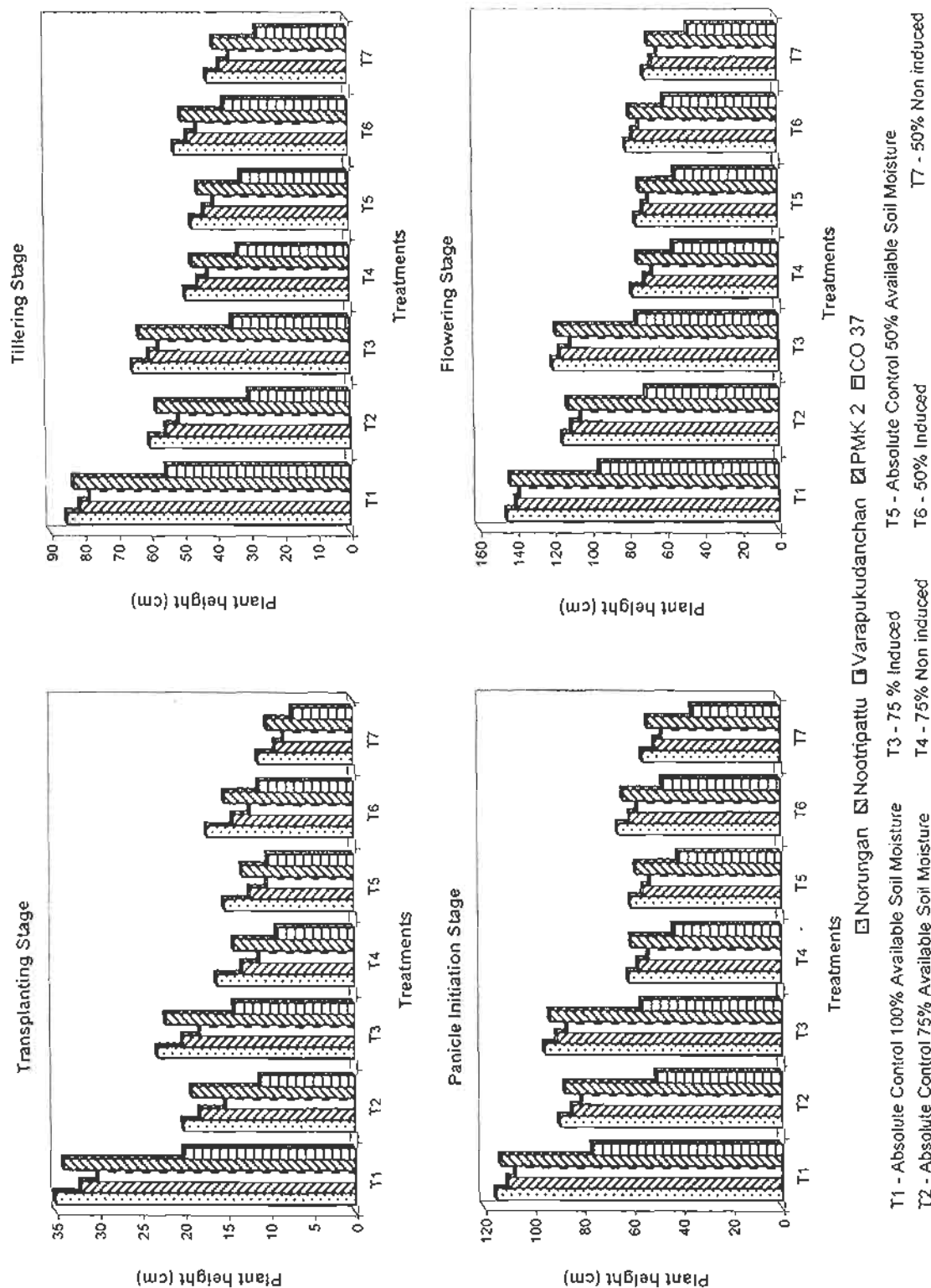


Table 19: Effect of water stress on root length(cm) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
TRANSPLANTING STAGE						
T1-AC 100%ASM	15.00	14.00	13.80	14.90	10.00	13.54
T2-AC 75% ASM	13.20	12.30	12.10	13.00	8.00	11.72
T3- 75% INDUCED	14.50	13.50	13.30	14.30	9.00	12.92
T4- 75% NON INDUCED	11.50	10.40	10.10	11.10	6.10	9.84
T5- AC 50% ASM	11.00	10.00	9.50	10.60	5.50	9.32
T6- 50% INDUCED	12.00	11.00	10.70	11.70	6.70	10.42
T7- 50 % NON INDUCED	9.30	8.40	7.90	9.10	4.00	7.74
Mean	12.36	11.37	10.06	12.10	7.04	
TILLERING STAGE						
T1-AC 100%ASM	20.00	19.00	18.80	19.80	15.00	18.52
T2-AC 75% ASM	18.20	17.00	16.80	17.80	12.00	16.36
T3- 75% INDUCED	19.30	18.00	17.70	19.00	13.00	17.40
T4- 75% NON INDUCED	16.50	15.40	15.00	16.20	10.50	14.72
T5- AC 50% ASM	16.00	15.00	14.50	15.50	10.00	14.20
T6- 50% INDUCED	17.00	16.00	15.60	16.70	11.00	15.26
T7- 50 % NON INDUCED	14.40	13.40	13.00	14.00	8.10	12.58
Mean	17.34	16.26	15.91	17.00	11.37	
PANICLE INITIATION STAGE						
T1-AC 100%ASM	30.00	29.00	28.80	29.80	24.00	28.32
T2-AC 75% ASM	28.00	27.00	26.80	27.60	20.90	26.06
T3- 75% INDUCED	29.10	28.00	27.70	28.70	22.00	27.10
T4- 75% NON INDUCED	26.50	25.50	25.00	26.10	19.40	24.50
T5- AC 50% ASM	26.00	25.00	24.40	25.50	18.90	23.96
T6- 50% INDUCED	27.00	26.10	25.60	26.70	20.00	25.08
T7- 50 % NON INDUCED	24.50	23.40	23.00	24.00	16.80	22.34
Mean	27.30	26.29	25.90	26.91	20.29	
FLOWERING STAGE						
T1-AC 100%ASM	32.00	31.00	30.80	31.80	27.00	30.52
T2-AC 75% ASM	30.40	29.50	29.20	30.20	25.00	28.86
T3- 75% INDUCED	31.50	30.50	30.30	31.20	26.00	29.90
T4- 75% NON INDUCED	28.50	27.50	27.20	28.20	23.00	26.88
T5- AC 50% ASM	28.00	27.00	26.60	27.60	22.50	26.34
T6- 50% INDUCED	29.00	28.00	27.80	28.70	23.60	27.42
T7- 50 % NON INDUCED	26.50	25.40	25.00	26.00	20.30	24.64
Mean	29.41	28.41	28.13	29.10	23.91	

CD(5%): G: 1.45 T: 1.72 S:1.30 GxT: NS GxS: NS TxS: NS GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 20: Effect of water stress on root length(cm) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	24.25	23.25	23.05	24.08	19.00	22.73
T2-AC 75% ASM	22.45	21.45	21.23	22.15	16.48	20.75
T3- 75% INDUCED	23.60	22.50	22.25	23.30	17.50	21.83
T4- 75% NON INDUCED	20.75	19.70	19.33	20.40	14.75	18.99
T5- AC 50% ASM	20.25	19.25	18.75	19.80	14.23	18.46
T6- 50% INDUCED	21.25	20.28	19.93	20.95	15.33	19.55
T7- 50 % NON INDUCED	18.68	17.65	17.23	18.28	12.30	16.83
G-Mean	21.60	20.58	20.25	21.28	15.65	

CD(5%): G:1.45 T: 1.72 GxT: NS
 AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
 NOT: Nootripattu, VAR: Varapukudanchan.

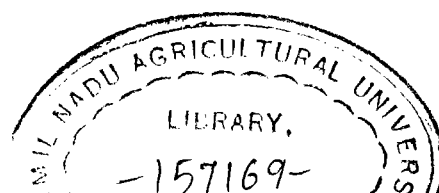
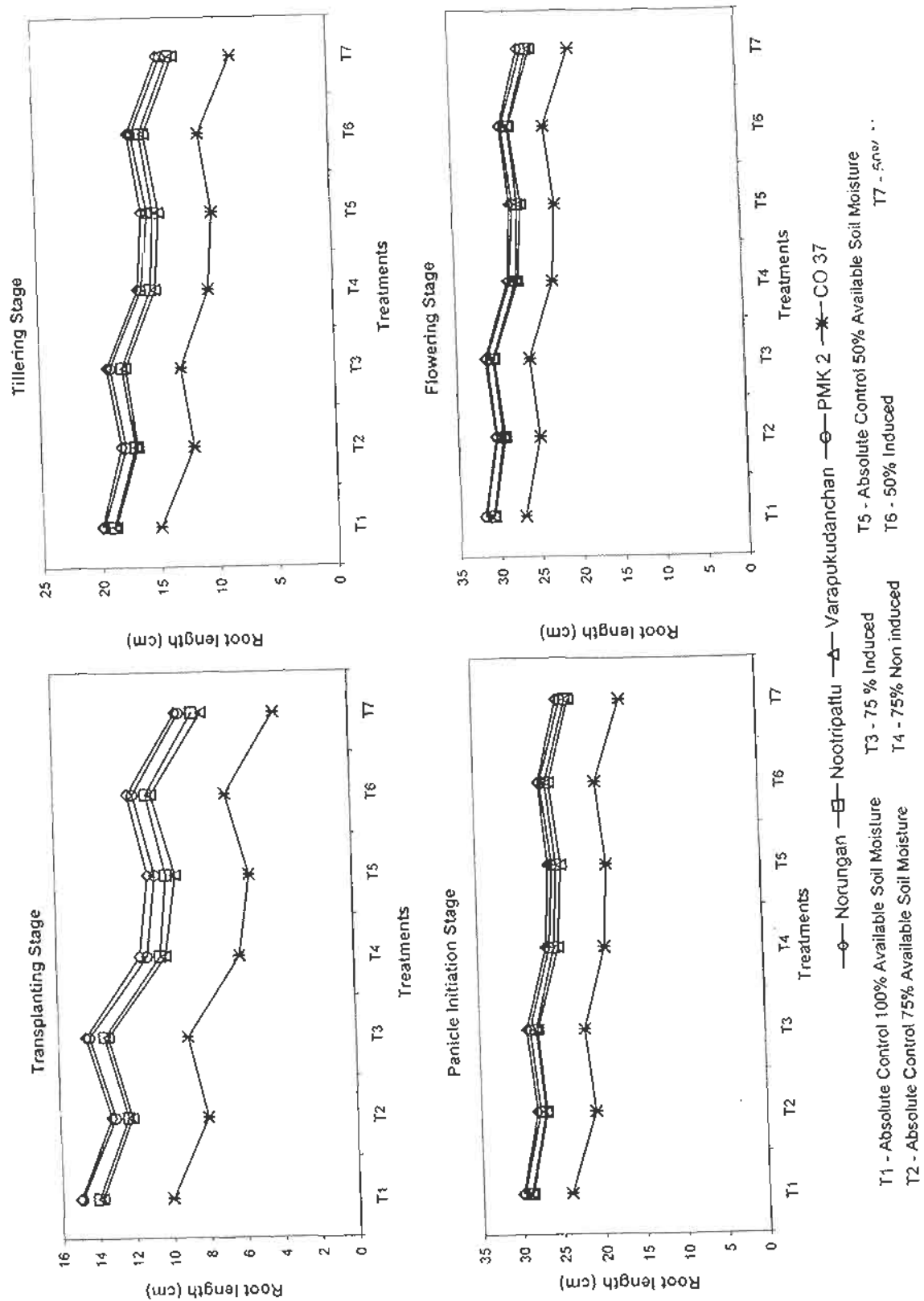


Fig. 2. Effect of water stress on root length (cm) in induced and non induced rice genotypes



stages. No significant differences were observed in their interactions. Root length decreased with increase in water stress. The induced seedlings shown maximum root length, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Among the genotypes, Norungan recorded the longest root length (21.60 cm), followed by PMK 2 (21.28 cm), Nootripattu (20.58 cm), Varapukudanchan (20.25 cm) and the lowest in CO 37 (15.65 cm). Among the treatments, T₁ (AC 100% ASM) recorded the longest root length (22.73 cm) and the lowest in T₇ (50% non induced, 16.83 cm). Significant increase in root length was noticed from transplanting stage to flowering stage.

4.3.3. Leaf number

The data relating to leaf number are given in Table 21, 22. Leaf number decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages, G x S and T x S. Among the genotypes PMK 2 recorded more number of leaves (23.23), followed by Norungan (20.63), Nootripattu (19.01), Varapukudanchan (18.60) and less number of leaves in CO 37 (14.34). Among the treatments T₁ (AC 100% ASM) recorded more number of leaves (25.52) and less in T₇ (50% non induced, 13.01). Significant increase in leaf number was noticed from transplanting stage to flowering stage. The induced seedlings shown more number of leaves, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.3.4. Leaf area

The data relating to leaf area are given in Table 23, 24. Leaf area decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages, and interactions. Among the genotypes PMK 2 recorded the

Table 21: Effect of water stress on leaf number in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
TRANSPLANTING STAGE						
T1-AC 100%ASM	4.00	4.00	4.00	4.00	4.00	4.00
T2-AC 75% ASM	4.00	3.90	3.90	4.00	3.80	3.92
T3- 75% INDUCED	4.00	3.90	3.90	4.00	3.80	3.92
T4- 75% NON INDUCED	3.60	3.50	3.50	3.60	3.40	3.52
T5- AC 50% ASM	3.40	3.30	3.30	3.40	3.20	3.32
T6- 50% INDUCED	3.60	3.50	3.50	3.60	3.40	3.52
T7- 50 % NON INDUCED	3.30	3.20	3.20	3.30	3.10	3.22
Mean	3.70	3.61	3.61	3.70	3.53	
TILLERING STAGE						
T1-AC 100%ASM	9.00	8.30	8.00	10.00	7.00	8.46
T2-AC 75% ASM	8.60	7.80	7.60	9.30	6.60	7.98
T3- 75% INDUCED	8.80	8.10	7.80	9.50	6.80	8.20
T4- 75% NON INDUCED	6.40	5.60	5.30	7.00	4.30	5.72
T5- AC 50% ASM	6.20	6.40	6.10	6.90	4.10	5.94
T6- 50% INDUCED	6.60	5.80	5.50	7.20	4.60	5.94
T7- 50 % NON INDUCED	5.70	5.60	5.50	5.90	3.80	5.30
Mean	7.33	6.80	6.54	7.97	5.31	
PANICLE INITIATION STAGE						
T1-AC 100%ASM	44.00	41.20	39.10	49.30	33.00	41.32
T2-AC 75% ASM	42.00	39.10	37.20	47.00	31.10	39.28
T3- 75% INDUCED	43.00	40.10	38.20	48.40	32.00	40.34
T4- 75% NON INDUCED	25.00	24.10	22.10	28.20	15.00	22.88
T5- AC 50% ASM	23.00	22.10	20.20	26.00	13.10	20.88
T6- 50% INDUCED	27.00	26.10	24.20	30.10	17.00	24.88
T7- 50 % NON INDUCED	20.10	19.00	19.20	24.10	11.00	18.68
Mean	32.01	30.24	28.60	36.16	21.74	
FLOWERING STAGE						
T1-AC 100%ASM	51.00	48.20	46.10	56.00	40.10	48.28
T2-AC 75% ASM	48.00	45.20	43.10	53.10	37.00	45.28
T3- 75% INDUCED	50.10	47.00	45.00	55.10	39.00	47.24
T4- 75% NON INDUCED	33.10	28.00	30.20	39.10	19.10	29.90
T5- AC 50% ASM	31.00	26.30	28.00	37.20	17.10	27.92
T6- 50% INDUCED	35.00	30.00	32.10	41.00	21.20	31.86
T7- 50 % NON INDUCED	28.00	23.10	25.00	34.10	14.00	24.84
Mean	39.46	35.40	35.64	45.09	26.79	

CD(5%): G: 1.27 T: 1.20 S: 1.14 GxT: NS GxS: 2.54 TxS: 3.00 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan

NOT: Nootripattu, VAR: Varapukudanchan.

Table 22: Effect of water stress on leaf number , in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	27.00	25.43	24.30	29.83	21.03	25.52
T2-AC 75% ASM	25.65	24.00	22.95	28.35	19.63	24.12
T3- 75% INDUCED	26.48	24.78	23.73	29.25	20.40	24.93
T4- 75% NON INDUCED	17.03	15.30	15.28	19.48	10.45	15.51
T5- AC 50% ASM	15.90	14.53	14.40	18.38	9.38	14.52
T6- 50% INDUCED	18.05	16.35	16.33	20.48	11.55	16.55
T7- 50 % NON INDUCED	14.28	12.73	13.23	16.85	7.98	13.01
G-Mean	20.63	19.01	18.60	23.23	14.34	

CD(5%): G:1.27 T:1.20 GxT: NS
 AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
 NOT: Nootripattu, VAR: Varapukudanchan.

Table 23: Effect of water stress on leaf area ($\text{cm}^2 \text{ plant}^{-1}$) in induced and non induced rice genotypes. 108

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	185.00	175.00	164.60	195.10	140.00	171.94
T2-AC 75% ASM	155.00	144.00	133.00	164.10	100.00	139.22
T3- 75% INDUCED	165.10	154.20	144.10	175.00	110.00	149.68
T4- 75% NON INDUCED	130.00	114.00	104.00	135.10	60.00	108.62
T5- AC 50% ASM	114.00	104.00	94.10	125.00	50.00	97.42
T6- 50% INDUCED	135.00	124.10	114.10	145.00	70.00	97.42
T7- 50 % NON INDUCED	103.00	93.00	84.00	115.00	40.00	87.00
Mean	141.01	129.76	119.70	150.61	81.43	
	TILLERING STAGE					
T1-AC 100%ASM	393.00	383.00	372.00	403.30	347.00	379.66
T2-AC 75% ASM	351.00	342.00	331.50	363.00	297.00	336.90
T3- 75% INDUCED	372.00	362.10	352.00	383.00	317.00	357.22
T4- 75% NON INDUCED	303.00	292.50	282.50	313.00	217.00	281.60
T5- AC 50% ASM	293.00	283.00	273.00	302.00	207.00	271.60
T6- 50% INDUCED	322.00	313.00	303.00	332.50	237.00	301.62
T7- 50 % NON INDUCED	283.00	273.00	262.00	291.00	197.00	261.20
Mean	331.09	321.23	310.86	341.11	259.86	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	706.00	696.00	685.00	716.00	660.00	692.60
T2-AC 75% ASM	576.10	565.00	555.00	585.00	419.00	540.02
T3- 75% INDUCED	585.50	575.00	565.00	596.00	430.00	550.30
T4- 75% NON INDUCED	416.00	436.10	426.00	456.00	380.00	422.82
T5- AC 50% ASM	435.00	421.10	416.00	445.00	370.00	417.42
T6- 50% INDUCED	456.00	446.10	436.00	466.00	390.10	438.84
T7- 50 % NON INDUCED	425.00	416.00	406.00	435.10	360.00	408.42
Mean	514.23	507.90	498.43	528.44	429.87	
	FLOWERING STAGE					
T1-AC 100%ASM	725.0	715.00	705.0	735.00	680.00	712.00
T2-AC 75% ASM	595.00	585.10	575.00	605.00	640.00	600.02
T3- 75% INDUCED	605.00	595.00	585.00	615.00	650.00	610.00
T4- 75% NON INDUCED	465.00	455.00	445.00	475.00	500.00	468.00
T5- AC 50% ASM	455.00	445.00	435.00	465.00	491.00	458.20
T6- 50% INDUCED	475.00	465.10	455.00	485.0	510.00	478.02
T7- 50 % NON INDUCED	445.10	435.00	425.00	455.00	481.00	448.22
Mean	537.87	527.89	517.86	547.86	564.57	

CD(5%): G: 0.63 T:0.74 S: 0.56 GxT:1.65 GxS: 1.25 TxS: 1.47 GxTxS:3.31

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 24: Effect of water stress on leaf area ($\text{cm}^2 \text{ plant}^{-1}$) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	502.25	492.25	481.65	512.35	456.75	489.05
T2-AC 75% ASM	419.28	409.03	398.63	429.28	364.00	404.04
T3- 75% INDUCED	431.90	421.58	411.53	442.25	376.75	416.80
T4- 75% NON INDUCED	328.50	324.40	314.38	344.78	289.25	320.26
T5- AC 50% ASM	324.25	313.28	304.53	334.25	279.50	311.16
T6- 50% INDUCED	347.15	337.08	327.03	357.13	301.78	334.03
T7- 50 % NON INDUCED	314.03	304.25	294.25	324.03	269.50	301.21
G-Mean	381.05	371.69	361.71	392.01	333.93	

CD(5%):

G: 0.63

T: 0.74

GxT:1.65

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

highest leaf area ($392.01 \text{ cm}^2 \text{ plant}^{-1}$) followed by Norungan ($381.05 \text{ cm}^2 \text{ plant}^{-1}$), Nootripattu ($371.69 \text{ cm}^2 \text{ plant}^{-1}$) and Varapukundanchan ($361.71 \text{ cm}^2 \text{ plant}^{-1}$). Among the treatments T_1 (AC 100% ASM) recorded the highest leaf area ($489.05 \text{ cm}^2 \text{ plant}^{-1}$), and less in T_7 (50% non induced, $301.21 \text{ cm}^2 \text{ plant}^{-1}$), significant increase in leaf area was noticed from transplanting stage to flowering stage. The induced seedlings showed highest leaf area, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.3.5. Root volume

The data relating to root volume are given in Table 25, 26. Root volume decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and $G \times S$. Among the genotypes Norungan recorded the maximum root volume (23.61 cc), followed by PMK 2 (23.08 cc), Nootripattu (22.59 cc), Varapukudanchan (22.07 cc) and the minimum in CO 37 (13.78 cc).

Among the treatments T_1 (AC 100% ASM) recorded the maximum root volume (24.40 cc) and the minimum in T_7 (50% non induced as 18.13 cc). Significant increase in root volume was noticed from transplanting stage to flowering stage. The induced seedlings showed maximum root volume, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.4. GROWTH ATTRIBUTES

4.4.1. Leaf area index (LAI)

The data relating to leaf area index are given in Table 27, 28. LAI decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and interactions.

Table 25: Effect of water stress on root volume(cc) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	11.00	10.00	9.60	10.50	7.00	9.60
T2-AC 75% ASM	9.00	8.10	7.60	8.60	5.10	7.70
T3- 75% INDUCED	9.50	8.60	8.00	9.00	5.60	8.10
T4- 75% NON INDUCED	6.20	5.20	4.70	5.70	2.50	4.90
T5- AC 50% ASM	6.00	5.00	4.50	5.50	2.40	4.70
T6- 50% INDUCED	6.50	5.40	5.00	6.00	2.80	5.10
T7- 50 % NON INDUCED	5.60	4.70	4.20	5.10	2.00	4.30
Mean	7.70	6.70	6.20	7.20	3.90	
	TILLERING STAGE					
T1-AC 100%ASM	26.00	25.10	24.00	25.30	16.10	23.30
T2-AC 75% ASM	24.00	23.10	22.70	23.50	14.00	21.50
T3- 75% INDUCED	24.50	23.60	23.20	24.00	14.50	22.00
T4- 75% NON INDUCED	21.40	20.00	19.60	20.70	11.50	18.60
T5- AC 50% ASM	21.00	19.60	19.20	20.40	11.00	18.20
T6- 50% INDUCED	21.80	20.50	20.00	21.20	12.00	19.10
T7- 50 % NON INDUCED	19.50	18.00	17.60	19.00	9.50	16.70
Mean	22.60	21.40	20.90	22.00	12.70	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	32.00	31.10	30.50	31.30	20.00	29.00
T2-AC 75% ASM	30.00	29.10	28.60	29.50	18.00	27.00
T3- 75% INDUCED	30.50	29.70	29.20	30.00	18.50	27.60
T4- 75% NON INDUCED	27.50	26.50	26.00	27.10	15.20	24.50
T5- AC 50% ASM	27.00	26.00	25.50	26.60	14.50	23.90
T6- 50% INDUCED	28.00	27.00	26.50	27.50	16.00	25.00
T7- 50 % NON INDUCED	25.50	24.50	24.00	25.00	13.00	22.40
Mean	28.60	27.70	27.20	28.10	16.50	
	FLOWERING STAGE					
T1-AC 100%ASM	39.00	38.00	37.30	38.20	26.00	35.70
T2-AC 75% ASM	35.00	35.50	35.00	36.00	23.20	32.90
T3- 75% INDUCED	37.00	36.10	35.40	36.50	24.00	33.80
T4- 75% NON INDUCED	34.50	33.60	33.00	34.00	21.00	31.20
T5- AC 50% ASM	34.00	33.10	32.60	32.90	20.40	30.60
T6- 50% INDUCED	35.00	34.00	33.50	34.60	21.70	31.80
T7- 50 % NON INDUCED	32.50	31.50	31.00	32.00	18.40	29.10
Mean	35.30	34.50	34.00	34.90	22.10	

CD(5%): G: 1.26 T: 1.50 S:1.30 GxT: NS GxS: 2.54 TxS: NS GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 26:Effect of water stress on root volume(cc) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	27.00	26.05	25.35	26.33	17.28	24.40
T2-AC 75% ASM	24.88	23.95	23.48	24.40	15.08	22.36
T3- 75% INDUCED	25.38	24.50	23.95	24.88	15.65	22.87
T4- 75% NON INDUCED	22.40	21.33	20.83	21.88	12.55	19.80
T5- AC 50% ASM	22.00	20.93	20.45	21.48	12.08	19.39
T6- 50% INDUCED	22.83	21.73	21.25	22.33	13.13	20.25
T7- 50 % NON INDUCED	20.78	19.68	19.20	20.28	10.73	18.13
G-Mean	23.61	22.59	22.07	23.08	13.78	

CD(5%): G:1.26 T: 1.50 GxT:NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 27: Effect of water stress on leaf area index in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	1.23	1.17	1.10	1.30	0.93	1.15
T2-AC 75% ASM	1.03	0.96	0.89	1.09	0.67	0.93
T3- 75% INDUCED	1.10	1.03	0.96	1.17	0.73	1.00
T4- 75% NON INDUCED	0.83	0.76	0.69	0.90	0.40	0.72
T5- AC 50% ASM	0.76	0.69	0.63	0.83	0.33	0.65
T6- 50% INDUCED	0.90	0.83	0.76	0.97	0.47	0.79
T7- 50 % NON INDUCED	0.69	0.62	0.55	0.77	0.27	0.58
Mean	0.93	0.87	0.80	1.00	0.54	
	TILLERING STAGE					
T1-AC 100%ASM	2.62	2.55	2.48	2.69	2.31	2.53
T2-AC 75% ASM	2.34	2.28	2.21	2.42	1.78	2.21
T3- 75% INDUCED	2.48	2.41	2.35	2.55	2.11	2.38
T4- 75% NON INDUCED	2.02	1.95	1.69	2.09	1.45	1.84
T5- AC 50% ASM	1.95	1.89	1.77	2.01	1.38	1.80
T6- 50% INDUCED	2.15	2.09	2.02	2.22	1.58	2.01
T7- 50 % NON INDUCED	1.89	1.82	1.75	1.94	1.31	1.76
Mean	2.21	2.14	2.04	2.27	1.70	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	4.71	4.64	4.57	4.77	4.40	4.62
T2-AC 75% ASM	3.84	3.77	3.70	3.90	2.79	3.60
T3- 75% INDUCED	3.91	3.83	3.77	3.97	2.87	3.67
T4- 75% NON INDUCED	2.97	2.91	2.84	3.04	2.53	2.86
T5- AC 50% ASM	2.90	2.84	2.77	2.97	2.47	2.79
T6- 50% INDUCED	3.04	2.97	2.91	3.11	2.60	2.93
T7- 50 % NON INDUCED	2.83	2.77	2.71	2.90	2.40	2.72
Mean	3.46	3.39	3.32	3.52	2.87	
	FLOWERING STAGE					
T1-AC 100%ASM	4.83	4.77	4.70	4.90	4.53	4.75
T2-AC 75% ASM	3.57	3.90	3.83	4.03	4.27	3.92
T3- 75% INDUCED	4.03	3.97	3.90	4.10	4.33	4.07
T4- 75% NON INDUCED	3.10	3.03	2.97	3.17	3.33	3.12
T5- AC 50% ASM	3.03	2.97	2.90	3.10	3.27	3.05
T6- 50% INDUCED	3.17	3.10	3.03	3.23	3.40	3.19
T7- 50 % NON INDUCED	3.03	2.90	2.90	2.83	3.03	2.94
Mean	3.54	3.52	3.46	3.62	3.74	

CD(5%): G:0.006 T:0.007 S: 0.005 GxT:0.016 GxS:0.012 TxS:0.015 GxTxS: 0.032

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
 NOT: Nootripattu, VAR: Varapukudanchan.

Table 28: Effect of water stress on leaf area index in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	3.35	3.28	3.21	3.42	3.04	3.26
T2-AC 75% ASM	2.70	2.73	2.66	2.86	2.38	2.66
T3- 75% INDUCED	2.88	2.81	2.75	2.95	2.51	2.78
T4- 75% NON INDUCED	2.23	2.16	2.05	2.30	1.93	2.13
T5- AC 50% ASM	2.16	2.10	2.02	2.23	1.86	2.07
T6- 50% INDUCED	2.32	2.25	2.18	2.38	2.01	2.23
T7- 50 % NON INDUCED	2.11	2.03	1.98	2.11	1.75	2.00
G-Mean	2.53	2.48	2.41	2.61	2.21	

CD(5%):

G: 0.006

T: 0.007

GxT:0.016

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Among the genotypes PMK 2 recorded the highest LAI (2.61) followed by Norungan (2.53), Nootripattu (2.48), Varapukudanchan (2.41) and the lowest in CO 37 (2.21). Among the treatments T_1 (AC 100% ASM) recorded the highest LAI (3.26) and the lowest in T_7 (50% non induced, 2.00).

Significant increase in LAI was noticed from transplanting stage to flowering stage. The induced seedlings showed the highest LAI when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.4.2. Leaf area duration (LAD)

The data relating to leaf area duration are presented in Table 29, 30. LAD decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and $T \times S$.

Among the genotypes PMK 2 recorded the highest (40.56 days), followed by Norungan (39.51 days), Nootripattu (38.63 days), Varapukudanchan (37.49 days) and the lowest in CO 37 (33.27 days). Among the treatments T_1 (AC 100% ASM) recorded the highest LAD (50.48 days) and lowest in T_7 (50% non induced, 31.12 days).

Significant increase in LAD was noticed from transplanting stage to flowering stage. The induced seedlings shown longest LAD, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.4.3. Specific leaf area (SLA)

The data relating to specific leaf area are shown in Table 31, 32. SLA decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and their interactions.

Table 29: Effect of water stress on leaf area duration (days) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TILLERING TO TRANSPLANTING STAGE					
T1-AC 100%ASM	28.90	27.90	26.86	29.92	24.35	27.59
T2-AC 75% ASM	25.30	24.30	23.25	26.36	18.35	23.51
T3- 75% INDUCED	26.86	25.82	24.81	27.90	21.35	25.35
T4- 75% NON INDUCED	21.40	20.35	17.85	22.38	13.85	19.17
T5- AC 50% ASM	20.35	19.35	18.36	21.35	12.85	18.45
T6- 50% INDUCED	22.91	21.86	20.86	23.90	15.35	20.98
T7- 50 % NON INDUCED	19.30	18.30	17.30	20.30	11.85	17.41
Mean	23.57	22.55	21.33	24.59	16.85	
	PANICLE INITIATION TO TILLERING STAGE					
T1-AC 100%ASM	54.95	53.95	52.85	55.97	50.35	53.61
T2-AC 75% ASM	46.36	45.35	44.35	47.40	34.30	43.55
T3- 75% INDUCED	47.90	46.86	45.85	48.95	37.35	45.38
T4- 75% NON INDUCED	37.45	36.46	33.95	38.45	29.85	35.23
T5- AC 50% ASM	36.40	35.46	34.45	37.35	28.85	34.50
T6- 50% INDUCED	38.96	37.96	36.95	39.95	31.36	37.04
T7- 50 % NON INDUCED	35.40	35.45	33.40	36.31	27.85	33.48
Mean	42.49	41.50	40.26	43.48	34.27	
	FLOWERING TO PANICLE INITIATION STAGE					
T1-AC 100%ASM	71.55	70.55	69.50	72.55	67.00	70.23
T2-AC 75% ASM	55.56	57.51	56.50	59.50	52.95	56.40
T3- 75% INDUCED	59.55	58.50	57.50	60.55	54.00	58.02
T4- 75% NON INDUCED	45.55	44.56	43.55	46.55	42.00	44.44
T5- AC 50% ASM	44.50	43.56	42.55	45.50	41.00	43.42
T6- 50% INDUCED	46.55	45.56	44.55	47.55	43.01	45.44
T7- 50 % NON INDUCED	44.01	42.55	42.05	43.01	4.75	42.47
Mean	52.47	51.83	50.89	53.60	48.67	

CD(5%): G: 0.61 T: 0.72 S: 0.47 GxT: NS GxS: 1.06 TxS: 1.25 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 30:Effect of water stress on leaf area duration (days) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	51.80	50.80	49.74	52.81	47.23	50.48
T2-AC 75% ASM	42.41	42.39	41.37	44.42	35.20	41.16
T3- 75% INDUCED	44.77	43.73	42.72	45.80	37.57	42.92
T4- 75% NON INDUCED	34.80	33.79	31.78	35.79	28.57	32.95
T5- AC 50% ASM	33.75	32.79	31.79	34.73	27.57	32.13
T6- 50% INDUCED	36.14	35.13	34.12	37.13	29.91	34.49
T7- 50 % NON INDUCED	32.90	31.77	30.93	33.21	26.82	31.12
G-Mean	39.51	38.63	37.49	40.56	33.27	

CD(5%):

G: 0.61

T: 0.72

GxT: NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 31: Effect of water stress on specific leaf area ($\text{cm}^2 \text{g}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	232.00	229.20	219.10	237.10	198.10	223.10
T2-AC 75% ASM	226.20	223.00	215.10	231.10	192.00	217.48
T3- 75% INDUCED	228.00	225.10	216.10	232.10	194.10	219.08
T4- 75% NON INDUCED	214.00	200.40	197.50	218.10	176.40	201.28
T5- AC 50% ASM	212.10	197.40	195.00	216.70	173.10	198.86
T6- 50% INDUCED	216.50	213.00	200.40	220.10	180.10	206.02
T7- 50 % NON INDUCED	200.40	185.40	180.20	204.10	160.50	186.12
Mean	218.46	210.50	203.34	222.76	182.04	
	TILLERING STAGE					
T1-AC 100%ASM	170.70	168.10	160.40	174.30	140.00	162.70
T2-AC 75% ASM	163.50	161.00	156.10	168.00	134.10	156.54
T3- 75% INDUCED	166.10	163.40	158.20	170.10	137.10	158.98
T4- 75% NON INDUCED	151.00	148.40	144.50	155.10	119.00	143.60
T5- AC 50% ASM	149.00	146.10	141.00	151.00	115.20	140.46
T6- 50% INDUCED	153.20	150.40	147.10	157.00	122.10	145.96
T7- 50 % NON INDUCED	137.10	136.40	130.10	140.20	106.10	129.98
Mean	155.80	153.40	148.20	159.39	124.80	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	138.20	136.00	131.60	142.10	108.10	131.20
T2-AC 75% ASM	131.10	128.40	121.00	135.40	101.60	123.30
T3- 75% INDUCED	134.20	131.40	124.20	138.00	104.10	126.38
T4- 75% NON INDUCED	115.30	112.10	105.40	117.10	85.40	107.06
T5- AC 50% ASM	113.40	110.10	103.10	115.30	82.10	104.80
T6- 50% INDUCED	117.40	115.00	107.10	120.10	90.10	109.94
T7- 50 % NON INDUCED	104.10	101.10	95.60	110.10	71.00	96.38
Mean	121.81	119.16	112.57	125.44	91.77	
	FLOWERING STAGE					
T1-AC 100%ASM	120.20	117.40	110.10	126.10	87.00	112.16
T2-AC 75% ASM	114.20	112.40	104.00	119.20	78.10	105.58
T3- 75% INDUCED	116.10	114.50	107.10	120.00	81.00	107.74
T4- 75% NON INDUCED	102.10	98.40	87.40	106.40	61.00	91.06
T5- AC 50% ASM	99.00	97.20	85.10	103.00	57.10	88.28
T6- 50% INDUCED	104.40	101.50	90.10	108.10	65.10	93.84
T7- 50 % NON INDUCED	90.10	86.40	75.00	92.10	45.10	77.74
Mean	106.59	103.97	94.11	110.70	67.77	

CD(5%): G: 0.53 T:0.62 S: 0.47 GxT: 1.39 GxS: 1.05 TxS:1.25 GxTxS:2.79

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 32: Effect of water stress on specific leaf area ($\text{cm}^2 \text{g}^{-1}$) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	165.28	162.68	155.30	169.90	133.30	157.29
T2-AC 75% ASM	158.50	156.20	149.05	163.43	126.45	150.73
T3- 75% INDUCED	161.10	158.60	151.40	165.05	129.08	153.05
T4- 75% NON INDUCED	145.60	139.83	133.70	149.18	110.45	135.75
T5- AC 50% ASM	143.38	137.70	131.05	146.50	106.88	133.10
T6- 50% INDUCED	147.88	144.98	136.18	151.33	114.35	138.94
T7- 50 % NON INDUCED	132.93	127.33	120.23	136.63	95.68	122.56
G-Mean	150.66	146.76	139.56	154.57	116.60	

CD(5%):

G: 0.53

T: 0.62

GxT: 1.39

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Among the genotypes PMK 2 recorded the highest SLA ($154.57 \text{ cm}^2 \text{ g}^{-1}$), followed by Norungan ($150.66 \text{ cm}^2 \text{ g}^{-1}$), Nootripattu ($146.76 \text{ cm}^2 \text{ g}^{-1}$), Varapukudanchan ($139.56 \text{ cm}^2 \text{ g}^{-1}$) and the lowest was recorded in CO 37 ($116.60 \text{ cm}^2 \text{ g}^{-1}$). Among the treatments T_1 (AC 100% ASM) recorded the highest SLA ($157.29 \text{ cm}^2 \text{ g}^{-1}$) and the lowest in T_7 (50% non induced, $122.56 \text{ cm}^2 \text{ g}^{-1}$).

Significant decrease in SLA was noticed from transplanting stage to flowering stage. The induced seedlings shown maximum SLA, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.4.4. Specific leaf weight (SLW)

The data relating to specific leaf weight are shown in Table 33, 34. SLW decreased with increase in water stress. Significant differences were observed in the treatments and stages. No significant differences were observed in their interactions.

Among the genotypes PMK 2 recorded the highest SLW (7.89 mg cm^{-2}), followed by Norungan (7.50 mg cm^{-2}), Nootripattu (7.44 mg cm^{-2}) and Varapukudanchan (7.36 mg cm^{-2}) and the lowest value was recorded in CO 37 (7.15 mg cm^{-2}). Among the treatments, T_1 (AC 100% ASM) recorded the highest SLW (8.16 mg cm^{-2}) and the lowest in T_7 (50% non induced, 7.09 mg cm^{-2}).

Table 33: Effect of water stress on specific leaf weight (mg cm^{-2}) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	3.98✓	3.96	3.80	4.39	3.65✓	3.96
T2-AC 75% ASM	3.19	3.15	3.02	3.98	2.85	3.24
T3- 75% INDUCED	3.20✓	3.17	3.04	3.99	2.87✓	3.25
T4- 75% NON INDUCED	3.04✓	2.99	2.93	3.57	2.74✓	3.05
T5- AC 50% ASM	3.00	2.90	2.87	3.52	2.70	3.00
T6- 50% INDUCED	3.10	3.02	2.96	3.61	2.80	3.10
T7- 50 % NON INDUCED	2.84	2.78	2.70	3.41	2.55	2.86
Mean	3.19	3.14	3.05	3.78	2.88	
	TILLERING STAGE					
T1-AC 100%ASM	5.10	5.07	4.96	5.75	74.70	5.12
T2-AC 75% ASM	4.57	4.53	4.43	4.99	4.18	4.54
T3- 75% INDUCED	4.60	4.55	4.46	5.01	4.21	4.57
T4- 75% NON INDUCED	4.26	4.20	4.17	4.57	4.07	4.25
T5- AC 50% ASM	4.21	4.16	4.12	4.50	4.01	4.20
T6- 50% INDUCED	4.30	4.25	4.21	4.60	4.10	4.29
T7- 50 % NON INDUCED	4.10	4.05	4.01	4.39	3.92	4.09
Mean	4.45	4.40	4.34	4.83	4.17	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	11.74	11.67	11.60	12.00	11.30	11.66
T2-AC 75% ASM	11.01	10.96	10.90	11.46	10.64	10.99
T3- 75% INDUCED	11.10	11.00	10.95	11.50	10.70	11.05
T4- 75% NON INDUCED	10.85	10.76	10.68	10.97	10.42	10.74
T5- AC 50% ASM	10.80	10.72	10.61	10.92	10.38	10.69
T6- 50% INDUCED	10.90	10.80	10.72	11.01	10.50	10.76
T7- 50 % NON INDUCED	10.69	10.60	10.50	10.81	10.24	10.57
Mean	11.01	10.93	10.85	11.24	10.60	
	FLOWERING STAGE					
T1-AC 100%ASM	12.00	11.90	11.80	12.50	11.28	11.90
T2-AC 75% ASM	11.73	11.67	11.60	11.95	11.41	11.67
T3- 75% INDUCED	11.80	11.71	11.66	12.00	11.45	11.72
T4- 75% NON INDUCED	11.00	10.95	10.87	11.45	10.61	10.98
T5- AC 50% ASM	10.97	10.92	10.83	11.40	10.54	10.93
T6- 50% INDUCED	11.10	11.00	10.92	11.50	10.71	11.04
T7- 50 % NON INDUCED	10.85	10.82	10.74	11.29	10.60	10.86
Mean	11.35	11.28	11.20	11.73	10.94	

CD(5%): G: NS T: 0.63 S: 0.47 GxT: NS GxS: NS TxS: NS GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 34: Effect of water stress on specific leaf weight (mg cm^{-2}) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	8.21	8.15	8.04	8.66	7.73	8.16
T2-AC 75% ASM	7.63	7.58	7.49	8.10	7.27	7.61
T3- 75% INDUCED	7.67	7.61	7.53	8.13	7.31	7.65
T4- 75% NON INDUCED	7.29	7.23	7.16	7.64	6.96	7.26
T5- AC 50% ASM	7.25	7.18	7.11	7.59	6.91	7.20
T6- 50% INDUCED	7.35	7.27	7.20	7.68	7.03	7.31
T7- 50 % NON INDUCED	7.12	7.06	6.99	7.48	6.83	7.09
G-Mean	7.50	7.44	7.36	7.89	7.15	

CD(5%):

G: NS

T: 0.63

GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Significant increase in SLW was noticed from transplanting stage to flowering stage. The induced seedlings showed maximum SLW, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.4.5. Net assimilation rate (NAR)

The data relating to NAR are given in Table 35, 36. NAR decreased with increase in water stress. Significant differences were observed in the genotypes treatments, stages and interactions.

Among the genotypes PMK 2 recorded the highest NAR ($1.2296 \text{ mg cm}^{-2} \text{ day}^{-1}$) followed by Norungan ($1.0624 \text{ mg cm}^{-2} \text{ day}^{-1}$) and lowest value was recorded in CO 37 ($0.9527 \text{ mg cm}^{-2} \text{ day}^{-1}$). Among the treatments T_1 (100% ASM) recorded the highest NAR ($1.2617 \text{ mg cm}^{-2} \text{ day}^{-1}$) and the lowest was recorded in T_7 (50% noninduced $0.8178 \text{ mg cm}^{-2} \text{ day}^{-1}$). Significant increase in NAR was noticed from transplanting stage to PI stage and then declined. The induced seedlings recorded better NAR than non induced seedlings under 75 and 50 per cent ASM.

4.4.6. Crop growth rate (CGR)

The data relating to crop growth rate are given in Table 37, 38. CGR decreased with increase in water stress. Significant differences were observed among the genotypes, treatments, stages, $G \times S$ and $T \times S$.

Among the genotypes PMK 2 recorded the highest CGR ($34.10 \text{ g cm}^{-2} \text{ day}^{-1}$), followed by Norungan ($31.00 \text{ g cm}^{-2} \text{ day}^{-1}$), Nootripattu ($28.06 \text{ g cm}^{-2} \text{ day}^{-1}$), Varapukudanchan ($25.11 \text{ g cm}^{-2} \text{ day}^{-1}$) and the lowest in CO 37 ($18.11 \text{ g cm}^{-2} \text{ day}^{-1}$). Among the treatments T_1 (AC 100% ASM) recorded the maximum CGR

Table 35:

Effect of water stress on Net assimilation rate ($\text{mg cm}^{-2} \text{ day}^{-1}$) in induced and non-induced rice genotypes

TREATMENT/ GENOTYPE	NOR	NOT	VAR	TILLERING - TRANSPLANTING		CO 37	T-Mean
				PMK 2			
AT1 - AC 100% ASM	1.3850	1.3450	1.3400	1.4380		1.2900	1.3596
T2 - AC 75% ASM	1.3150	1.2478	1.2165	1.3345		1.2100	1.2648
T3 - 75% INDUCED	1.3450	1.3170	1.2940	1.3850		1.2550	1.3192
T4 - 75% NON-INDUCED	1.2300	1.1350	1.0950	1.2450		1.0250	1.1460
T5 - AC 50% ASM	1.1700	1.1165	1.0450	1.2050		1.0050	1.1083
T6 - 50% INDUCED	1.2350	1.2300	1.1480	1.2850		1.0850	1.1966
T7 - 50% NON-INDUCED	1.0650	1.0375	1.0440	1.0945		0.9850	1.0452
MEAN	1.2493	1.2041	1.1646	1.2839		1.1221	
PANICLE INITIATION - TILLERING							
T1 - AC 100% ASM	1.9450	1.8205	1.7550	2.5350		1.7100	1.9531
T2 - AC 75% ASM	1.8050	1.6270	1.5120	2.2850		1.3750	1.7208
T3 - 75% INDUCED	1.8600	1.6900	1.6335	2.4100		1.5500	1.8287
T4 - 75% NON-INDUCED	1.5100	1.3750	1.3150	1.8750		1.0700	1.4290
T5 - AC 50% ASM	1.4100	1.2450	1.1545	1.7895		1.0500	1.3304
T6 - 50% INDUCED	1.5465	1.4175	1.3300	1.9100		1.1600	1.4728
T7 - 50% NON-INDUCED	1.2450	1.0650	1.0550	1.6060		1.0050	1.1952
MEAN	1.6174	1.4629	1.3936	2.0586		1.2747	
FLOWERING - PANICLE INITIATION							
T1 - AC 100% ASM	0.4850	0.4630	0.4585	0.5120		0.4428	0.4722
T2 - AC 75% ASM	0.3750	0.3450	0.3020	0.4350		0.2550	0.3424
T3 - 75% INDUCED	0.4265	0.4010	0.3690	0.4800		0.3050	0.3963
T4 - 75% NON-INDUCED	0.2550	0.2220	0.1795	0.2650		0.9500	0.3743
T5 - AC 50% ASM	0.2355	0.1740	0.1550	0.2360		0.7075	0.3016
T6 - 50% INDUCED	0.2830	0.2650	0.2390	0.3300		0.1350	0.2504
T7 - 50% NON-INDUCED	0.1801	0.1430	0.1250	0.1840		0.1110	0.1486
MEAN	0.3200	0.2876	0.2611	0.3488		0.4152	

(CD = 0.05)

G = 0.00829

T = 0.00981

S = 0.00642

GxT = 0.02194

GxS = 0.01436

TxS = 0.01699

GxTxS = 0.03800

AC : Absolute Control; ASM : Available Soil Moisture; NOR: Norungan; NOT: Nootripattu; VAR: Varapukudanchan

Table 36: Effect of water stress on Net assimilation rate ($\text{mg cm}^{-2} \text{ day}^{-1}$) in induced and non-induced rice genotypes

TREATMENT/ GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1 - AC 100% ASM	1.2717	1.2095	1.1845	1.4950	1.1476	1.2617
T2 - AC 75% ASM	1.1650	1.0733	0.0102	1.3515	0.9467	1.1093
T3 - 75% INDUCED	1.2105	1.1360	1.0988	1.4250	1.0367	1.1814
T4 - 75% NON INDUCED	0.9983	0.9107	0.8632	1.1283	1.0150	0.9831
T5 - AC 50% ASM	0.9385	0.8452	0.7848	1.0722	0.9218	0.9125
T6 - 50% INDUCED	1.0215	0.9708	0.9057	1.1750	0.7933	0.9833
T7 - 50% NON INDUCED	0.8313	0.7485	0.7417	0.9602	0.8075	0.8178
MEAN	1.0624	0.9848	0.9413	1.2296	0.9527	

CD (0.05%) G. = 0.0829 T= 0.00981 GxT = 0.02194

AC : Absolute Control; ASM : Available Soil Moisture; NOR: Norungan; NOT: Nootripattu
VAR: Varapukudanchan;

Table 37: Effect of water stress on crop growth rate ($\text{g cm}^{-2} \text{ day}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TILLERING TO TRANSPLANTING STAGE					
T1-AC 100%ASM	24.35	23.98	23.90	24.44	20.40	23.41
T2-AC 75% ASM	19.90	19.75	19.67	19.95	15.11	18.88
T3- 75% INDUCED	20.00	19.98	19.96	20.04	15.56	19.11
T4- 75% NON INDUCED	15.39	15.30	15.20	15.45	14.60	15.19
T5- AC 50% ASM	15.10	15.20	14.98	15.16	14.31	14.95
T6- 50% INDUCED	15.20	14.97	14.90	15.56	14.67	15.06
T7- 50 % NON INDUCED	14.70	14.59	14.47	14.76	13.87	14.48
Mean	17.81	17.68	17.58	17.91	15.50	
	PANICLE INITIATION TO TILLERING STAGE					
T1-AC 100%ASM	67.11	58.67	50.22	75.56	42.22	58.76
T2-AC 75% ASM	55.11	46.67	38.22	63.51	31.56	47.01
T3- 75% INDUCED	63.51	55.07	46.62	71.96	39.56	55.34
T4- 75% NON INDUCED	47.56	39.07	30.67	56.00	19.56	38.57
T5- AC 50% ASM	39.11	30.67	22.22	47.56	11.07	30.13
T6- 50% INDUCED	53.00	44.56	36.11	61.44	28.00	44.62
T7- 50 % NON INDUCED	31.11	22.67	14.22	39.56	8.00	23.11
Mean	50.93	42.48	34.04	59.37	25.71	
	FLOWERING TO PANICLE INITIATION STAGE					
T1-AC 100%ASM	29.00	28.92	28.80	30.01	20.07	27.36
T2-AC 75% ASM	26.05	25.90	25.70	27.01	16.00	24.13
T3- 75% INDUCED	27.75	27.50	27.00	28.00	17.00	25.45
T4- 75% NON INDUCED	22.90	22.85	22.50	23.00	11.70	20.59
T5- AC 50% ASM	21.01	20.98	20.70	22.01	10.02	18.94
T6- 50% INDUCED	23.01	22.90	22.60	24.00	12.05	20.91
T7- 50 % NON INDUCED	20.05	19.00	18.75	21.02	5.01	16.77
Mean	24.25	24.01	23.72	25.01	13.12	

CD(5%): G: 0.61 T: 0.72 S: 0.47 GxT: NS GxS: 1.06 TxS: 1.25 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 38: Effect of water stress on crop growth rate ($\text{g cm}^{-2} \text{ day}^{-1}$) in induced and non induced rice genotypes. (GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	40.15	37.19	34.31	43.34	27.56	36.51
T2-AC 75% ASM	33.69	30.77	27.86	36.82	20.89	30.01
T3- 75% INDUCED	37.09	34.18	31.19	40.00	24.04	33.30
T4- 75% NON INDUCED	28.62	25.74	22.79	31.48	15.29	24.78
T5- AC 50% ASM	25.07	22.28	19.30	28.24	11.80	21.34
T6- 50% INDUCED	30.40	27.48	24.54	33.67	18.24	26.86
T7- 50 % NON INDUCED	21.95	18.75	15.81	25.11	8.96	18.12
G-Mean	31.00	28.06	25.11	34.10	18.11	

CD(5%):

G: 0.61

T: 0.72

GxT: NS

AC: Absolute control, ASM: Available soil moisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

(36.51 g cm⁻² day⁻¹) and the minimum was recorded in T₇ (50% non induced, 18.12 g cm⁻² day⁻¹).

Significant increase in CGR was noticed from transplanting stage to panicle initiation stage and then declined. The induced seedlings recorded maximum CGR, when compared with non induced seedlings under 75 and 50 per cent ASM.

4.4.7. Relative growth rate (RGR)

The influence of various treatments on RGR is given in Table 39, 40. RGR decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and interactions.

Among the genotypes, PMK 2 recorded the highest RGR (0.3426 g g⁻¹ day⁻¹), followed by Norungan (0.2758 g g⁻¹ day⁻¹), Nootripattu (0.2333 g g⁻¹ day⁻¹), Varapukudanchan (0.1815 g g⁻¹ day⁻¹) and the lowest in CO 37 (0.1284 g g⁻¹ day⁻¹). Among the treatments T₁ (AC 100% ASM) recorded the maximum RGR (0.3278 g g⁻¹ day⁻¹) and the minimum was recorded in T₇ (50% non induced, 0.1368 g g⁻¹ day⁻¹). Significant increase in RGR was noticed from transplanting stage to panicle initiation stage and then declined. The induced seedlings showed maximum RGR, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.5. PHYSIOLOGICAL PARAMETERS

4.5.1. Pigments

4.5.1.1. Total chlorophyll

The data relating to total chlorophyll are given in Table 41, 42 and Fig. 3. Total chlorophyll decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and T x S.

Table 39: Effect of water stress on relative growth rate ($\text{g g}^{-1} \text{ day}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	*CO 37	T-Mean
	TILLERING TO TRANSPLANTING STAGE					
T1-AC 100%ASM	0.0820	0.0814	0.0794	0.0835	0.0775	0.0808
T2-AC 75% ASM	0.0773	0.0764	0.0743	0.0787	0.0724	0.0758
T3- 75% INDUCED	0.0789	0.0786	0.0763	0.0810	0.0743	0.0778
T4- 75% NON INDUCED	0.0640	0.0631	0.0625	0.0671	0.0617	0.0637
T5- AC 50% ASM	0.0628	0.0620	0.0614	0.0660	0.0610	0.0626
T6- 50% INDUCED	0.0690	0.0672	0.0668	0.0687	0.0640	0.0669
T7- 50 % NON INDUCED	0.0618	0.0607	0.0601	0.0651	0.0591	0.0614
Mean	0.0707	0.0699	0.0687	0.0729	0.0671	
	PANICLE INITIATION TO TILLERING STAGE					
T1-AC 100%ASM	1.0133	0.8967	0.7333	1.2333	0.6267	0.8987
T2-AC 75% ASM	0.8333	0.7067	0.5527	1.0733	0.3527	0.7037
T3- 75% INDUCED	0.9593	0.8377	0.6793	1.1933	0.5800	0.8499
T4- 75% NON INDUCED	0.6900	0.5601	0.4100	0.8610	0.2210	0.5484
T5- AC 50% ASM	0.5933	0.4667	0.3133	0.7660	0.1067	0.4492
T6- 50% INDUCED	0.7193	0.5933	0.4400	0.8933	0.2533	0.5798
T7- 50 % NON INDUCED	0.4733	0.3467	0.1933	0.6467	0.0810	0.3482
Mean	0.7545	0.6283	0.4746	0.9524	0.3173	
	FLOWERING TO PANICLE INITIATION STAGE					
T1-AC 100%ASM	0.0046	0.0040	0.0036	0.0049	0.0030	0.0040
T2-AC 75% ASM	0.0021	0.0017	0.0011	0.0027	0.0006	0.0016
T3- 75% INDUCED	0.0025	0.0019	0.0015	0.0030	0.0010	0.0020
T4- 75% NON INDUCED	0.0017	0.0013	0.0008	0.0020	0.0004	0.0012
T5- AC 50% ASM	0.0015	0.0010	0.0005	0.0017	0.0003	0.0010
T6- 50% INDUCED	0.0019	0.0015	0.0009	0.0022	0.0004	0.0014
T7- 50 % NON INDUCED	0.0012	0.0008	0.0003	0.0014	0.0002	0.0008
Mean	0.0022	0.0017	0.0012	0.0026	0.0008	

CD(5%): G: 0.02 T:0.02 S: 0.01 GxT: 0.04 GxS: 0.03 TxS: 0.03 GxTxS:0.08

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 40:Effect of water stress on relative growth rate ($\text{g g}^{-1} \text{ day}^{-1}$) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	0.3666	0.3240	0.2721	0.4406	0.2357	0.3278
T2-AC 75% ASM	0.3042	0.2616	0.2094	0.3849	0.1419	0.2604
T3- 75% INDUCED	0.3469	0.3061	0.2524	0.4258	0.2184	0.3099
T4- 75% NON INDUCED	0.2519	0.2082	0.1578	0.3100	0.0944	0.2044
T5- AC 50% ASM	0.2192	0.1766	0.1251	0.2779	0.0560	0.1709
T6- 50% INDUCED	0.2631	0.2207	0.1662	0.3214	0.1059	0.2161
T7- 50 % NON INDUCED	0.1788	0.1361	0.0846	0.2377	0.0468	0.1368
G-Mean	0.2758	0.2333	0.1815	0.3426	0.1284	

CD(5%):

G: 0.02

T: 0.02

GxT: 0.04

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 41: Effect of water stress on total chlorophyll (mg g⁻¹F.W) in induced and Non induced genotypes

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
TRANSPLANTING STAGE						
T1-AC 100%ASM	1.65	1.60	1.54	1.73	1.40	1.58
T2-AC 75% ASM	1.45	1.40	1.34	1.52	1.10	1.36
T3- 75% INDUCED	1.50	1.45	1.4	1.60	1.22	1.43
T4- 75% NON INDUCED	0.96	0.94	0.85	1.02	0.60	0.87
T5- AC 50% ASM	0.92	0.87	0.80	0.98	0.55	0.82
T6- 50% INDUCED	1.05	1.00	0.96	1.10	0.75	0.97
T7- 50 % NON INDUCED	0.80	0.77	0.70	0.88	0.45	0.72
Mean	1.19	1.15	1.08	1.26	0.87	
TILLERING STAGE						
T1-AC 100%ASM	1.93	1.90	1.85	1.98	1.70	1.87
T2-AC 75% ASM	1.77	1.75	1.70	1.83	1.54	1.72
T3- 75% INDUCED	1.82	1.80	1.75	1.87	1.60	1.77
T4- 75% NON INDUCED	1.25	1.20	1.15	1.32	1.00	1.18
T5- AC 50% ASM	1.24	1.16	1.10	1.27	0.90	1.13
T6- 50% INDUCED	1.30	1.25	1.20	1.35	1.05	1.23
T7- 50 % NON INDUCED	1.10	1.05	0.96	1.15	0.75	1.00
Mean	1.49	1.44	1.39	1.54	1.22	
PANICLE INITIATION STAGE						
T1-AC 100%ASM	2.26	2.21	2.15	2.31	2.00	2.19
T2-AC 75% ASM	2.00	1.94	1.90	2.05	1.69	1.92
T3- 75% INDUCED	2.05	2.00	1.94	2.10	1.75	1.97
T4- 75% NON INDUCED	1.85	1.81	1.75	1.90	1.45	1.75
T5- AC 50% ASM	1.80	1.75	1.69	1.86	1.25	1.67
T6- 50% INDUCED	1.90	1.85	1.80	1.95	1.52	1.80
T7- 50 % NON INDUCED	1.60	1.54	1.49	1.65	1.01	1.46
Mean	1.92	1.87	1.82	1.97	1.52	
FLOWERING STAGE						
T1-AC 100%ASM	2.70	2.64	2.58	2.78	2.45	2.63
T2-AC 75% ASM	2.50	2.45	2.33	2.55	2.13	2.39
T3- 75% INDUCED	2.55	2.48	2.40	2.60	2.20	2.45
T4- 75% NON INDUCED	2.15	2.10	2.04	2.20	1.80	2.06
T5- AC 50% ASM	2.10	2.04	2.00	2.16	1.70	2.00
T6- 50% INDUCED	2.20	2.13	2.10	2.25	1.85	2.11
T7- 50 % NON INDUCED	1.85	1.80	1.72	1.90	1.45	1.74
Mean	2.29	2.23	2.17	2.35	1.94	

CD(5%): G: 0.06 T:0.07 S:0.05 GxT: NS GxS: NS TxS: 0.13 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 42: Effect of water stress on total chlorophyll ($\text{mg/g}^{-1}\text{F.W}$) content in induced and Non induced Rice genotypes. (GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	2.14	2.09	2.03	2.20	1.89	2.07
T2-AC 75% ASM	1.93	1.89	1.82	1.99	1.62	1.85
T3- 75% INDUCED	1.98	1.93	1.87	2.04	1.69	1.90
T4- 75% NON INDUCED	1.55	1.51	1.45	1.61	1.21	1.47
T5- AC 50% ASM	1.52	1.46	1.40	1.57	1.10	1.41
T6- 50% INDUCED	1.61	1.56	1.52	1.66	1.29	1.53
T7- 50 % NON INDUCED	1.34	1.29	1.22	1.40	0.92	1.23
G-Mean	1.72	1.67	1.61	1.78	1.39	

CD(5%):

G: 0.06

T: 0.07

GxT: NS

AC: Absolute control. ASM: Available soil moisture, NOR: Norungan
NOT: Nootripattu. VAR: Varapukudanchan.

Fig. 3. Effect of water stress on total chlorophyll (mgg⁻¹ FW) in induced and non induced rice genotypes

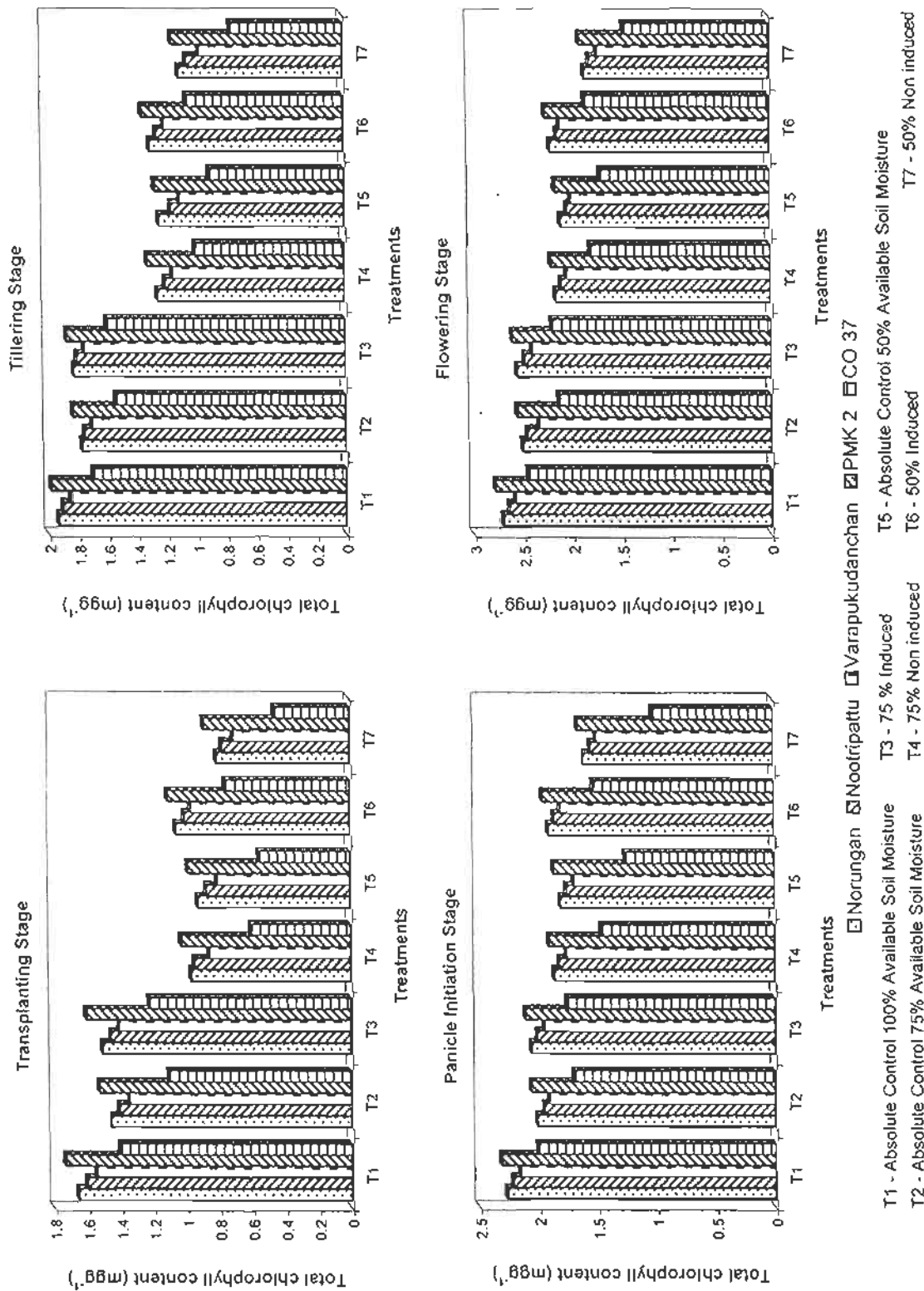


Table 43: Effect of water stress on RWC(%) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	96.00	94.50	95.30	94.20	95.70	95.14
T2-AC 75% ASM	94.30	93.40	94.10	93.70	94.70	94.04
T3- 75% INDUCED	95.00	94.00	94.80	94.00	95.10	94.58
T4- 75% NON INDUCED	93.10	93.00	93.70	93.00	94.00	93.36
T5- AC 50% ASM	91.50	92.00	92.40	91.70	93.00	92.12
T6- 50% INDUCED	92.40	92.70	93.00	92.10	93.70	92.78
T7- 50 % NON INDUCED	91.10	91.40	92.00	91.00	92.20	91.54
Mean	93.34	93.00	93.61	92.81	94.06	
	TILLERING STAGE					
T1-AC 100%ASM	97.00	95.80	97.30	96.80	96.10	96.60
T2-AC 75% ASM	96.60	94.70	96.40	96.00	95.10	95.76
T3- 75% INDUCED	96.30	95.10	97.00	96.20	95.40	96.00
T4- 75% NON INDUCED	96.40	94.20	96.10	95.60	94.80	95.42
T5- AC 50% ASM	96.00	93.70	95.00	94.40	93.80	94.58
T6- 50% INDUCED	96.10	94.00	95.30	95.10	94.50	95.00
T7- 50 % NON INDUCED	95.20	93.10	94.30	94.00	93.20	93.96
Mean	96.23	94.37	95.91	95.44	94.70	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	97.60	97.70	98.00	98.80	95.60	97.54
T2-AC 75% ASM	96.80	97.00	96.30	98.10	95.10	96.66
T3- 75% INDUCED	97.20	97.40	97.60	98.40	95.40	97.20
T4- 75% NON INDUCED	96.40	96.8	96.00	97.70	95.00	96.38
T5- AC 50% ASM	96.00	96.30	95.40	97.00	94.40	95.82
T6- 50% INDUCED	96.10	96.60	95.70	97.20	94.70	96.06
T7- 50 % NON INDUCED	96.00	96.10	95.00	96.70	94.10	95.58
Mean	96.59	96.84	96.29	97.70	94.90	
	FLOWERING STAGE					
T1-AC 100%ASM	97.90	97.90	98.30	99.00	95.60	97.74
T2-AC 75% ASM	96.80	97.20	96.90	98.30	95.30	96.90
T3- 75% INDUCED	98.30	97.50	97.70	98.60	95.50	97.52
T4- 75% NON INDUCED	96.50	96.80	96.30	97.80	95.10	96.50
T5- AC 50% ASM	96.20	96.50	95.60	97.00	94.50	95.96
T6- 50% INDUCED	96.20	96.80	95.80	97.30	94.80	96.18
T7- 50 % NON INDUCED	96.30	96.30	95.20	96.90	94.30	95.80
Mean	96.89	97.00	96.54	97.84	95.01	

CD(5%): G: 0.53 T:0.62 S: 0.47 GxT: NS GxS: 1.05 TxS: NS GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
 NOT: Nootripattu, VAR: Varapukudanchan.

Table 44: Effect of water stress on RWC (%) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	97.13	96.47	97.22	97.20	95.75	96.76
T2-AC 75% ASM	96.12	95.58	95.93	96.52	95.35	96.33
T3- 75% INDUCED	96.70	96.00	96.78	96.80	95.35	96.33
T4- 75% NON INDUCED	95.60	95.20	95.52	96.02	94.73	95.41
T5- AC 50% ASM	94.93	94.63	94.60	95.03	93.63	94.62
T6- 50% INDUCED	95.20	95.02	94.95	95.42	94.42	95.01
T7- 50 % NON INDUCED	94.65	94.22	94.13	94.65	93.45	94.22
G-Mean	95.76	95.30	95.59	95.95	94.67	

CD(5%):

G: 0.53

T: 0.62

GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 4. Effect of water stress on relative water content (%) in induced and non induced rice genotypes

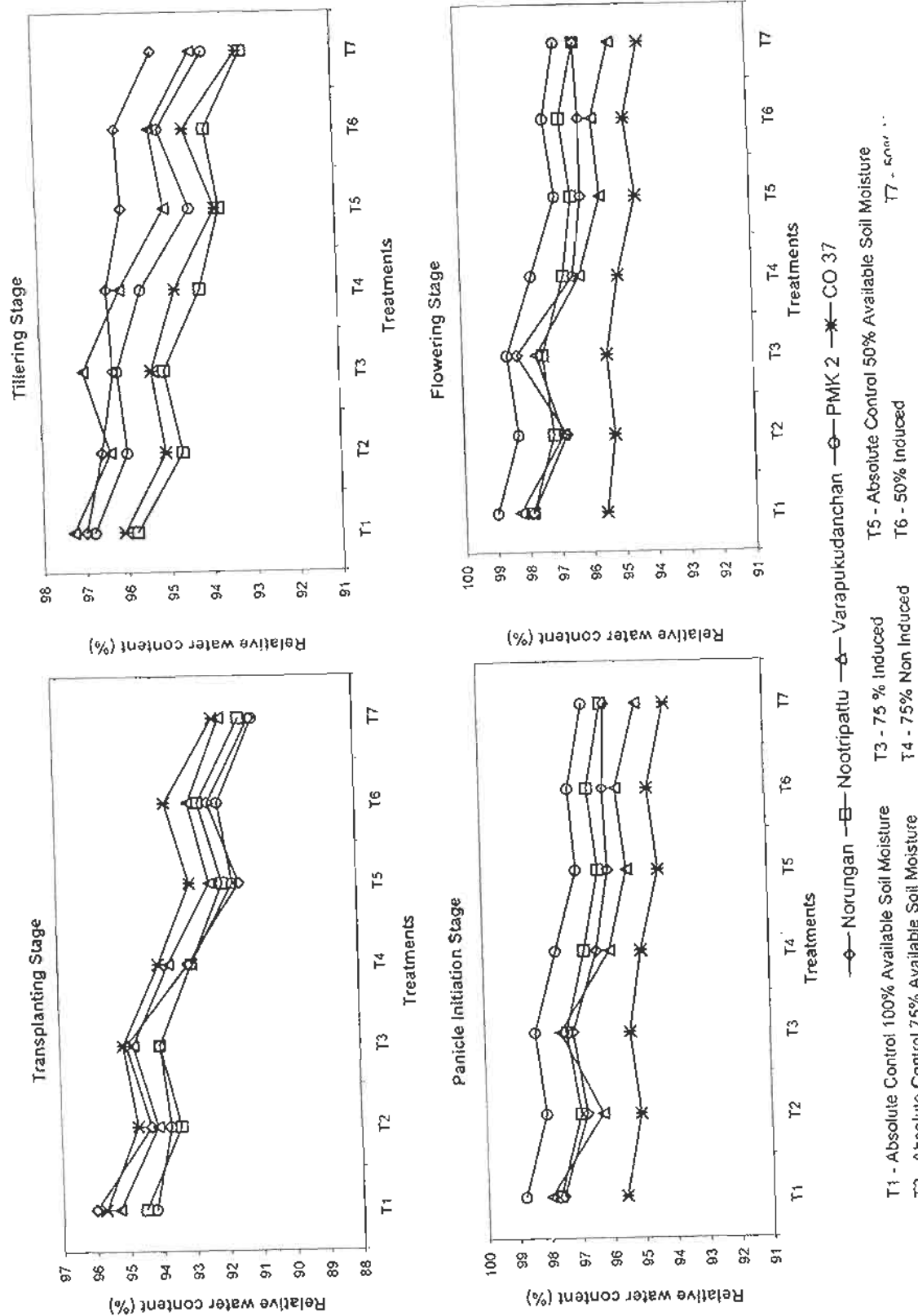


Table 45: Effect of water stress on transpiration rate (μ moles of $H_2O\ m^{-2}\ S^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	6.72	7.31	7.86	8.23	7.98	7.62
T2-AC 75% ASM	6.03	7.12	7.21	8.01	7.32	7.14
T3- 75% INDUCED	5.16	6.03	6.76	7.16	7.06	6.43
T4- 75% NON INDUCED	5.86	6.93	7.02	7.90	7.16	6.97
T5- AC 50% ASM	5.01	5.96	6.72	7.36	6.98	6.41
T6- 50% INDUCED	4.86	5.03	6.08	6.83	6.21	5.80
T7- 50 % NON INDUCED	4.98	5.21	6.23	7.03	6.62	6.01
Mean	5.52	6.23	6.84	7.50	7.05	
	TILLERING STAGE					
T1-AC 100%ASM	7.84	8.55	8.73	9.99	8.96	8.81
T2-AC 75% ASM	7.62	8.53	8.92	9.79	8.84	8.74
T3- 75% INDUCED	6.93	7.84	7.84	8.83	8.63	8.01
T4- 75% NON INDUCED	7.03	7.97	7.84	8.84	8.62	8.06
T5- AC 50% ASM	6.73	6.84	7.93	8.63	7.96	7.62
T6- 50% INDUCED	5.41	6.21	7.32	7.93	7.41	6.86
T7- 50 % NON INDUCED	7.93	6.63	7.51	8.43	7.83	7.67
Mean	7.07	7.51	8.01	8.92	8.32	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	8.43	9.46	9.63	11.13	9.89	9.71
T2-AC 75% ASM	7.81	8.26	8.63	10.94	8.43	8.81
T3- 75% INDUCED	5.25	6.76	6.43	8.43	6.74	6.72
T4- 75% NON INDUCED	6.69	7.23	7.43	9.76	7.81	7.78
T5- AC 50% ASM	4.84	5.21	5.26	7.86	5.63	5.76
T6- 50% INDUCED	3.82	4.82	3.21	6.53	4.87	4.65
T7- 50 % NON INDUCED	4.62	5.01	4.73	7.43	5.41	5.44
Mean	5.92	6.68	6.47	8.87	6.97	
	FLOWERING STAGE					
T1-AC 100%ASM	8.63	9.12	9.84	11.86	10.01	9.89
T2-AC 75% ASM	7.93	8.26	8.42	10.96	8.63	8.84
T3- 75% INDUCED	6.78	7.66	7.68	8.62	8.44	7.83
T4- 75% NON INDUCED	6.93	7.82	8.21	9.84	8.54	8.27
T5- AC 50% ASM	6.63	6.61	7.84	8.54	7.84	7.49
T6- 50% INDUCED	5.23	6.06	7.01	7.86	7.24	6.68
T7- 50 % NON INDUCED	5.86	6.42	7.32	8.23	7.64	7.09
Mean	6.86	7.42	8.05	9.42	8.33	

CD(5%): G: 0.09 T: 0.11 S: 0.08 GxT: 0.25 GxS: 0.19 TxS: 0.22 GxTxS: 0.50

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 46: Effect of water stress on transpiration rate (μ moles of $H_2O\ m^{-2}\ S^{-1}$) in induced and non induced rice genotypes(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	7.90	8.61	9.02	10.30	9.21	9.01
T2-AC 75% ASM	7.35	8.04	8.30	9.92	8.30	8.38
T3- 75% INDUCED	6.03	7.07	7.18	8.26	7.72	7.25
T4- 75% NON INDUCED	6.63	7.49	7.63	9.09	8.03	7.77
T5- AC 50% ASM	5.80	6.16	6.94	8.10	7.10	6.82
T6- 50% INDUCED	4.83	5.53	5.90	7.29	6.43	6.00
T7- 50 % NON INDUCED	5.85	5.82	6.45	7.78	6.88	6.55
G-Mean	6.34	6.96	7.34	8.68	7.67	

CD(5%):

G: 0.09

T: 0.11

GxT: 0.25

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Among the genotypes, PMK 2 recorded the highest total chlorophyll content (1.78 mg g^{-1}), followed by Norungan (1.72 mg g^{-1}), Nootripattu (1.67 mg g^{-1}), Varapukudanchan (1.61 mg g^{-1}) and the lowest in CO 37 (1.39 mg g^{-1}). Among the treatments T_1 (AC 100% ASM) recorded the highest total chlorophyll content (2.07 mg g^{-1}) and the lowest in T_7 (50% non induced, 1.23 mg g^{-1}).

Significant increase in total chlorophyll content was noticed from transplanting stage to flowering stage. The induced seedlings showed maximum total chlorophyll content, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.5.2. Relative water content (RWC)

The data relating to RWC are given in Table 43, 44 and Fig. 4. RWC decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and interactions.

Among the genotypes, PMK 2 recorded the highest RWC (95.95%), followed by Norungan (95.76%), Nootripattu (95.30%), Varapukudanchan (95.59%) and the lowest in CO 37 (94.67%). Among the treatments, T_1 (AC 100% ASM) recorded the highest RWC (96.76%) and the lowest in T_7 (50% non induced, 94.22%). Significant increase in RWC was noticed from transplanting stage to flowering stage.

4.5.3. Transpiration rate

The data relating to transpiration rate are given in Table 45, 46. Transpiration rate decreased with increase in water stress. Significant differences were observed in the genotypes, treatments, stages and interactions.

Among the genotypes PMK 2 recorded the highest transpiration rate ($8.68 \mu \text{ moles of H}_2\text{O m}^{-2} \text{ S}^{-1}$) and the lowest in Norungan ($6.34 \mu \text{ moles of H}_2\text{O m}^{-2} \text{ S}^{-1}$). Among the treatments, T_1 (AC 100% ASM) recorded the highest transpiration rate ($9.01 \mu \text{ moles of H}_2\text{O m}^{-2} \text{ S}^{-1}$) and the lowest in T_6 (50% induced, $6.00 \mu \text{ moles of H}_2\text{O m}^{-2} \text{ S}^{-1}$).

Significant increase in transpiration rate was noticed from transplanting stage to flowering stage. The induced seedlings shown less transpiration rate, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

4.5.4. Leaf diffusive resistance

The data relating to leaf diffusive resistance are given in Table 47, 48 and Fig. 5. Significant differences were observed in the genotypes, treatments, stages and interactions.

Among the genotypes PMK 2 recorded the highest leaf diffusive resistance ($1.09 \mu \text{ moles of CO}_2 \text{ m}^{-2} \text{ S}^{-1}$) and the lowest in Norungan ($0.94 \mu \text{ moles of CO}_2 \text{ m}^{-2} \text{ S}^{-1}$). Among the treatments T_6 (50% induced) recorded the highest leaf diffusive resistance ($1.14 \mu \text{ moles of CO}_2 \text{ m}^{-2} \text{ S}^{-1}$) and the lowest in T_1 (AC 100% ASM, $0.89 \mu \text{ moles of CO}_2 \text{ m}^{-2} \text{ S}^{-1}$).

Significant decrease in leaf diffusive resistance was noticed from transplanting stage to flowering stage. The induced seedlings recorded high leaf diffusive resistance, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Table 47: Effect of water stress on leaf diffusive resistance (μ moles of $\text{CO}_2 \text{ m}^{-2} \text{ S}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	1.00	1.01	1.14	1.15	1.14	1.09
T2-AC 75% ASM	1.09	1.08	1.17	1.18	1.17	1.14
T3- 75% INDUCED	1.16	1.17	1.23	1.24	1.22	1.20
T4- 75% NON INDUCED	1.11	1.12	1.21	1.20	1.18	1.16
T5- AC 50% ASM	1.19	1.18	1.25	1.28	1.24	1.23
T6- 50% INDUCED	1.23	1.26	1.28	1.38	1.36	1.30
T7- 50 % NON INDUCED	1.21	1.22	1.27	1.31	1.29	1.26
Mean	1.14	1.15	1.22	1.25	1.23	
	TILLERING STAGE					
T1-AC 100%ASM	0.85	0.76	0.81	0.94	0.87	0.85
T2-AC 75% ASM	0.88	0.81	0.84	0.92	0.90	0.87
T3- 75% INDUCED	0.93	0.91	0.94	1.08	0.97	0.97
T4- 75% NON INDUCED	0.90	0.87	0.91	0.96	0.92	0.91
T5- AC 50% ASM	0.94	0.95	0.97	1.12	1.04	1.00
T6- 50% INDUCED	0.98	1.02	1.12	1.36	1.21	1.14
T7- 50 % NON INDUCED	0.96	1.00	1.06	1.21	1.12	1.07
Mean	0.92	0.90	0.95	1.08	1.00	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	0.81	0.72	0.80	0.91	0.85	0.82
T2-AC 75% ASM	0.80	0.80	0.81	0.90	0.89	0.84
T3- 75% INDUCED	0.84	0.90	0.91	0.97	0.95	0.91
T4- 75% NON INDUCED	0.81	0.85	0.90	0.94	0.91	0.88
T5- AC 50% ASM	0.88	0.95	0.96	1.11	0.98	0.98
T6- 50% INDUCED	0.94	0.99	1.10	1.20	1.12	1.07
T7- 50 % NON INDUCED	0.91	0.96	1.04	1.17	1.02	1.02
Mean	0.86	0.88	0.93	1.03	0.96	
	FLOWERING STAGE					
T1-AC 100%ASM	0.73	0.71	0.78	0.90	0.82	0.79
T2-AC 75% ASM	0.79	0.76	0.80	0.87	0.83	0.81
T3- 75% INDUCED	0.81	0.88	0.90	0.94	0.93	0.89
T4- 75% NON INDUCED	0.80	0.83	0.89	0.93	0.89	0.87
T5- AC 50% ASM	0.86	0.91	0.94	1.10	0.97	0.96
T6- 50% INDUCED	0.91	0.98	1.07	1.17	1.07	1.04
T7- 50 % NON INDUCED	0.90	0.96	1.01	1.07	1.01	0.99
Mean	0.83	0.86	0.91	1.00	0.93	

CD(5%): G:0.01 T:0.01 S:0.01 GxT:0.02 GxS:0.02 TxS: 0.02 GxTxS:0.04

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

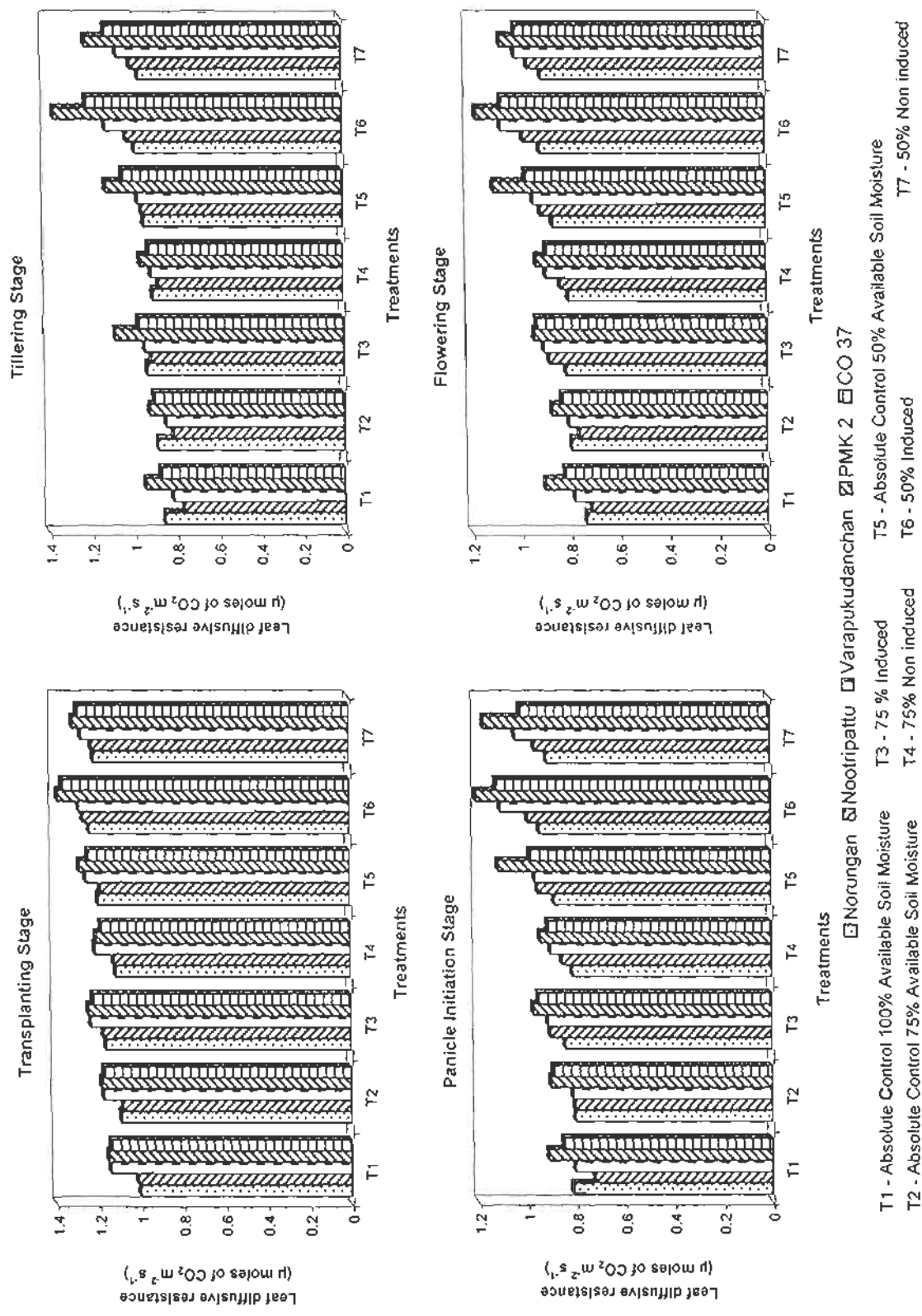
Table 48: Effect of water stress on leaf diffusive resistance (μ moles of $\text{CO}_2 \text{ m}^{-2} \text{ S}^{-1}$) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	0.85	0.80	0.88	0.97	0.92	0.89
T2-AC 75% ASM	0.89	0.86	0.91	0.97	0.95	0.91
T3- 75% INDUCED	0.94	0.97	0.99	1.06	1.02	0.96
T4- 75% NON INDUCED	0.91	0.92	0.98	1.01	0.98	0.96
T5- AC 50% ASM	0.97	1.00	1.03	1.15	1.06	1.04
T6- 50% INDUCED	1.02	1.06	1.14	1.28	1.19	1.14
T7- 50 % NON INDUCED	0.99	1.04	1.10	1.19	1.11	1.09
G-Mean	0.94	0.95	1.00	1.09	1.03	

CD(5%): G:0.01 T: 0.01 GxT: 0.02

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 5. Effect of water stress on leaf diffusive resistance (μ moles of $\text{CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) in induced and non induced rice genotypes



4.5.5. Leaf water potential

The data relating to Leaf water potential are given in Table 49, 50 and Fig. 6. Significant differences were observed in the genotypes, treatments, stages and interactions.

Among the genotypes Norungan recorded the highest Leaf water potential (-0.83 MPa) followed by Varapukudanchan (-0.85 MPa), and the lowest in CO 37 (-0.91 MPa). Among the treatments T_1 (AC 100% ASM) recorded the highest Leaf water potential (-0.81 MPa) and the lowest in T_7 (50% Non induced, -0.93 MPa). Significant decrease in leaf water potential was noticed from transplanting stage to flowering stage.

4.6. BIOCHEMICAL PARAMETERS

4.6.1. Carbohydrate fraction

4.6.1.1. Reducing sugars

The data relating to reducing sugar are given in Table 51, 52 and Fig. 7. Reducing sugar content increased with increase in water stress. The induced seedlings showed higher accumulation of reducing sugar, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Significant differences were observed in the genotypes, treatments and stages. No significant differences were observed in their interactions. Among the genotypes PMK 2 recorded the highest reducing sugar (10.42 mg g^{-1}) in all stages, and the lowest in CO 37 (7.99 mg g^{-1}). Among the treatments, T_6 (50% induced) recorded the maximum reducing sugar (11.45 mg g^{-1}), and the minimum in T_1 (AC 100% ASM, 7.44 mg g^{-1}). Significant increase in reducing sugar was noticed from transplanting stage to flowering stage.

Table 49: Effect of water stress on leaf water potential (MPa) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	-0.75	-0.76	-0.73	-0.79	-0.81	-0.77
T2-AC 75% ASM	-0.76	-0.79	-0.76	-0.82	-0.85	-0.80
T3- 75% INDUCED	-0.75	-0.77	-0.71	-0.80	-0.83	-0.77
T4- 75% NON INDUCED	-0.80	-0.82	-0.79	-0.84	-0.86	-0.82
T5- AC 50% ASM	-0.81	-0.85	-0.82	-0.85	-0.89	-0.84
T6- 50% INDUCED	-0.80	-0.83	-0.81	-0.84	-0.87	-0.83
T7- 50 % NON INDUCED	-0.86	-0.89	-0.86	-0.88	-0.93	-0.88
Mean	-0.79	-0.82	-0.78	-0.83	-0.86	
	TILLERING STAGE					
T1-AC 100%ASM	-0.77	-0.79	-0.78	-0.80	-0.83	-0.79
T2-AC 75% ASM	-0.80	-0.83	-0.81	-0.81	-0.88	-0.83
T3- 75% INDUCED	-0.79	-0.81	-0.79	-0.80	-0.85	-0.81
T4- 75% NON INDUCED	-0.84	-0.86	-0.83	-0.84	-0.88	-0.85
T5- AC 50% ASM	-0.87	-0.89	-0.86	-0.87	-0.92	-0.88
T6- 50% INDUCED	-0.86	-0.91	-0.90	-0.85	-0.91	-0.89
T7- 50 % NON INDUCED	-0.89	-0.93	-0.91	-0.88	-0.96	-0.91
Mean	-0.83	-0.86	-0.84	-0.84	-0.89	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	-0.80	-0.85	-0.82	-0.84	-0.85	-0.83
T2-AC 75% ASM	-0.82	-0.88	-0.84	-0.87	-0.93	-0.87
T3- 75% INDUCED	-0.80	-0.86	-0.85	-0.85	-0.91	-0.85
T4- 75% NON INDUCED	-0.84	-0.90	-0.89	-0.89	-0.93	-0.89
T5- AC 50% ASM	-0.87	-0.93	-0.92	-0.91	-0.96	-0.92
T6- 50% INDUCED	-0.85	-0.97	-0.95	-0.90	-0.94	-0.92
T7- 50 % NON INDUCED	-0.89	-0.90	-0.98	-0.94	-0.99	-0.94
Mean	-0.84	-0.90	-0.89	-0.89	-0.93	
	FLOWERING STAGE					
T1-AC 100%ASM	-0.82	-0.89	-0.84	-0.86	-0.86	-0.85
T2-AC 75% ASM	-0.83	-0.93	-0.86	-0.87	-0.96	-0.89
T3- 75% INDUCED	-0.82	-0.91	-0.85	-0.86	-0.94	-0.88
T4- 75% NON INDUCED	-0.85	-0.96	-0.89	-0.88	-0.95	-0.91
T5- AC 50% ASM	-0.86	-0.97	-0.94	-0.91	-0.99	-0.93
T6- 50% INDUCED	-0.85	-0.98	-0.98	-0.90	-0.98	-0.94
T7- 50 % NON INDUCED	-0.88	-0.99	-0.99	-0.94	-1.03	-0.97
Mean	-0.84	-0.95	-0.91	-0.89	-0.96	

CD(5%): G: 0.005 T:0.006 S: 0.004 GxT: 0.01 GxS: 0.01 TxS: 0.01 GxTxS: 0.03

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan

NOT: Nootripattu, VAR: Varapukudanchan.

Table 50: Effect of water stress on leaf water potential (MPa) in induced and non induced rice genotypes. (GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	-0.79	-0.82	-0.79	-0.82	-0.84	-0.81
T2-AC 75% ASM	-0.80	-0.86	-0.82	-0.84	-0.91	-0.85
T3- 75% INDUCED	-0.79	-0.84	-0.79	-0.83	-0.88	-0.83
T4- 75% NON INDUCED	-0.83	-0.89	-0.85	-0.86	-0.91	-0.87
T5- AC 50% ASM	-0.85	-0.91	-0.88	-0.89	-0.94	-0.89
T6- 50% INDUCED	-0.84	-0.92	-0.91	-0.87	-0.92	-0.89
T7- 50 % NON INDUCED	-0.88	-0.93	-0.94	-0.91	-0.98	-0.93
G-Mean	-0.83	-0.88	-0.85	-0.86	-0.91	

CD(5%): G: 0.005 T: 0.006 GxT: 0.01

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan

NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 6. Effect of water stress on leaf water potential (MPa) in induced and non induced rice genotypes

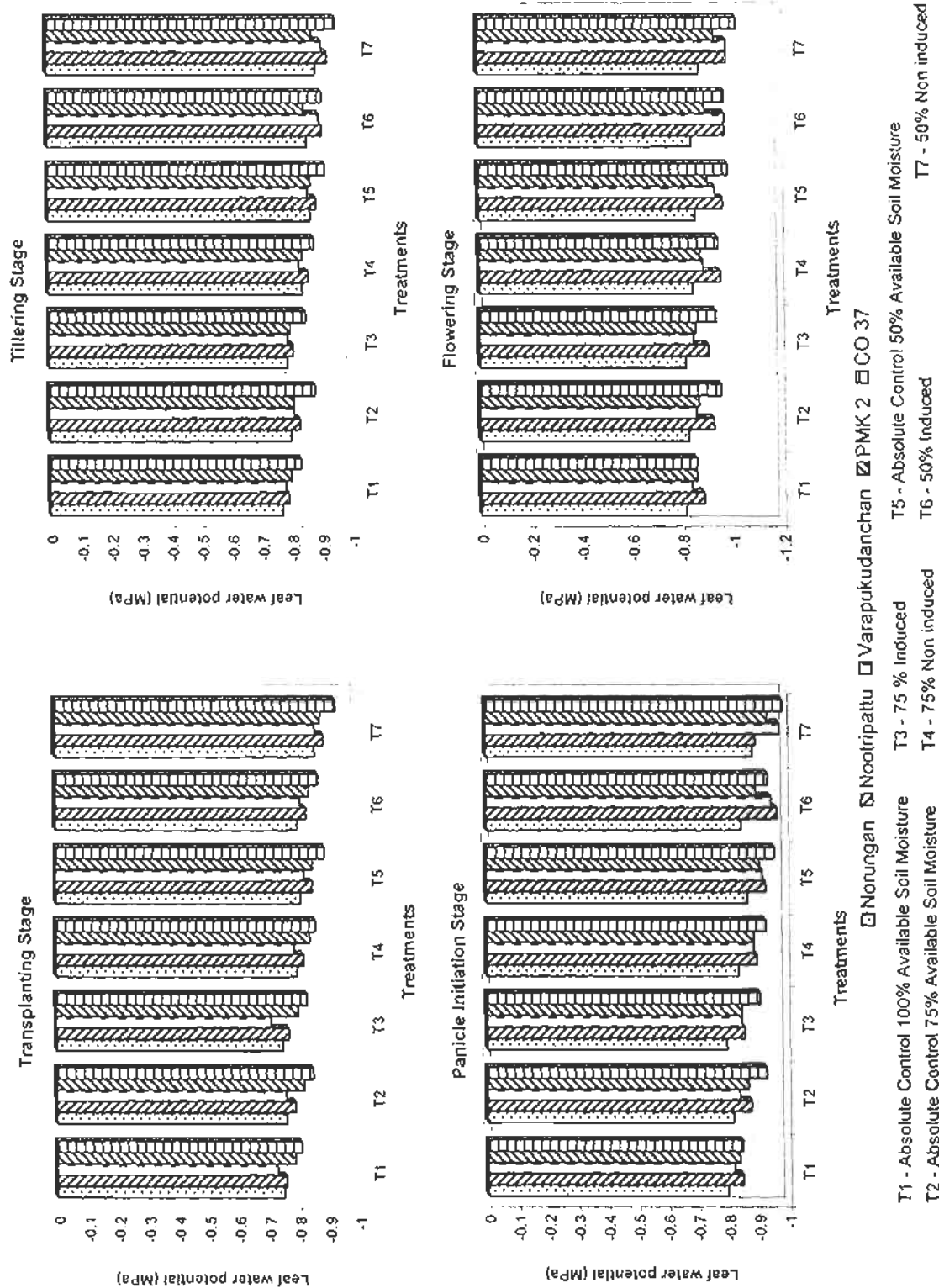


Table 51: Effect of water stress on reducing sugars ($\text{mg g}^{-1}\text{FW}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	5.00	4.50	4.00	5.25	3.00	4.35
T2-AC 75% ASM	6.01	5.0	5.02	6.13	4.00	5.33
T3- 75% INDUCED	7.00	6.50	6.02	7.15	5.00	6.33
T4- 75% NON INDUCED	5.50	5.00	4.60	5.60	3.50	4.84
T5- AC 50% ASM	8.00	7.50	7.00	8.50	6.50	7.50
T6- 50% INDUCED	8.5	8.01	7.60	9.00	7.00	8.02
T7- 50 % NON INDUCED	7.50	7.00	6.50	8.00	6.00	7.00
Mean	6.79	6.29	5.82	7.09	5.00	*
	TILLERING STAGE					
T1-AC 100%ASM	7.50	7.00	6.40	8.01	5.00	6.78
T2-AC 75% ASM	8.50	8.02	7.40	9.01	6.00	7.79
T3- 75% INDUCED	9.50	9.01	9.10	10.02	7.00	8.93
T4- 75% NON INDUCED	8.00	7.50	7.00	8.50	5.50	7.30
T5- AC 50% ASM	10.50	10.00	9.40	11.00	8.00	9.78
T6- 50% INDUCED	11.40	11.00	10.40	12.00	9.00	10.76
T7- 50 % NON INDUCED	9.70	9.50	9.00	10.50	7.50	9.24
Mean	9.30	8.86	8.39	9.86	6.86	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	9.50	9.00	8.60	10.00	7.04	8.83
T2-AC 75% ASM	10.40	10.00	9.40	11.01	9.30	10.02
T3- 75% INDUCED	11.50	11.00	10.40	12.04	10.30	11.05
T4- 75% NON INDUCED	10.00	9.50	9.00	10.60	10.70	9.96
T5- AC 50% ASM	12.40	12.00	11.50	13.00	13.10	12.40
T6- 50% INDUCED	13.40	13.00	12.60	14.00	12.10	13.02
T7- 50 % NON INDUCED	11.80	11.50	10.80	12.30	10.40	11.36
Mean	11.29	10.86	10.33	11.85	10.42	
	FLOWERING STAGE					
T1-AC 100%ASM	10.50	10.00	9.50	11.00	8.03	9.81
T2-AC 75% ASM	11.40	11.00	10.40	12.00	9.00	10.76
T3- 75% INDUCED	12.50	12.00	11.50	1300	10.00	11.80
T4- 75% NON INDUCED	11.00	10.50	10.00	11.50	8.50	10.30
T5- AC 50% ASM	13.50	13.00	12.60	14.00	12.00	13.02
T6- 50% INDUCED	14.30	14.00	13.60	15.00	13.00	13.98
T7- 50 % NON INDUCED	12.90	12.50	12.00	13.60	11.00	12.40
Mean	12.30	11.86	11.37	12.87	10.22	

CD(5%): G:1.02 T:1.20 S:0.91 GxT:NS GxS:NS TxS: NS GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

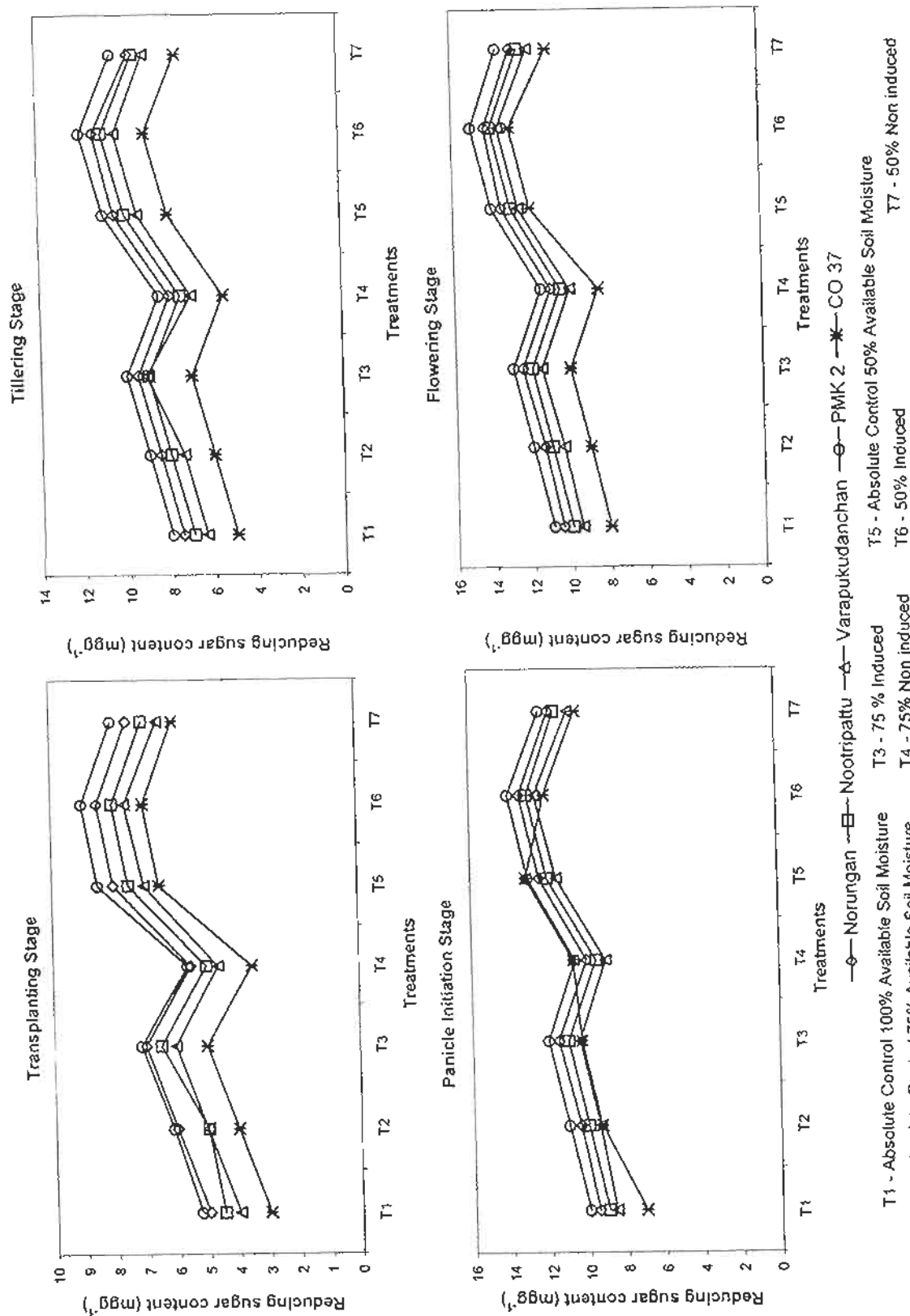
Table 52:Effect of water stress on reducing sugars ($\text{mg g}^{-1}\text{FW}$) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	8.13	7.63	7.13	8.57	5.77	7.44
T2-AC 75% ASM	9.08	8.63	8.06	9.54	7.08	8.48
T3- 75% INDUCED	10.13	9.63	9.11	10.55	8.07	9.50
T4- 75% NON INDUCED	8.63	8.13	7.65	9.05	6.63	8.02
T5- AC 50% ASM	11.10	10.63	10.13	11.63	9.40	10.58
T6- 50% INDUCED	11.90	11.50	11.05	12.50	10.28	11.45
T7- 50 % NON INDUCED	10.48	10.13	9.57	11.10	8.73	10.00
G-Mean	9.92	9.47	8.96	10.42	7.99	

CD(5%): G:1.02 T: 1.20 GxT: NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 7. Effect of water stress on reducing sugars ($\text{mg g}^{-1}\text{FW}$) in induced and non induced rice genotypes



4.6.1.2. Total sugar

The influence of various treatments on total sugars are given in Table 53, 54 and Fig. 8. Significant differences were observed in the genotypes, treatments and stages. No significant differences were observed in their interactions. Total sugar content increased with increase in water stress. The induced seedlings recorded higher accumulation of total sugar, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Among the genotypes Norungan recorded the highest total sugar (22.36 mg g^{-1}), followed by PMK 2 (22.17 mg g^{-1}), Nootripattu (21.86 mg g^{-1}), Varapukundanchan (21.46 mg g^{-1}) and the lowest was recorded in CO 37 (17.15 mg g^{-1}). Among the treatments, T_6 (50% induced) registered the highest total sugar (23.83 mg g^{-1}) and the lowest in T_1 (AC 100% ASM, 19.10 mg g^{-1}). Significant increase in total sugar was noticed from transplanting stage to flowering stage.

4.6.1.13. Starch

Starch content is presented in Table 55, 56. Starch content decreased with increase in water stress, non induced seedlings showing higher accumulation of starch, when it was compared with induced seedlings under 75 and 50 per cent ASM.

Among the genotypes PMK 2 registered maximum amount of starch content (37.39 mg g^{-1}) followed by Norungan (36.51 mg g^{-1}), Nootripattu (36.10 mg g^{-1}), Varapukundanchan (35.55 mg g^{-1}) and the lowest was recorded in CO 37 (33.24 mg g^{-1}). Among the treatments, T_1 (AC 100% ASM) registered the maximum starch content (38.51 mg g^{-1}) and the minimum in T_6 (50% induced, 34.18 mg g^{-1}). Significant increase in starch content was noticed from transplanting stage to flowering stage. Significant differences were observed in the genotypes, treatments, stages and $G \times S$.

Table 53: Effect of water stress on total sugars (mgg⁻¹FW) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	15.91	15.84	15.80	16.01	10.02	14.72
T2-AC 75% ASM	17.01	16.30	16.00	17.50	11.00	15.56
T3- 75% INDUCED	18.00	17.40	17.00	18.50	12.40	16.66
T4- 75% NON INDUCED	16.50	16.00	15.50	17.00	10.60	15.12
T5- AC 50% ASM	20.00	19.50	19.00	20.50	14.00	18.60
T6- 50% INDUCED	21.00	20.40	20.00	21.50	15.00	19.58
T7- 50 % NON INDUCED	19.00	18.40	18.00	19.50	13.00	17.58
Mean	18.20	17.69	17.33	18.64	12.29	
	TILLERING STAGE					
T1-AC 100%ASM	19.01	18.95	18.00	19.08	14.01	17.81
T2-AC 75% ASM	20.01	19.00	18.40	20.50	15.00	18.58
T3- 75% INDUCED	21.00	19.50	19.00	21.50	16.00	19.40
T4- 75% NON INDUCED	19.50	18.50	18.00	20.00	14.50	18.10
T5- AC 50% ASM	23.00	22.40	22.00	23.50	18.00	21.78
T6- 50% INDUCED	24.00	23.50	23.00	24.40	19.00	22.78
T7- 50 % NON INDUCED	22.00	21.30	21.00	22.50	17.00	20.76
Mean	21.22	20.45	19.91	21.64	16.22	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	20.92	20.83	20.80	21.01	16.04	19.92
T2-AC 75% ASM	21.40	21.0	20.40	22.00	17.00	20.36
T3- 75% INDUCED	22.50	22.00	21.50	23.00	18.00	21.40
T4- 75% NON INDUCED	21.00	20.50	20.00	21.60	16.50	19.92
T5- AC 50% ASM	24.40	24.00	23.50	25.00	20.00	23.38
T6- 50% INDUCED	25.50	25.00	24.40	26.00	21.00	24.38
T7- 50 % NON INDUCED	23.30	23.00	22.50	24.00	19.00	22.36
Mean	22.72	22.34	21.87	23.23	18.22	
	FLOWERING STAGE					
T1-AC 100%ASM	24.95	24.91	24.85	25.01	20.01	23.95
T2-AC 75% ASM	26.25	26.20	26.16	26.31	21.00	25.18
T3- 75% INDUCED	27.30	27.26	27.21	27.35	22.00	26.22
T4- 75% NON INDUCED	25.50	25.00	24.50	26.00	20.50	24.30
T5- AC 50% ASM	29.00	28.50	28.00	29.50	23.00	27.60
T6- 50% INDUCED	30.00	29.50	29.00	30.30	24.00	28.56
T7- 50 % NON INDUCED	28.00	27.40	27.31	28.40	22.50	26.72
Mean	27.29	26.97	26.72	27.55	21.86	

CD(5%): G:1.18 T:1.40 S:1.06 GxT:NS GxS: NS TxS:NS GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 54: Effect of water stress on total sugars(mgg⁻¹FW) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	20.20	20.14	19.86	20.28	15.02	19.10
T2-AC 75% ASM	21.17	20.63	20.24	21.58	16.00	19.92
T3- 75% INDUCED	22.20	21.54	21.18	22.59	17.10	20.92
T4- 75% NON INDUCED	20.63	20.00	19.50	21.15	18.75	19.36
T5- AC 50% ASM	24.10	23.60	23.13	24.63	19.75	22.84
T6- 50% INDUCED	25.13	24.60	24.10	25.55	17.88	23.83
T7- 50 % NON INDUCED	23.08	22.53	22.20	23.60	17.15	21.86
G-Mean	22.36	21.86	21.46	22.17	17.15	

CD(5%): G:1.18 T: 1.40 GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 8. Effect of water stress ($\text{mg g}^{-1}\text{FW}$) on total sugars in induced and non induced rice genotypes

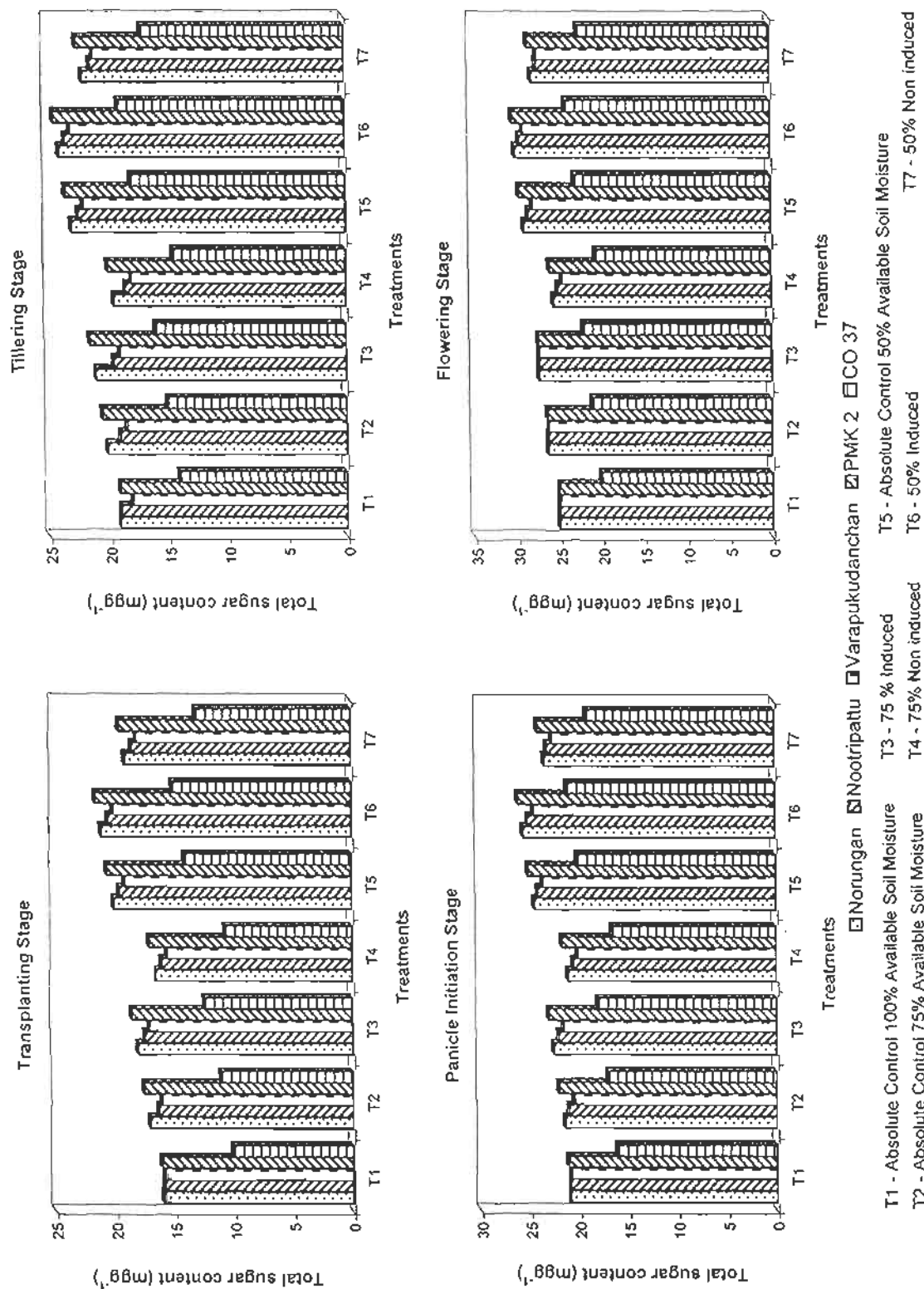


Table 55: Effect of water stress on starch content (mgg^{-1}FW) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	30.45	30.40	30.35	30.50	29.00	30.14
T2-AC 75% ASM	28.00	27.40	27.00	28.50	26.50	27.48
T3- 75% INDUCED	27.50	27.00	26.30	28.00	26.00	26.96
T4- 75% NON INDUCED	28.30	28.00	27.50	29.00	27.00	27.96
T5- AC 50% ASM	26.15	26.10	25.60	26.20	24.40	25.64
T6- 50% INDUCED	26.05	26.00	25.50	26.10	24.00	25.53
T7- 50 % NON INDUCED	26.30	26.20	25.71	26.22	24.50	25.79
Mean	27.54	27.30	26.85	27.79	25.91	
	TILLERING STAGE					
T1-AC 100%ASM	34.10	34.00	33.50	34.21	31.00	33.36
T2-AC 75% ASM	32.00	31.40	31.00	32.50	29.50	31.28
T3- 75% INDUCED	31.50	31.00	29.40	32.00	29.00	30.58
T4- 75% NON INDUCED	32.50	32.00	31.40	33.00	30.00	31.78
T5- AC 50% ASM	30.50	30.00	29.50	30.60	27.50	29.62
T6- 50% INDUCED	29.50	29.00	28.40	30.00	27.00	28.78
T7- 50 % NON INDUCED	30.70	30.20	29.70	30.81	27.70	29.82
Mean	31.54	31.09	30.41	31.87	28.81	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	41.40	41.00	40.50	42.00	38.00	40.58
T2-AC 75% ASM	40.10	39.50	39.00	40.60	37.00	39.24
T3- 75% INDUCED	39.40	39.00	38.60	40.00	36.00	38.60
T4- 75% NON INDUCED	40.50	40.00	39.40	41.00	37.50	39.68
T5- AC 50% ASM	38.00	37.60	37.00	38.60	34.50	37.14
T6- 50% INDUCED	37.50	37.00	36.40	38.00	34.00	36.58
T7- 50 % NON INDUCED	38.50	38.00	37.50	39.00	35.00	37.60
Mean	39.34	38.87	38.34	39.89	36.00	
	FLOWERING STAGE					
T1-AC 100%ASM	51.30	51.00	50.50	52.00	45.00	49.96
T2-AC 75% ASM	46.00	45.60	45.10	50.80	43.00	46.10
T3- 75% INDUCED	45.60	45.00	44.40	50.10	42.00	45.42
T4- 75% NON INDUCED	46.50	46.00	45.40	51.40	44.00	46.66
T5- AC 50% ASM	48.00	47.50	47.00	48.70	40.50	46.34
T6- 50% INDUCED	47.50	47.00	46.50	48.20	40.00	45.84
T7- 50 % NON INDUCED	48.30	47.80	47.30	49.00	41.00	46.68
Mean	47.60	47.13	46.60	50.03	42.21	

CD(5%):G: 0.93 T:1.10 S:0.83 GxT:NS GxS:1.86 TxS:NS GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 56: Effect of water stress on starch content (mg g^{-1} FW) in induced and non induced rice genotypes. (GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	39.31	39.10	38.71	39.68	35.75	38.51
T2-AC 75% ASM	36.53	35.98	35.53	38.10	34.00	36.03
T3- 75% INDUCED	36.00	35.50	34.68	37.53	33.25	35.39
T4- 75% NON INDUCED	36.95	36.50	35.93	38.60	34.63	36.52
T5- AC 50% ASM	35.66	35.30	34.78	36.03	31.73	34.70
T6- 50% INDUCED	35.14	34.75	34.20	35.58	31.25	34.18
T7- 50 % NON INDUCED	35.95	35.55	35.05	37.39	32.05	34.97
G-Mean	36.51	36.10	35.55	37.39	33.24	

CD(5%): G:0.93 T: 1.10 GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

4.7. PROTEINS AND ENZYMES

4.7.1. Soluble protein

The data relating to soluble protein are given in Table 57, 58 and Fig. 9. Soluble protein content decreased with increase in water stress. The induced seedlings showed higher accumulation of soluble proteins, when it was compared with non induced seedlings under 75 and 50 per cent ASM. Significant differences were observed in the genotypes, treatments, stages and T x S.

Among the genotypes PMK 2 recorded the highest soluble protein (3.61 mg g^{-1}) followed by Norungan (3.43 mg g^{-1}), Nootripattu (3.29 mg g^{-1}), Varapukudanchan (3.16 mg g^{-1}), and the lowest in CO 37 (2.56 mg g^{-1}). Among the treatments T_1 (AC 100% ASM) recorded the highest soluble protein content (4.72 mg g^{-1}) and the lowest in T_7 (2.16 mg g^{-1}). Significant increase in soluble protein content was noticed from transplanting stage to flowering stage.

4.7.2. Nitrate reductase activity

The data relating to Nitrate reductase activity are given in Table 59, 60 and Fig. 10. Nitrate reductase activity decreased with increase in water stress. The induced seedlings showed higher nitrate reductase enzyme activity, when it was compared with non induced seedlings under 75 and 50 per cent ASM. Significant differences were observed in the genotypes, treatments, stages, G x S and T x S. Among the genotypes, PMK 2 recorded the highest nitrate reductase activity ($10.38 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$) followed by Norungan ($10.18 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$), Nootripattu ($10.05 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$), Varapukudanchan ($9.93 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$) and the lowest was recorded in CO 37 ($7.93 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$).

Among the treatments T_1 (AC 100% ASM) recorded the highest nitrate reductase activity ($12.91 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$) and the lowest in T_7

Table 57: Effect of water stress on soluble protein(mg g⁻¹ FW)in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	1.72	1.65	1.60	1.80	0.75	1.49
T2-AC 75% ASM	1.40	1.37	1.34	1.45	0.46	1.20
T3- 75% INDUCED	1.45	1.40	1.36	1.50	0.50	1.24
T4- 75% NON INDUCED	0.91	0.87	0.82	0.96	0.21	0.75
T5- AC 50% ASM	0.86	0.82	0.77	0.91	0.17	0.71
T6- 50% INDUCED	0.95	0.91	0.86	1.00	0.25	0.79
T7- 50 % NON INDUCED	0.82	0.78	0.72	0.85	0.12	0.66
Mean	1.16	1.11	1.07	1.21	0.34	
	TILLERING STAGE					
T1-AC 100%ASM	2.00	1.96	1.92	2.50	1.80	2.04
T2-AC 75% ASM	1.80	1.70	1.60	1.90	1.10	1.62
T3- 75% INDUCED	2.04	2.00	1.96	2.10	1.35	1.89
T4- 75% NON INDUCED	1.05	0.95	0.87	1.15	0.33	0.87
T5- AC 50% ASM	0.92	0.85	0.80	1.02	0.21	0.76
T6- 50% INDUCED	1.10	1.00	0.92	1.20	0.40	0.92
T7- 50 % NON INDUCED	0.85	0.83	0.75	0.94	0.16	0.70
Mean	1.39	1.32	1.26	1.54	0.76	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	5.80	5.70	5.57	5.90	4.97	5.59
T2-AC 75% ASM	4.40	4.30	4.19	4.50	3.30	4.14
T3- 75% INDUCED	4.85	4.80	4.75	4.90	3.85	4.63
T4- 75% NON INDUCED	3.10	2.90	2.81	3.29	1.47	2.71
T5- AC 50% ASM	3.00	2.80	2.68	3.18	1.89	2.71
T6- 50% INDUCED	3.20	3.00	2.95	3.40	2.10	2.93
T7- 50 % NON INDUCED	2.90	2.70	2.54	3.01	1.70	2.57
Mean	3.89	3.74	3.64	4.03	2.75	
	FLOWERING STAGE					
T1-AC 100%ASM	10.20	10.09	10.00	10.30	8.30	9.78
T2-AC 75% ASM	8.90	8.81	8.71	9.00	7.90	8.66
T3- 75% INDUCED	9.00	8.91	8.81	9.10	8.01	8.76
T4- 75% NON INDUCED	6.00	5.40	5.00	6.60	5.30	5.66
T5- AC 50% ASM	5.40	5.00	4.60	6.10	4.90	5.20
T6- 50% INDUCED	6.50	6.00	5.40	7.00	5.90	6.16
T7- 50 % NON INDUCED	5.00	4.60	4.10	5.50	4.40	4.72
Mean	7.29	6.97	6.66	7.66	6.39	

CD(5%): G: 0.45 T:0.53 S:0.40 GxT: NS GxS: NS TxS: 1.05 GxTxS: NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 58: Effect of water stress on soluble protein (mg/g⁻¹FW) content in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	4.93	4.85	4.77	5.13	3.94	4.72
T2-AC 75% ASM	4.13	4.05	3.96	4.21	3.19	3.91
T3- 75% INDUCED	4.34	4.27	4.22	4.40	3.43	4.13
T4- 75% NON INDUCED	2.77	2.53	2.38	3.00	1.79	2.50
T5- AC 50% ASM	2.55	2.37	2.21	2.80	2.16	2.34
T6- 50% INDUCED	2.94	2.73	2.53	3.15	1.60	2.70
T7- 50 % NON INDUCED	2.39	2.22	2.03	2.58	2.56	2.16
G-Mean	3.43	3.29	3.16	3.61	2.56	

CD(5%):

G: 0.45

T: 0.53

GxT: NS

AC: Absolute control. ASM: Available soil moisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 9. Effect of water stress on soluble protein (mgg^{-1} FW) in induced and non induced rice genotypes

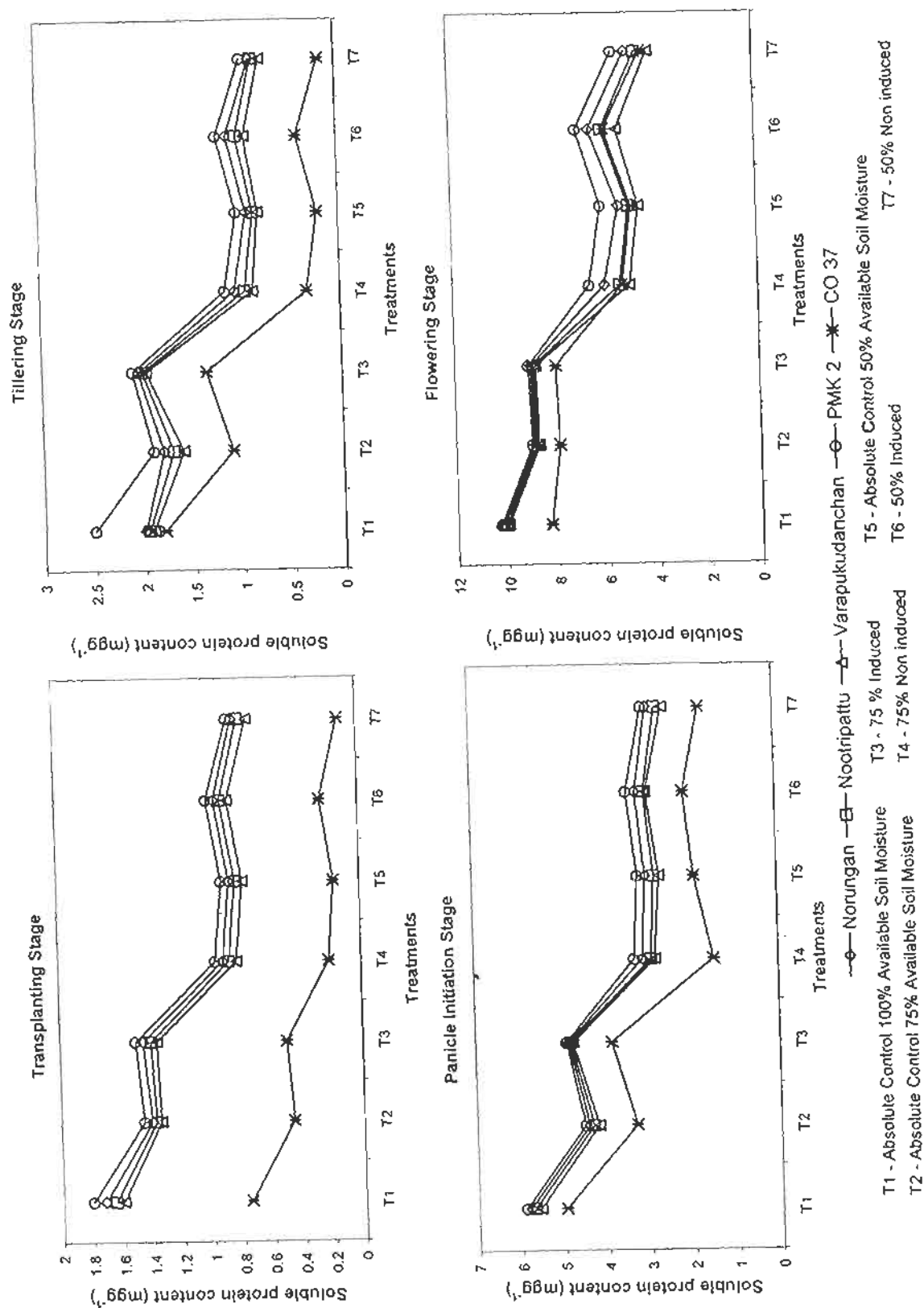


Table 59: Effect of water stress on nitrate reductase (μ moles $\text{NO}_2 \text{ g}^{-1} \text{ hr}^{-1}$) activity in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
TRANSPLANTING STAGE						
T1-AC 100%ASM	2.95	2.91	2.86	3.01	1.40	2.63
T2-AC 75% ASM	2.39	2.35	2.30	2.44	0.67	2.03
T3- 75% INDUCED	2.45	2.41	2.36	2.50	0.74	2.09
T4- 75% NON INDUCED	1.38	1.33	1.30	1.45	0.19	1.13
T5- AC 50% ASM	1.33	1.27	1.22	1.40	0.15	1.07
T6- 50% INDUCED	1.42	1.38	1.38	1.33	1.50	0.24
T7- 50 % NON INDUCED	1.28	1.22	1.16	1.34	0.10	1.02
Mean	1.89	1.84	1.79	1.95	0.50	
TILLERING STAGE						
T1-AC 100%ASM	8.90	8.81	8.70	9.12	7.50	8.61
T2-AC 75% ASM	6.00	5.95	5.91	6.50	5.40	5.95
T3- 75% INDUCED	6.90	6.81	6.72	7.00	5.60	6.61
T4- 75% NON INDUCED	4.00	3.90	3.80	4.50	3.00	3.84
T5- AC 50% ASM	3.90	3.81	3.70	4.30	2.90	3.72
T6- 50% INDUCED	5.00	4.91	4.82	5.10	3.80	4.73
T7- 50 % NON INDUCED	3.10	2.90	2.80	3.45	2.10	2.87
Mean	5.40	5.30	5.21	5.71	4.33	
PANICLE INITIATION STAGE						
T1-AC 100%ASM	18.20	18.10	18.00	18.31	15.94	17.71
T2-AC 75% ASM	15.10	15.00	14.80	15.30	12.10	14.46
T3- 75% INDUCED	16.20	16.00	15.95	16.40	13.00	15.51
T4- 75% NON INDUCED	13.30	13.10	12.90	13.50	11.00	12.76
T5- AC 50% ASM	13.00	12.90	12.80	13.40	10.80	12.58
T6- 50% INDUCED	14.00	13.80	13.60	14.20	12.00	13.52
T7- 50 % NON INDUCED	12.90	12.70	12.50	13.20	10.50	12.36
Mean	14.67	14.51	14.36	14.90	12.19	
FLOWERING STAGE						
T1-AC 100%ASM	23.70	23.50	23.30	23.90	19.00	22.68
T2-AC 75% ASM	20.01	19.80	19.70	20.08	16.10	19.14
T3- 75% INDUCED	21.00	20.90	20.81	21.10	17.00	20.16
T4- 75% NON INDUCED	16.90	16.7	16.50	17.10	13.00	16.04
T5- AC 50% ASM	16.50	16.20	16.00	16.80	12.60	15.62
T6- 50% INDUCED	18.00	17.90	17.80	18.20	14.10	17.20
T7- 50 % NON INDUCED	15.10	14.80	14.50	15.40	11.10	14.18
Mean	18.74	18.54	18.37	18.94	14.70	

CD(5%): G:0.52 T:0.61 S:0.46 GxT:NS GxS:1.03 TxS:1.22 GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 60: Effect of water stress on nitrate reductase (μ moles $\text{NO}_2 \text{ g}^{-1} \text{ hr}^{-1}$) activity in induced and non induced rice genotypes. (GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	13.44	13.44	13.22	13.59	10.96	12.91
T2-AC 75% ASM	10.88	10.78	10.68	11.08	8.57	10.40
T3- 75% INDUCED	11.64	11.53	11.46	11.75	9.09	11.09
T4- 75% NON INDUCED	8.90	8.76	8.63	9.14	6.80	8.44
T5- AC 50% ASM	8.68	8.55	8.43	8.98	6.61	8.25
T6- 50% INDUCED	9.61	9.50	9.39	9.75	7.54	9.15
T7- 50 % NON INDUCED	8.10	7.90	7.74	8.35	5.95	7.61
G-Mean	10.18	10.05	9.93	10.38	7.93	

CD(5%):

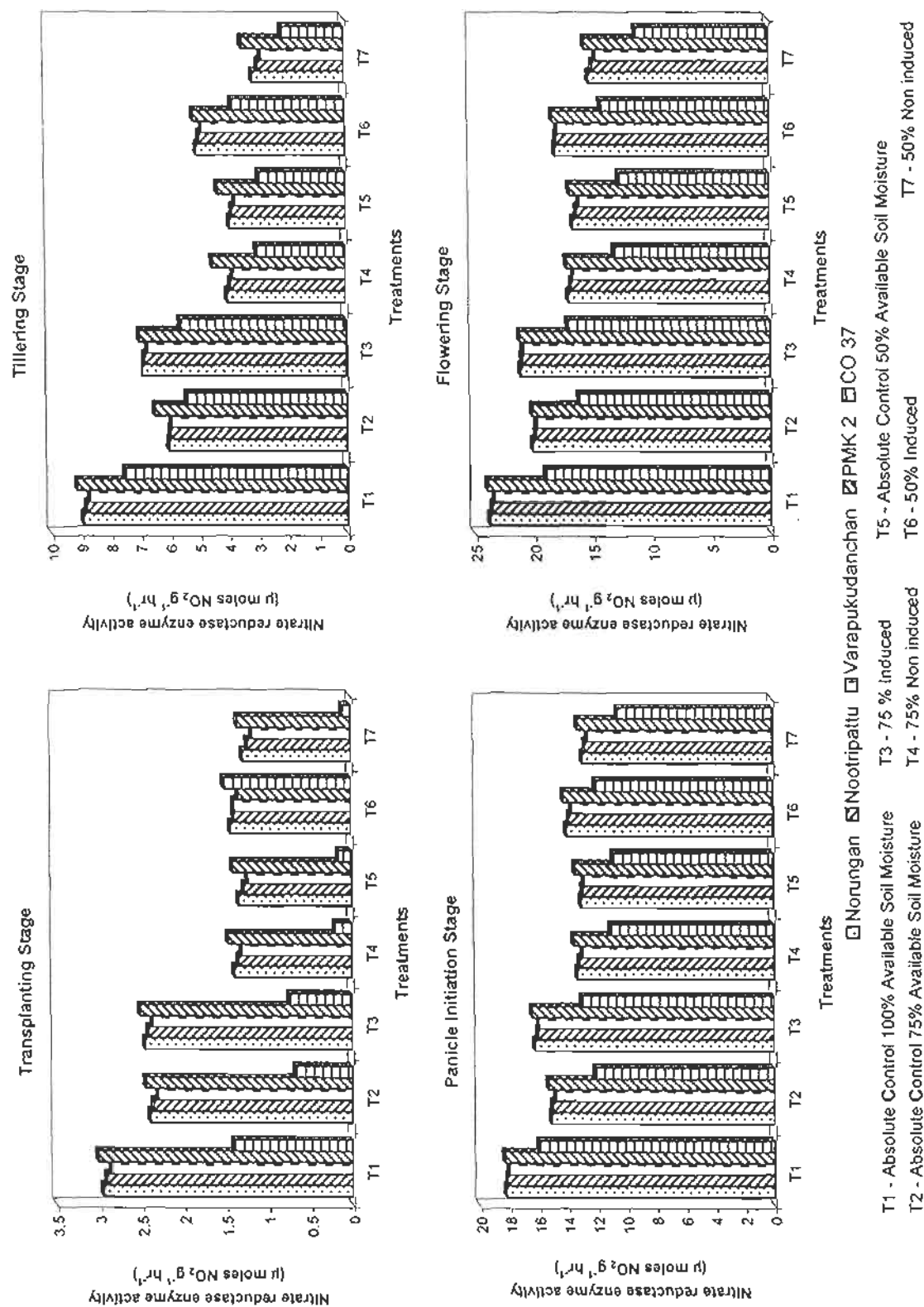
G: 0.52

T: 0.61

GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 10. Effect of water stress on nitrate reductase enzyme activity ($\mu\text{ moles NO}_2\text{ g}^{-1}\text{ hr}^{-1}$) in induced and non induced rice genotypes



(50% non induced, $7.61 \mu \text{ moles of NO}_2 \text{ g}^{-1} \text{ h}^{-1}$). Significant increase in nitrate reductase activity was noticed from transplanting to flowering stage.

4.7.3. Catalase activity

The influence of various treatments on catalase activity are given in Table 61, 62. Catalase activity increased with increase in water stress, significant differences were observed in the genotypes, treatments, stages, G x S and T x S. The induced seedlings showed higher catalase activity, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Among the genotypes PMK 2 recorded the maximum catalase activity ($431.93 \mu \text{ moles of H}_2\text{O}_2 \text{ 100 mg}^{-1} \text{ min}^{-1}$) in all stages, and the minimum in CO 37 ($343.82 \mu \text{ moles of H}_2\text{O}_2 \text{ 100 mg}^{-1} \text{ min}^{-1}$). Among the treatments, T₆ (50% induced) registered the highest catalase activity ($425.95 \mu \text{ moles of H}_2\text{O}_2 \text{ 100 mg}^{-1} \text{ min}^{-1}$) and the lowest in T₁ (AC 100% ASM, $380.50 \mu \text{ moles of H}_2\text{O}_2 \text{ 100 mg}^{-1} \text{ min}^{-1}$). Significant increase in catalase activity was noticed from transplanting stage to flowering stage.

4.7.4. Peroxidase activity

Peroxidase activity in response to different water regimes is presented in Table 63, 64. Peroxidase activity increased with increase in water stress. Significant differences were observed in the genotypes, treatments, and stages. No significant differences were observed in their interactions. The induced seedlings showed higher peroxidase activity compared with non induced seedlings under 75 and 50 per cent ASM.

Table 61: Effect of water stress on catalase activity (μ moles of H_2O_2 $100\text{ mg}^{-1}\text{ min}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	180.00	170.00	157.00	190.00	120.00	163.40
T2-AC 75% ASM	192.00	182.00	171.00	200.00	131.00	175.20
T3- 75% INDUCED	200.00	189.00	180.00	210.00	140.00	183.80
T4- 75% NON INDUCED	182.00	171.00	160.00	192.00	120.00	165.00
T5- AC 50% ASM	210.00	200.00	191.00	221.00	146.00	193.60
T6- 50% INDUCED	220.00	209.00	200.00	230.00	158.00	203.40
T7- 50 % NON INDUCED	205.00	196.00	186.00	216.00	143.00	189.20
Mean	198.43	188.14	177.86	208.43	136.86	
	TILLERING STAGE					
T1-AC 100%ASM	291.00	280.00	271.00	300.00	220.00	272.40
T2-AC 75% ASM	305.00	296.00	283.00	314.00	235.00	286.60
T3- 75% INDUCED	310.00	300.00	289.00	320.00	241.00	275.60
T4- 75% NON INDUCED	295.00	287.00	271.00	302.00	223.00	275.60
T5- AC 50% ASM	328.00	316.00	306.00	340.00	259.00	309.60
T6- 50% INDUCED	334.00	322.00	310.00	345.00	264.00	315.00
T7- 50 % NON INDUCED	319.00	305.00	294.00	330.00	247.00	299.00
Mean	311.71	300.86	289.14	321.57	241.14	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	570.00	558.00	550.00	580.00	480.00	547.60
T2-AC 75% ASM	581.00	572.0	560.00	590.00	490.00	558.60
T3- 75% INDUCED	605.00	595.00	589.00	600.00	502.00	578.20
T4- 75% NON INDUCED	575.00	568.00	555.00	585.00	485.00	553.60
T5- AC 50% ASM	615.00	605.0	595.00	625.00	525.00	593.00
T6- 50% INDUCED	620.00	609.00	600.00	630.00	530.00	597.80
T7- 50 % NON INDUCED	610.00	600.00	591.00	620.00	520.00	588.20
Mean	596.57	586.71	577.14	604.29	504.57	
	FLOWERING STAGE					
T1-AC 100%ASM	560.00	551.0	540.00	570.00	472.0	538.60
T2-AC 75% ASM	575.0	565.00	555.00	585.00	485.00	553.00
T3- 75% INDUCED	580.00	570.00	561.00	590.00	491.00	558.40
T4- 75% NON INDUCED	565.00	555.00	544.00	574.00	473.00	542.20
T5- AC 50% ASM	605.00	594.00	585.00	615.00	511.00	582.00
T6- 50% INDUCED	610.00	600.00	591.00	620.00	517.0	587.60
T7- 50 % NON INDUCED	595.00	585.00	574.00	600.00	500.00	570.80
Mean	584.29	574.29	564.29	593.43	492.71	

CD(5%): G:1.06 T: 1.26 S:0.95 GxT:NS GxS:2.12 TxS: 2.51 GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 62: Effect of water stress on catalase activity (μ moles of H_2O_2 $100\text{ mg}^{-1}\text{ min}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	400.25	389.75	379.50	410.00	323.00	380.50
T2-AC 75% ASM	413.25	403.75	392.25	422.25	335.25	393.35
T3- 75% INDUCED	423.75	413.50	404.75	430.00	343.50	403.10
T4- 75% NON INDUCED	404.25	395.25	382.50	413.25	325.25	384.10
T5- AC 50% ASM	439.50	428.75	419.25	450.25	360.00	419.55
T6- 50% INDUCED	446.00	435.0	425.25	456.25	367.25	425.95
T7- 50 % NON INDUCED	432.25	421.50	411.25	441.50	352.50	411.80
G-Mean	422.75	412.50	402.11	431.93	343.82	

CD(5%):

G: 1.06

T: 1.26

GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table.63:Effect of water stress on peroxidase activity($\mu\text{g hr}^{-1} \text{g}^{-1}$)in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	3.00	2.50	2.0	3.61	1.60	2.54
T2-AC 75% ASM	4.10	3.51	3.01	4.90	2.80	3.66
T3- 75% INDUCED	5.10	4.50	4.00	5.90	3.70	4.64
T4- 75% NON INDUCED	3.80	3.15	2.70	4.60	2.00	3.25
T5- AC 50% ASM	7.30	6.80	5.90	7.50	5.00	6.50
T6- 50% INDUCED	7.50	7.00	6.30	8.10	5.50	6.88
T7- 50 % NON INDUCED	6.81	6.25	5.30	7.00	4.50	5.97
Mean	5.37	4.82	4.17	5.94	3.59	
	TILLERING STAGE					
T1-AC 100%ASM	5.00	4.50	4.00	5.50	3.45	4.49
T2-AC 75% ASM	6.01	5.50	5.01	6.80	4.52	5.57
T3- 75% INDUCED	7.00	6.50	6.00	7.80	5.50	6.56
T4- 75% NON INDUCED	5.70	5.20	4.70	6.50	4.30	5.28
T5- AC 50% ASM	8.30	7.80	7.31	8.81	6.61	7.77
T6- 50% INDUCED	8.50	8.00	7.50	9.00	6.80	7.96
T7- 50 % NON INDUCED	8.00	7.25	6.80	8.30	6.30	7.33
Mean	6.93	6.39	5.90	7.53	5.35	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	9.00	8.50	8.00	9.50	7.40	8.48
T2-AC 75% ASM	10.02	9.51	9.00	10.61	8.41	9.51
T3- 75% INDUCED	11.00	10.50	10.00	11.60	9.40	10.50
T4- 75% NON INDUCED	9.70	9.21	8.71	10.32	8.10	9.21
T5- AC 50% ASM	12.70	12.20	11.70	13.25	9.85	11.94
T6- 50% INDUCED	13.00	12.50	12.00	13.60	10.15	12.25
T7- 50 % NON INDUCED	12.40	11.91	11.41	12.90	9.54	11.63
Mean	11.12	10.62	10.12	11.68	8.98	
	FLOWERING STAGE					
T1-AC 100%ASM	7.00	6.50	6.00	7.50	5.40	6.48
T2-AC 75% ASM	8.00	7.52	7.02	8.51	6.43	7.50
T3- 75% INDUCED	9.00	8.51	8.00	9.50	7.41	8.48
T4- 75% NON INDUCED	7.70	7.20	6.70	8.20	6.12	7.18
T5- AC 50% ASM	10.70	10.10	9.65	11.21	9.09	1.15
T6- 50% INDUCED	11.00	10.50	10.00	11.50	9.40	10.48
T7- 50 % NON INDUCED	10.40	9.80	9.32	10.90	8.80	9.84
Mean	9.11	8.59	8.10	9.62	7.52	

CD(5%): G:0.53 T:0.63 S:0.47 GxT:NS GxS:NS TxS:NS GxTxS:NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 64: Effect of water stress on peroxidase activity ($\mu\text{g hr}^{-1} \text{g}^{-1}$) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	6.00	5.50	5.00	6.53	4.46	5.50
T2-AC 75% ASM	7.03	6.51	6.01	7.71	5.54	6.56
T3- 75% INDUCED	8.03	7.50	7.00	8.70	6.50	7.55
T4- 75% NON INDUCED	6.73	6.19	5.70	7.40	5.13	6.23
T5- AC 50% ASM	9.75	9.23	8.64	10.19	7.64	9.09
T6- 50% INDUCED	10.00	9.50	8.95	10.55	7.96	9.39
T7- 50 % NON INDUCED	9.40	8.80	8.21	9.78	7.29	8.69
G-Mean	8.13	7.60	7.07	8.69	6.36	

CD(5%): G:0.53 T: 0.63 GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Among the genotypes PMK 2 recorded the highest peroxidase activity ($8.69 \mu\text{g hr}^{-1} \text{g}^{-1}$), followed by Norungan ($8.13 \mu\text{g hr}^{-1} \text{g}^{-1}$), Nootripattu ($7.60 \mu\text{g hr}^{-1} \text{g}^{-1}$), Varapukudanchan ($7.07 \mu\text{g hr}^{-1} \text{g}^{-1}$) and the lowest was recorded in CO 37 ($6.36 \mu\text{g hr}^{-1} \text{g}^{-1}$).

Among the treatments, T_6 (50% induced) registered the highest peroxidase activity ($9.39 \mu\text{g hr}^{-1} \text{g}^{-1}$) and the lowest in T_1 (AC 100% ASM, $5.50 \mu\text{g hr}^{-1} \text{g}^{-1}$). Significant increase in peroxidase activity was noticed from transplanting stage to flowering stage.

4.7.5. Superoxide dismutase activity (SOD)

The influence of various treatments on SOD activity is given in Table 65, 66 and Fig. 14. Significant differences were observed in the genotypes, treatments and stages. No significant differences were observed in their interactions. SOD activity increased with increase in water stress. The induced seedlings showed higher SOD activity compared to non induced seedlings under 75 and 50 per cent ASM.

Among the genotypes PMK 2 recorded the highest SOD activity ($7.96 \text{ enzyme units mg protein}^{-1} \text{ min}^{-1}$) in all stages, and the lowest in CO 37 ($5.88 \text{ enzyme units mg protein}^{-1} \text{ min}^{-1}$). Among the treatments, T_6 (50% induced) recorded the maximum SOD activity ($8.75 \text{ enzyme units mg protein}^{-1} \text{ min}^{-1}$) and the minimum in T_1 (AC 100% ASM, $4.98 \text{ enzyme units mg protein}^{-1} \text{ min}^{-1}$). Significant increase in SOD activity was noticed from transplanting stage to flowering stage.

4.7.6. Ascorbic acid oxidase activity

The data relating to ascorbic acid oxidase activity are depicted in Table 67, 68 and Fig. 11. Ascorbic acid oxidase activity increased with increase in water stress.

Table 65: Effect of water stress on superoxide dismutase activity (enzyme units mg protein⁻¹ min⁻¹) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	3.00	2.50	2.00	3.40	1.40	2.46
T2-AC 75% ASM	3.52	3.00	2.51	4.00	2.00	3.01
T3- 75% INDUCED	4.00	3.50	3.00	4.50	2.55	3.51
T4- 75% NON INDUCED	3.00	2.51	2.00	3.52	1.50	2.51
T5- AC 50% ASM	5.51	5.00	4.45	6.01	4.01	5.00
T6- 50% INDUCED	5.95	5.45	5.00	6.50	4.50	5.48
T7- 50 % NON INDUCED	5.00	4.50	4.01	5.51	3.51	4.51
Mean	4.28	3.78	3.28	4.78	2.78	
	TILLERING STAGE					
T1-AC 100%ASM	5.00	4.49	4.00	5.35	3.29	4.43
T2-AC 75% ASM	6.50	6.01	5.51	6.92	4.90	5.97
T3- 75% INDUCED	7.00	6.52	6.01	7.40	5.39	6.46
T4- 75% NON INDUCED	6.00	5.51	5.01	6.43	4.35	5.46
T5- AC 50% ASM	8.51	8.00	7.50	9.01	7.00	8.00
T6- 50% INDUCED	9.00	8.49	7.97	9.50	7.45	8.48
T7- 50 % NON INDUCED	8.02	7.51	7.02	8.51	6.52	7.52
Mean	7.15	6.65	6.15	7.59	5.56	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	8.10	7.60	7.05	8.63	6.40	7.56
T2-AC 75% ASM	9.71	9.12	8.60	10.21	8.00	9.13
T3- 75% INDUCED	10.20	9.60	9.10	10.70	8.50	9.62
T4- 75% NON INDUCED	9.21	8.61	8.08	9.72	7.51	8.63
T5- AC 50% ASM	11.60	11.07	10.60	12.10	10.01	11.08
T6- 50% INDUCED	12.10	11.60	11.05	12.60	10.50	11.57
T7- 50 % NON INDUCED	11.05	10.60	10.09	11.60	9.51	10.57
Mean	10.28	9.74	9.22	10.79	8.63	
	FLOWERING STAGE					
T1-AC 100%ASM	6.00	5.50	5.00	6.45	4.50	5.49
T2-AC 75% ASM	7.55	7.00	6.52	8.05	5.92	7.01
T3- 75% INDUCED	8.10	7.55	7.00	8.60	6.40	7.53
T4- 75% NON INDUCED	7.00	6.51	6.00	7.51	5.40	6.48
T5- AC 50% ASM	9.50	9.01	8.52	10.01	7.92	8.99
T6- 50% INDUCED	10.00	9.51	9.00	10.50	8.40	9.48
T7- 50 % NON INDUCED	9.00	8.51	8.00	9.51	7.40	8.48
Mean	8.16	7.66	7.15	8.66	6.56	

CD(5%): G:0.53 T:0.63 S:0.47 GxT:NS GxS:NS TxS: NS GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 66: Effect of water stress on superoxide dismutase activity (enzyme units mg protein⁻¹ min⁻¹) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	5.53	5.02	4.51	5.96	3.90	4.98
T2-AC 75% ASM	6.82	6.28	5.79	7.30	5.21	6.28
T3- 75% INDUCED	7.33	6.79	6.28	7.80	5.71	6.78
T4- 75% NON INDUCED	6.30	5.78	5.27	6.79	4.69	5.77
T5- AC 50% ASM	8.78	8.27	7.77	9.28	7.24	8.27
T6- 50% INDUCED	9.26	8.76	8.25	9.78	7.71	8.75
T7- 50 % NON INDUCED	8.27	7.78	7.28	8.78	6.73	7.77
G-Mean	7.47	6.96	6.45	7.96	5.88	

CD(5%): G:0.53 T: 0.63 GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 14. Effect of water stress on superoxide dismutase activity (enzyme units $\text{mg protein}^{-1} \text{min}^{-1}$) in induced and non induced rice genotypes

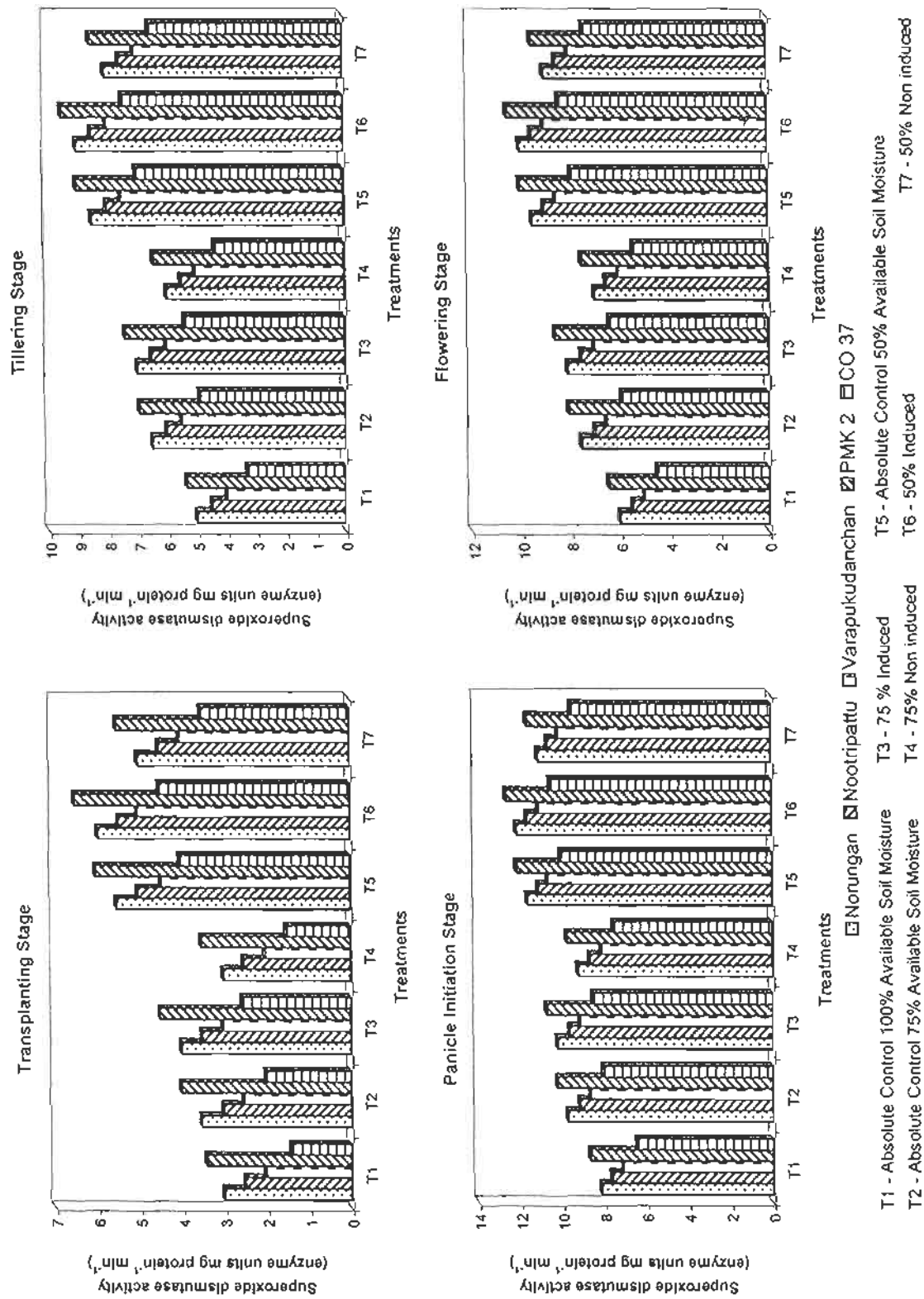


Table 67: Effect of water stress on ascorbic acid oxidase activity (enzyme units g⁻¹ min⁻¹) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
TRANSPLANTING STAGE						
T1-AC 100%ASM	2.51	2.01	1.51	1.50	3.00	2.11
T2-AC 75% ASM	4.02	3.51	3.00	2.00	4.51	3.41
T3- 75% INDUCED	4.50	4.00	3.51	2.47	5.02	3.90
T4- 75% NON INDUCED	3.51	3.00	2.52	1.51	4.00	2.91
T5- AC 50% ASM	6.50	6.00	5.51	4.85	6.90	5.95
T6- 50% INDUCED	7.00	6.52	6.01	5.20	7.40	6.43
T7- 50 % NON INDUCED	6.00	5.51	5.00	4.30	6.41	5.44
Mean	4.86	4.36	3.87	3.12	5.32	
TILLERING STAGE						
T1-AC 100%ASM	4.20	3.60	3.10	2.30	4.80	3.60
T2-AC 75% ASM	5.55	5.10	4.50	4.00	6.18	5.07
T3- 75% INDUCED	6.10	5.60	5.00	4.50	6.70	5.58
T4- 75% NON INDUCED	5.50	4.62	4.00	3.51	5.80	4.69
T5- AC 50% ASM	7.80	7.30	6.75	6.15	8.45	7.29
T6- 50% INDUCED	8.30	7.80	7.20	6.70	8.80	7.76
T7- 50 % NON INDUCED	7.31	6.80	6.20	5.80	8.00	6.82
Mean	6.39	5.83	5.25	4.71	6.96	
PANICLE INITIATION STAGE						
T1-AC 100%ASM	7.00	6.51	6.00	5.35	7.40	6.45
T2-AC 75% ASM	8.50	8.00	7.50	6.85	9.00	7.97
T3- 75% INDUCED	9.00	8.51	8.00	7.30	9.45	8.45
T4- 75% NON INDUCED	8.00	7.51	7.00	6.30	8.52	7.47
T5- AC 50% ASM	10.50	10.00	9.51	8.80	11.00	9.96
T6- 50% INDUCED	11.00	10.50	10.00	9.30	11.50	10.46
T7- 50 % NON INDUCED	10.00	9.51	9.00	8.28	10.51	9.46
Mean	9.14	8.65	8.14	7.45	9.63	
FLOWERING STAGE						
T1-AC 100%ASM	5.20	4.60	4.10	3.60	5.70	4.64
T2-AC 75% ASM	6.70	6.10	5.55	5.10	7.20	6.13
T3- 75% INDUCED	7.25	6.70	6.10	4.40	6.75	5.60
T4- 75% NON INDUCED	6.20	5.60	5.04	4.40	6.75	5.60
T5- AC 50% ASM	8.70	8.15	7.60	7.00	9.20	8.64
T6- 50% INDUCED	9.20	8.70	8.10	7.50	9.70	8.64
T7- 50 % NON INDUCED	8.20	7.8	7.10	6.50	8.70	7.66
Mean	7.35	6.81	6.23	5.67	7.86	

CD(5%): G:0.69 T:0.81 S:0.61 GxT:NS GxS:NS TxS: NS GxTxS:NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table.68:Effect of water stress on ascorbic acid oxidase activity(enzyme units $\text{g}^{-1} \text{min}^{-1}$) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	4.73	4.18	3.68	3.19	5.23	4.20
T2-AC 75% ASM	6.19	5.68	5.14	4.49	6.72	5.64
T3- 75% INDUCED	6.71	6.20	5.65	4.97	7.23	6.15
T4- 75% NON INDUCED	5.80	5.18	4.64	3.93	6.27	5.16
T5- AC 50% ASM	8.38	7.86	7.34	6.70	8.89	7.83
T6- 50% INDUCED	8.88	8.38	7.83	7.18	9.35	8.32
T7- 50 % NON INDUCED	7.88	7.40	6.83	6.22	8.40	7.35
G-Mean	6.94	6.41	5.87	5.24	7.44	

CD(5%):

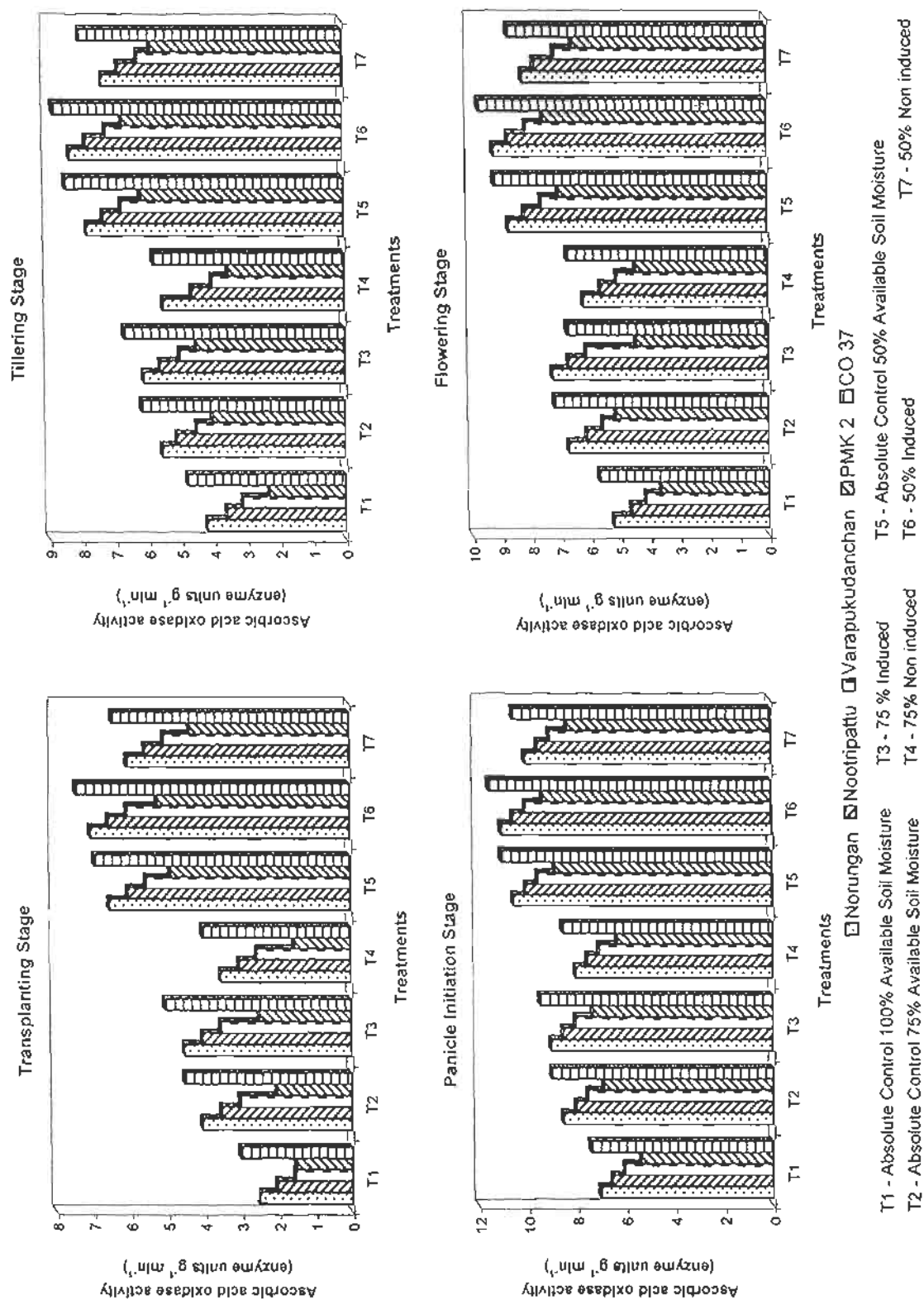
G: 0.69

T: 0.81

GxT: NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 11. Effect of water stress on ascorbic acid oxidase activity (enzyme units $\text{g}^{-1} \text{min}^{-1}$) in induced and non induced rice genotypes



The induced seedlings expressed higher ascorbic acid oxidase activity, when it was compared with non induced seedlings under 75 and 50 per cent ASM. Significant differences were observed in the genotypes, treatments, and stages. No significant differences were observed in their interactions.

Among the genotypes CO 37 recorded the highest ascorbic acid oxidase activity ($7.44 \text{ enzyme units g}^{-1} \text{ min}^{-1}$) in all stages and the lowest in PMK 2 ($5.24 \text{ enzyme units g}^{-1} \text{ min}^{-1}$). Among the treatments, T_6 (50% induced) recorded the highest ascorbic acid oxidase activity ($8.32 \text{ enzyme units g}^{-1} \text{ min}^{-1}$) and the lowest in T_1 (AC 100% ASM, $4.20 \text{ enzyme units g}^{-1} \text{ min}^{-1}$). Significant increase in ascorbic acid oxidase activity was noticed from transplanting stage to flowering stage.

4.8. AMINO ACIDS

4.8.1. Proline

The influence of various treatments on proline status is given in Table 69, 70 and Fig. 12. Significant differences were observed in the genotypes, treatments and stages. No significant differences were observed in their interactions. Proline content increased with increase in water stress. The induced seedlings shown higher accumulation of proline, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Among the genotypes PMK 2 recorded the highest proline content ($4.76 \mu \text{ moles g}^{-1}$), followed by Norungan ($4.69 \mu \text{ moles g}^{-1}$), Nootripattu ($4.64 \mu \text{ moles g}^{-1}$) and Varapukudanchan ($4.34 \mu \text{ moles g}^{-1}$) and the lowest was recorded by CO 37 ($2.86 \mu \text{ moles g}^{-1}$). Among the treatments T_6 (50% induced) recorded the maximum proline content ($5.01 \mu \text{ moles g}^{-1}$), and the minimum in T_1

Table 69: Effect of water stress on proline content (μ moles g^{-1} FW) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	1.43	1.40	1.35	1.45	0.75	1.20
T2-AC 75% ASM	2.30	2.27	2.20	2.35	1.75	2.05
T3- 75% INDUCED	2.36	2.32	2.25	2.40	1.20	2.11
T4- 75% NON INDUCED	2.25	2.20	2.15	2.30	1.10	2.00
T5- AC 50% ASM	3.30	3.25	3.20	3.35	2.15	3.05
T6- 50% INDUCED	3.34	3.30	3.25	3.40	2.20	3.10
T7- 50 % NON INDUCED	3.20	3.15	3.10	3.22	2.05	2.94
Mean	2.60	2.56	2.50	2.64	1.51	
	TILLERING STAGE					
T1-AC 100%ASM	2.10	2.05	2.00	2.18	1.12	1.89
T2-AC 75% ASM	3.10	3.05	3.00	3.16	2.07	2.88
T3- 75% INDUCED	3.15	3.11	3.05	3.20	2.13	2.93
T4- 75% NON INDUCED	3.05	3.00	2.95	3.10	2.01	2.82
T5- AC 50% ASM	4.04	4.00	3.95	4.10	2.95	3.71
T6- 50% INDUCED	4.10	4.04	4.00	4.15	3.00	3.86
T7- 50 % NON INDUCED	3.92	3.85	3.80	4.00	2.80	3.67
Mean	3.35	3.30	3.25	3.41	2.30	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	4.00	3.93	3.88	4.50	2.30	3.72
T2-AC 75% ASM	5.50	5.44	4.81	5.54	3.20	4.90
T3- 75% INDUCED	5.53	5.50	4.90	5.60	3.31	4.97
T4- 75% NON INDUCED	5.44	5.40	4.70	5.50	3.10	4.83
T5- AC 50% ASM	6.47	6.40	5.60	6.52	4.00	5.80
T6- 50% INDUCED	6.54	6.50	5.70	6.60	4.10	5.89
T7- 50 % NON INDUCED	6.34	6.30	5.50	6.43	3.90	5.69
Mean	5.69	5.64	5.01	5.81	3.42	
	FLOWERING STAGE					
T1-AC 100%ASM	5.90	5.84	5.50	5.95	3.00	5.24
T2-AC 75% ASM	6.80	6.74	6.35	6.84	3.95	6.14
T3- 75% INDUCED	6.85	6.80	6.40	6.90	4.00	6.19
T4- 75% NON INDUCED	6.74	6.70	6.30	6.80	3.90	6.09
T5- AC 50% ASM	7.90	7.84	7.25	7.94	4.85	7.16
T6- 50% INDUCED	7.94	7.90	7.30	8.00	4.90	7.21
T7- 50 % NON INDUCED	7.80	7.72	7.15	7.82	4.75	7.05
Mean	7.13	7.08	6.61	7.18	4.19	

CD(5%): G: 0.61 T: 0.72 S: 0.55 GxT: NS GxS: NS TxS: NS GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 70. Effect of water stress on proline content (μ moles g^{-1}) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	3.36	3.31	3.18	3.52	1.79	3.03
T2-AC 75% ASM	4.43	4.38	4.09	4.47	2.59	3.99
T3- 75% INDUCED	4.47	4.43	4.15	4.52	2.66	4.05
T4- 75% NON INDUCED	4.37	4.33	4.02	4.43	2.53	3.93
T5- AC 50% ASM	5.43	5.37	5.00	5.48	3.49	4.95
T6- 50% INDUCED	5.48	5.44	5.06	5.54	3.55	5.01
T7- 50 % NON INDUCED	5.32	5.26	4.89	5.37	3.38	4.84
G-Mean	4.69	4.64	4.34	4.76	2.86	

CD(5%):

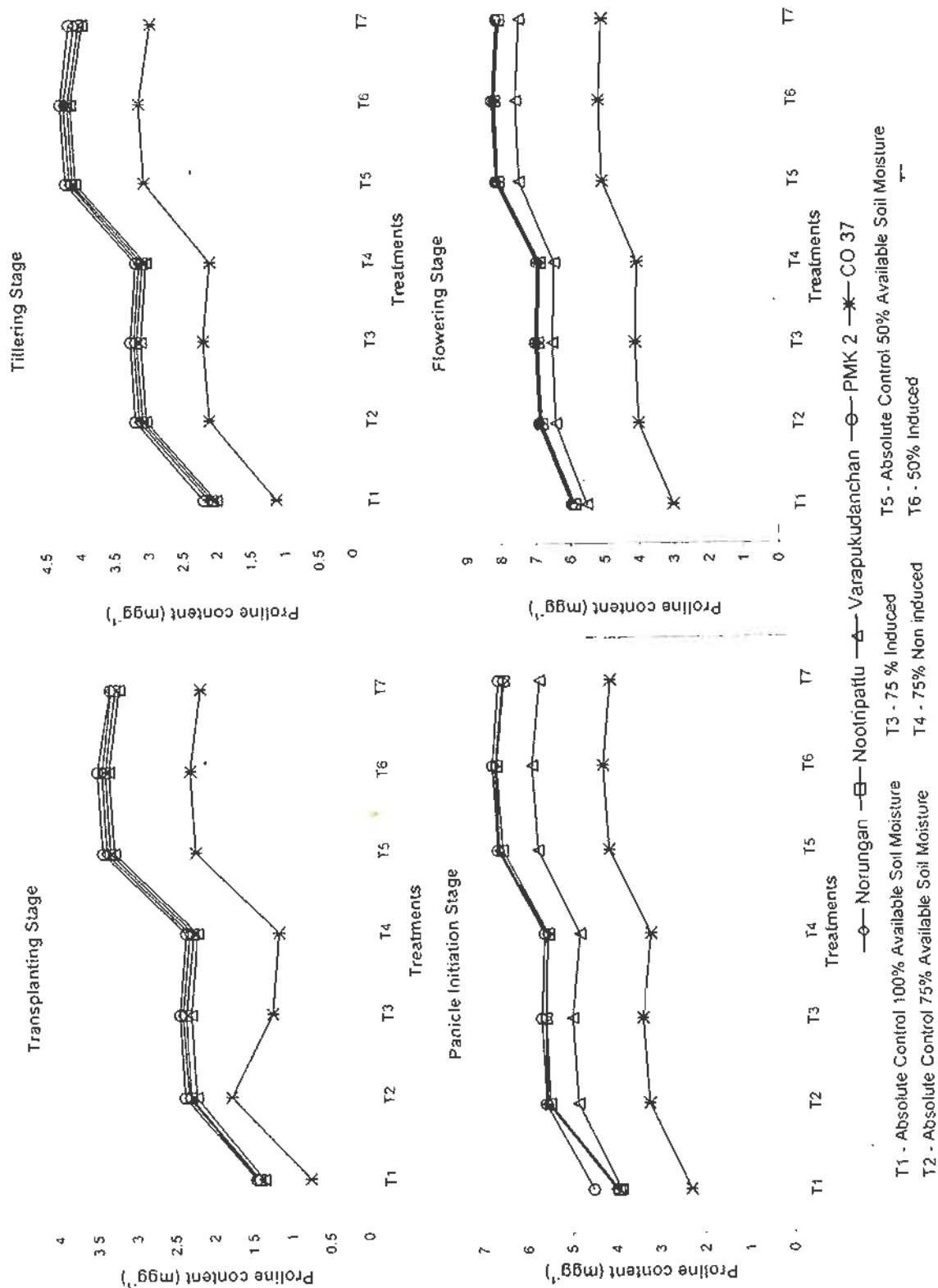
G: 0.61

T: 0.72

GxT: NS

AC: Absolute control. ASM: Available soil moisture. NOR: Norungan
 NOT: Nootripattu. VAR: Varapukudanchan.

Fig. 12. Effect of water stress on proline content (mg g^{-1}) in induced and non induced rice genotypes



(AC 100% ASM, $3.03 \mu \text{ moles g}^{-1}$). Significant increase in proline content was noticed from transplanting stage to flowering stage.

4.9. OTHER METABOLITES

4.9.1. Total phenolics

The data relating to total phenolics content are given in Table 71, 72 and Fig. 13. Total phenolics increased with increase in water stress. The induced seedlings registered higher accumulation of total phenolics content than the non induced seedlings under 75 and 50 per cent ASM. Significant differences were observed in the genotypes, treatments and stages.

Among the genotypes PMK 2 was recorded the maximum total phenolics content (4.66 mg g^{-1}), followed by Norungan (4.32 mg g^{-1}), Nootripattu (3.93 mg g^{-1}) and Varapukudanchan (3.61 mg g^{-1}) and the minimum in CO 37 (2.58 mg g^{-1}). Among the treatments, T_6 (50% ASM induced) recorded the highest total phenolics content (4.85 mg g^{-1}), and the lowest in T_1 (AC 100% ASM, 2.74 mg g^{-1}). Significant increase in total phenolics content was noticed from transplanting stage to flowering stage.

4.9.2. Ascorbic acid

The influence of various treatments on ascorbic acid is given in Table 73, 74. Significant differences were observed in the genotypes, treatments, stages, $G \times S$ and $T \times S$. Ascorbic acid decreased with increase in water stress. The induced seedlings recorded higher accumulation of ascorbic acid, when it was compared with non induced seedlings under 75 and 50 per cent ASM.

Among the genotypes PMK 2 recorded the highest ascorbic acid ($54.54 \mu \text{g g}^{-1}$) followed by Norungan ($49.23 \mu \text{g g}^{-1}$), Nootripattu ($43.57 \mu \text{g g}^{-1}$), Varapukudanchan ($38.50 \mu \text{g g}^{-1}$) and the lowest in CO 37 ($28.54 \mu \text{g g}^{-1}$). Among the treatments T_1

Table 71: Effect of water stress on phenolics content (mg g⁻¹FW) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	2.00	1.60	1.40	2.50	0.70	1.64
T2-AC 75% ASM	2.80	2.20	1.80	3.30	1.00	2.22
T3- 75% INDUCED	3.00	2.50	2.00	3.50	1.30	2.46
T4- 75% NON INDUCED	2.60	2.00	1.60	3.00	0.80	2.00
T5- AC 50% ASM	3.90	3.40	3.00	4.30	1.90	3.30
T6- 50% INDUCED	4.00	3.60	3.30	4.50	2.20	3.52
T7- 50 % NON INDUCED	3.60	3.10	2.70	4.00	1.50	2.98
Mean	3.13	2.63	2.26	3.59	1.34	
	TILLERING STAGE					
T1-AC 100%ASM	2.70	2.50	2.30	3.00	1.60	2.42
T2-AC 75% ASM	3.40	3.00	2.70	3.70	2.00	2.96
T3- 75% INDUCED	3.70	3.40	3.10	4.00	2.50	3.34
T4- 75% NON INDUCED	3.00	2.60	2.40	3.50	1.70	2.64
T5- AC 50% ASM	4.40	4.00	3.70	4.70	3.00	3.96
T6- 50% INDUCED	4.60	4.30	4.00	5.00	3.30	4.24
T7- 50 % NON INDUCED	4.00	3.60	3.40	4.40	2.70	3.62
Mean	3.69	3.34	3.09	4.04	2.40	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	3.70	3.40	3.00	4.00	2.00	3.22
T2-AC 75% ASM	4.60	4.10	3.70	4.80	2.70	3.98
T3- 75% INDUCED	4.80	4.40	4.00	5.10	3.10	4.28
T4- 75% NON INDUCED	4.30	3.80	3.40	4.50	2.40	3.68
T5- AC 50% ASM	5.80	5.50	5.30	6.00	3.70	5.26
T6- 50% INDUCED	6.00	5.70	5.50	6.30	4.10	5.52
T7- 50 % NON INDUCED	5.50	5.30	5.00	5.60	3.30	4.94
Mean	4.96	4.60	4.27	5.19	3.04	
	FLOWERING STAGE					
T1-AC 100%ASM	4.10	3.80	3.50	4.50	2.50	3.78
T2-AC 75% ASM	5.20	4.70	4.40	5.50	3.20	4.60
T3- 75% INDUCED	5.40	5.00	4.70	5.70	3.50	4.86
T4- 75% NON INDUCED	5.00	4.50	4.10	5.20	2.90	4.34
T5- AC 50% ASM	6.30	6.00	5.60	6.70	4.20	5.76
T6- 50% INDUCED	6.60	6.30	6.00	7.00	4.60	6.10
T7- 50 % NON INDUCED	6.00	5.80	5.40	6.30	3.90	5.48
Mean	5.51	5.16	4.81	5.84	3.54	

CD(5%): G: 0.55 T: 0.65 S: 0.50 GxT: NS GxS: NS TxS: NS GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 72: Effect of water stress on Phenolics content ($\text{mg g}^{-1}\text{FW}$) in induced and non induced rice genotypes.(GxT)

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	3.13	2.83	2.55	3.50	1.70	2.74
T2-AC 75% ASM	4.00	3.50	3.15	4.33	2.23	3.44
T3- 75% INDUCED	4.23	3.83	3.45	4.58	2.60	3.74
T4- 75% NON INDUCED	3.73	3.23	2.88	4.05	1.95	3.17
T5- AC 50% ASM	5.10	4.73	4.40	5.43	3.20	4.57
T6- 50% INDUCED	5.30	4.98	4.70	5.70	3.55	4.85
T7- 50 % NON INDUCED	4.78	4.45	4.13	5.07	2.85	4.26
G-Mean	4.32	3.93	3.61	4.66	2.58	

CD(5%):

G: 0.55

T: 0.66

GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Fig. 13. Effect of water stress on phenolics content ($\text{mg g}^{-1}\text{FW}$) in induced and non induced rice genotypes

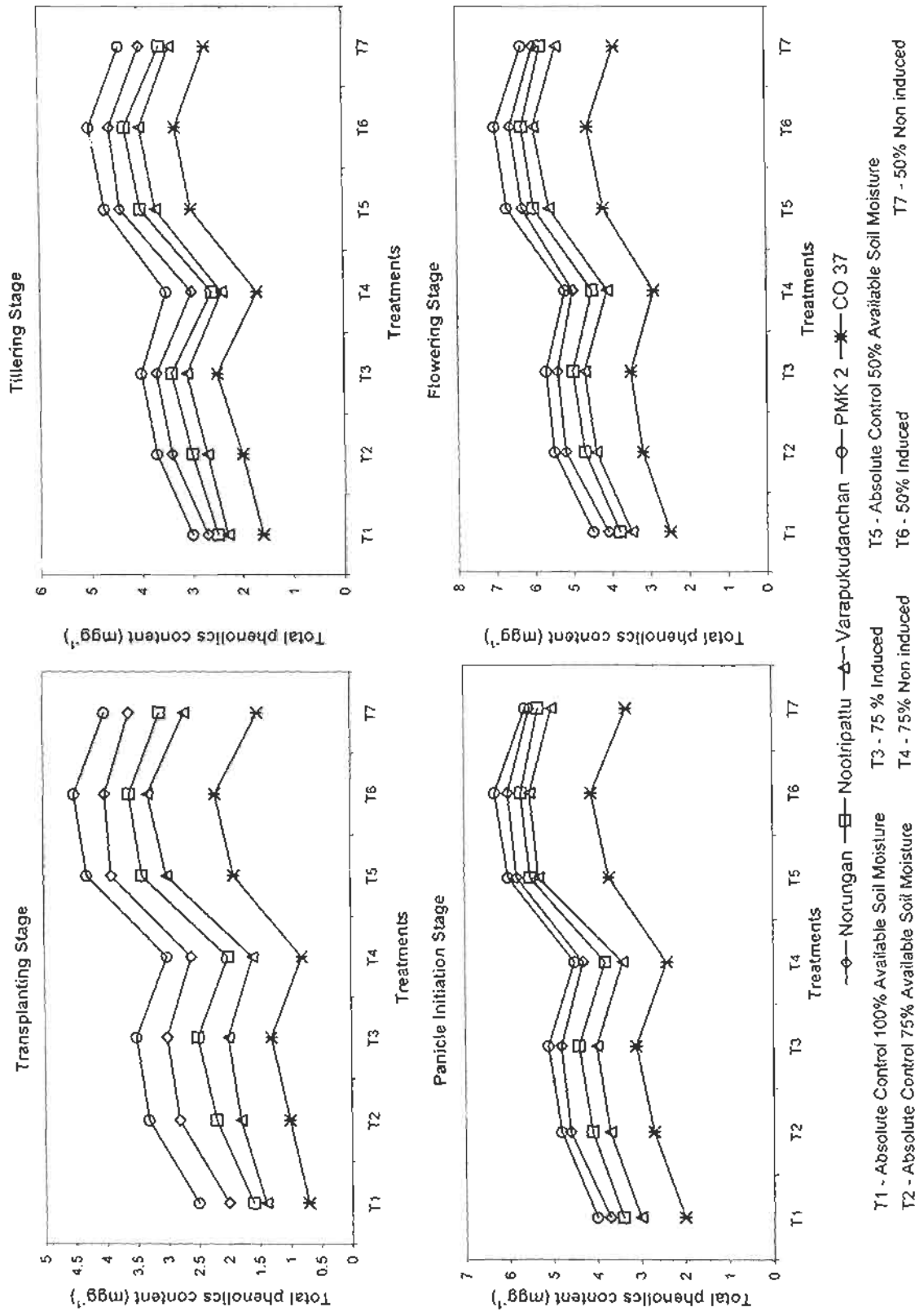


Table 73: Effect of water stress on ascorbic acid ($\mu\text{g g}^{-1}$) in induced and non induced rice genotypes.

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	42.00	37.00	31.00	47.00	25.00	36.40
T2-AC 75% ASM	35.00	30.00	24.00	41.00	18.00	29.60
T3- 75% INDUCED	39.00	34.00	28.00	44.00	22.00	33.40
T4- 75% NON INDUCED	30.00	25.00	20.00	36.00	13.00	24.80
T5- AC 50% ASM	24.00	19.00	14.00	29.00	7.00	18.60
T6- 50% INDUCED	28.00	23.00	18.00	33.00	11.00	22.60
T7- 50 % NON INDUCED	22.00	17.00	12.00	27.00	4.00	16.40
Mean	31.43	26.43	21.00	36.71	14.29	
	TILLERING STAGE					
T1-AC 100%ASM	51.00	45.00	40.00	56.00	30.00	44.40
T2-AC 75% ASM	44.00	38.00	33.00	49.00	23.00	37.40
T3- 75% INDUCED	48.00	42.00	37.00	53.00	27.00	41.40
T4- 75% NON INDUCED	40.00	34.00	28.00	45.00	19.00	33.20
T5- AC 50% ASM	32.00	26.00	20.00	37.00	11.00	25.20
T6- 50% INDUCED	36.00	30.00	24.00	41.00	15.00	29.20
T7- 50 % NON INDUCED	30.00	24.00	18.00	34.00	8.00	22.80
Mean	40.14	34.14	28.57	45.00	19.00	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	83.00	78.00	73.00	88.00	62.00	76.80
T2-AC 75% ASM	75.00	70.00	66.00	79.00	51.00	68.20
T3- 75% INDUCED	80.00	75.00	70.00	84.00	57.00	73.20
T4- 75% NON INDUCED	71.00	66.00	61.00	75.00	46.00	63.80
T5- AC 50% ASM	61.00	50.00	45.00	66.00	35.00	51.40
T6- 50% INDUCED	66.00	55.00	50.00	71.00	40.00	56.40
T7- 50 % NON INDUCED	58.00	47.00	41.00	63.00	31.00	48.00
Mean	70.57	63.00	58.00	75.14	46.00	
	FLOWERING STAGE					
T1-AC 100%ASM	70.00	65.00	60.00	75.00	49.00	63.80
T2-AC 75% ASM	60.00	56.00	51.00	66.00	40.00	54.60
T3- 75% INDUCED	64.00	61.00	55.00	70.00	44.00	58.80
T4- 75% NON INDUCED	56.00	51.00	47.00	62.00	36.00	50.40
T5- AC 50% ASM	46.00	40.00	37.00	52.00	25.00	40.00
T6- 50% INDUCED	51.00	46.00	42.00	57.00	30.00	45.20
T7- 50 % NON INDUCED	42.00	36.00	33.00	47.00	20.00	35.60
Mean	55.57	50.71	46.43	61.29	34.86	

CD(5%): G:0.59 T:0.70 S:0.53 GxT: NS GxS: 1.17 TxS: 1.39 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 74:Effect of water stress on ascorbic acid ($\mu\text{g g}^{-1}$) in induced and non induced rice genotypes.(GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	61.50	56.25	51.00	66.50	41.50	55.35
T2-AC 75% ASM	53.50	48.50	43.50	58.75	33.00	47.45
T3- 75% INDUCED	57.75	53.00	47.50	62.75	37.50	51.70
T4- 75% NON INDUCED	49.25	44.00	39.00	54.50	28.50	43.05
T5- AC 50% ASM	40.75	33.75	29.00	46.00	19.50	33.80
T6- 50% INDUCED	45.25	38.50	33.50	50.50	24.00	38.35
T7- 50.% NON INDUCED	38.00	31.00	26.00	42.75	15.75	30.70
G-Mean	49.23	43.57	38.50	54.54	28.54	

CD(5%): G:0.59 T: 0.70 GxT: NS

AC: Absolute control, ASM:Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

(AC 100% ASM) recorded the maximum ascorbic acid ($55.35 \mu\text{g g}^{-1}$), and the minimum in T_7 (50% non induced, $30.70 \mu\text{g g}^{-1}$). Significant increase in ascorbic acid was noticed from transplanting stage to flowering stage.

4.10. TOTAL DRY MATTER PRODUCTION (TDMP)

The data relating to TDMP are given in Table 75, 76. TDMP decreased with increase in water stress. Significant differences were observed among the genotypes, treatments, stages, $G \times S$ and $T \times S$. Among the genotypes PMK 2 recorded the highest TDMP ($13.10 \text{ g plant}^{-1}$), followed by Norungan ($12.08 \text{ g plant}^{-1}$), Nootripattu ($11.02 \text{ g plant}^{-1}$), Varapukudanchan ($9.99 \text{ g plant}^{-1}$) and the lowest was recorded in CO 37 ($8.17 \text{ g plant}^{-1}$). Among the treatments T_1 (AC 100% ASM) recorded the highest TDMP ($14.15 \text{ g plant}^{-1}$) and lowest in T_7 (50% non induced, $7.78 \text{ g plant}^{-1}$).

Significant increase in TDMP was noticed from transplanting stage to flowering stage. The induced seedlings registered the highest TDMP compared to non induced seedlings under 75 and 50 per cent ASM.

4.11. YIELD AND YIELD COMPONENTS

As a final assessment of different treatments affecting the yield, the related components were studied and the relevant data on the chosen parameters are presented in Table 77.

4.11.1. Number of tillers plant^{-1}

The treatments varied significantly for the number of tillers plant^{-1} . Significant differences were observed among genotypes, treatments and interactions. Among the genotypes tolerant variety PMK 2 recorded the maximum tillers plant^{-1} (11.09),

Table 75: Effect of water stress on total dry matter production (g plant^{-1}) in induced and non induced rice genotypes. 185

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
	TRANSPLANTING STAGE					
T1-AC 100%ASM	2.40	2.30	2.20	2.50	1.90	2.26
T2-AC 75% ASM	2.10	2.00	1.90	2.20	1.50	1.94
T3- 75% INDUCED	2.20	2.10	2.00	2.30	1.60	2.04
T4- 75% NON INDUCED	1.80	1.70	1.60	1.90	1.30	1.66
T5- AC 50% ASM	1.70	1.69	1.59	1.89	1.29	1.63
T6- 50% INDUCED	1.90	1.80	1.70	2.00	1.40	1.76
T7- 50 % NON INDUCED	1.68	1.58	1.48	1.78	1.18	1.54
Mean	1.97	1.88	1.78	2.08	1.45	
	TILLERING STAGE					
T1-AC 100%ASM	7.90	7.81	7.72	8.00	6.40	7.57
T2-AC 75% ASM	6.62	6.50	6.41	6.71	4.90	6.23
T3- 75% INDUCED	6.71	6.62	6.51	6.82	5.10	6.35
T4- 75% NON INDUCED	5.30	5.21	5.10	5.31	4.51	5.06
T5- AC 50% ASM	5.21	5.12	5.13	5.31	4.51	5.06
T6- 50% INDUCED	5.40	5.30	5.20	5.50	4.70	5.22
T7- 50 % NON INDUCED	5.01	4.92	4.81	5.12	4.30	4.83
Mean	6.02	5.93	5.84	6.12	4.93	
	PANICLE INITIATION STAGE					
T1-AC 100%ASM	23.20	21.00	19.10	25.00	16.00	20.86
T2-AC 75% ASM	19.10	17.00	15.10	21.00	12.00	16.84
T3- 75% INDUCED	21.20	19.00	17.10	23.00	14.10	18.88
T4- 75% NON INDUCED	16.10	14.00	12.00	18.10	9.10	13.86
T5- AC 50% ASM	14.20	12.10	10.10	16.00	7.20	11.92
T6- 50% INDUCED	18.10	16.00	14.10	20.10	11.00	15.86
T7- 50 % NON INDUCED	12.00	10.20	8.10	14.00	5.10	9.88
Mean	17.70	15.61	13.66	19.60	10.64	
	FLOWERING STAGE					
T1-AC 100%ASM	28.20	26.10	24.30	30.00	21.00	25.92
T2-AC 75% ASM	24.00	22.10	20.10	26.00	17.10	21.86
T3- 75% INDUCED	26.10	24.00	22.10	28.00	19.20	23.88
T4- 75% NON INDUCED	21.00	19.10	17.20	23.00	14.10	18.88
T5- AC 50% ASM	19.10	17.00	15.20	21.00	12.10	16.88
T6- 50% INDUCED	23.00	21.10	19.00	25.10	16.10	20.86
T7- 50 % NON INDUCED	17.00	15.10	13.00	19.20	10.10	14.88
Mean	22.63	20.64	18.70	24.61	15.67	

CD(5%): G: 0.53 T: 0.63 S: 0.47 GxT: NS GxS: 1.06 TxS: 1.25 GxTxS: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 76: Effect of water stress on total dry matter production (g plant^{-1}) in induced and non induced rice genotypes (GxT).

TREATMENT/GENOTYPE	NOR	NOT	VAR	PMK 2	CO 37	T-Mean
T1-AC 100%ASM	15.43	14.30	13.33	16.38	11.33	14.15
T2-AC 75% ASM	12.96	11.90	10.88	13.98	8.88	11.72
T3- 75% INDUCED	14.05	12.93	11.93	15.03	10.00	12.79
T4- 75% NON INDUCED	11.05	10.00	8.98	12.10	7.28	9.88
T5- AC 50% ASM	10.05	8.98	8.01	11.05	6.27	8.87
T6- 50% INDUCED	12.10	11.05	10.00	13.18	8.30	10.93
T7- 50 % NON INDUCED	8.92	7.95	6.85	10.03	5.13	7.78
G-Mean	12.08	11.02	9.99	13.10	8.17	

CD(5%):

G: 0.53

T: 0.63

GxT: NS

AC: Absolute control, ASM: Available soilmoisture, NOR: Norungan
NOT: Nootripattu, VAR: Varapukudanchan.

Table 77: Effect of water stress on yield and yield components in induced and noninduced rice genotypes

TREATMENTS/ YIELD COMPONENTS	No of tillers/pl	Panicle length (cm)	No of productive tillers/ pl	Filled grains (%)	1000 grains weight (g)	Yield (g pl ⁻¹)	Harvest index (%)
NORUNGAN							
T1-AC 100% ASM	13.80	22.00	6.20	90.00	28.90	3.00	48.00
T2-AC 75% ASM	12.30	19.10	4.90	86.00	28.86	2.52	44.30
T3-75% ASM INDUCED	12.60	20.10	5.10	88.40	28.89	2.71	46.20
T4-75% ASM NON INDUCED	9.60	17.20	3.70	77.50	28.83	1.92	42.00
T5-AC 50% ASM	9.30	16.30	3.60	74.00	28.81	1.86	40.10
T6-50% ASM INDUCED	9.90	17.50	3.80	80.00	28.84	2.04	42.20
T7- 50% ASM NON INDUCED	6.20	15.40	3.40	68.50	28.80	1.22	36.10
Mean	10.53	18.23	4.39	80.63	28.85	2.18	42.70
NOOTRIPATTU							
T1-AC 100% ASM	13.50	21.00	6.00	88.00	24.50	2.70	47.00
T2-AC 75% ASM	11.70	18.10	4.80	83.90	24.45	2.19	43.20
T3-75% ASM INDUCED	12.20	19.00	5.00	96.30	24.47	2.37	45.00
T4-75% ASM NON INDUCED	8.80	16.70	3.50	74.00	24.42	1.55	39.80
T5-AC 50% ASM	8.50	16.00	3.40	71.10	24.41	1.50	38.20
T6-50% ASM INDUCED	9.20	17.00	3.60	77.10	24.43	1.67	40.10
T7- 50% ASM NON INDUCED	5.40	15.10	3.20	67.10	24.40	0.82	34.30
Mean	9.90	17.56	4.21	78.21	24.44	1.83	41.09
VARAPUKUDANCHAN							
T1-AC 100% ASM	13.00	20.00	5.80	86.00	25.30	2.40	46.00
T2-AC 75% ASM	11.10	17.00	4.50	82.00	25.28	1.87	42.10
T3-75% ASM INDUCED	11.70	18.20	4.70	84.10	25.29	2.03	44.30
T4-75% ASM NON INDUCED	8.10	15.70	3.20	71.20	25.25	1.19	38.00
T5-AC 50% ASM	7.80	15.20	3.10	67.00	24.24	1.15	36.40
T6-50% ASM INDUCED	8.60	16.10	3.30	74.20	25.26	1.30	38.30
T7- 50% ASM NON INDUCED	4.70	14.00	2.90	63.70	25.22	0.41	32.00
Mean	9.29	16.60	3.93	75.46	25.26	1.48	39.59
PMK 2							
T1-AC 100% ASM	14.00	24.00	7.80	92.00	25.60	4.80	50.00
T2-AC 75% ASM	12.80	21.00	6.40	88.00	25.56	4.35	46.50
T3-75% ASM INDUCED	13.00	22.00	6.70	90.10	25.58	4.60	48.00
T4-75% ASM NON INDUCED	10.30	19.70	4.10	81.15	25.52	3.87	43.70
T5-AC 50% ASM	10.00	19.30	4.00	79.00	25.51	3.75	42.00
T6-50% ASM INDUCED	10.50	20.00	4.20	83.00	25.54	3.98	44.00
T7- 50% ASM NON INDUCED	7.00	18.20	3.90	76.50	25.49	3.21	38.20
Mean	11.09	20.60	5.30	84.25	25.54	4.08	44.63
CO 37							
T1-AC 100% ASM	14.00	24.00	8.00	97.50	22.50	7.50	50.00
T2-AC 75% ASM	10.30	13.80	4.20	82.00	22.48	6.60	39.00
T3-75% ASM INDUCED	11.00	15.00	4.40	87.10	22.49	6.70	42.00
T4-75% ASM NON INDUCED	6.40	12.30	2.90	68.10	22.44	5.26	32.00
T5-AC 50% ASM	6.00	11.80	2.70	60.00	22.43	5.25	29.00
T6-50% ASM INDUCED	7.00	13.00	3.00	72.00	22.46	5.34	33.00
T7- 50% ASM NON INDUCED	3.00	10.50	2.00	57.00	22.41	3.68	22.00
Mean	8.24	14.34	3.89	74.81	22.46	5.76	35.29
CD (5 %) : TxG	0.29	0.29	0.74	2.88	0.56	0.11	2.90

followed by Norungan (10.53) and minimum was recorded in susceptible variety CO 37 (8.24). Among the treatments, T₁ (AC 100% ASM) recorded the maximum tillers plant⁻¹ (13.66) and minimum was recorded in T₇ (50% non induced, 5.26).

Number of tillers decreased due to increase in water stress. The tolerant variety PMK 2 registered 26.4, 28.6 per cent reduction over absolute control 100 per cent ASM (T₁) under 75 per cent ASM (T₂) and 50 per cent ASM (T₅) respectively. At 75 and 50 per cent ASM conditions PMK 2 induced seedlings registered 1.6, 5 per cent increase over control T₂ (75% ASM) and T₅ (50%, ASM), but non induced seedlings registered 19.5, 30 per cent reduction over controls T₂, T₅ respectively.

The susceptible variety CO 37 registered 0.26, 57 per cent reduction over absolute control 100 per cent ASM (T₁) under 75 per cent ASM (T₂) and 50 per cent ASM (T₅). At 75 and 50 per cent ASM conditions CO 37 induced seedlings registered 6.8, 16.7 per cent increase over control T₂ (75% ASM), and T₅ (50% ASM) respectively but non induced seedlings registered 37.9, 50 per cent reduction over control T₂ and T₅ respectively.

4.11.2. Number of productive tillers plant⁻¹

The treatments varied significantly for the number of productive tillers plant⁻¹. Significant differences were observed between genotypes, treatments and interactions. Among the genotypes tolerant variety PMK 2 recorded the maximum productive tillers plant⁻¹ (5.30), followed by Norungan (4.39) and minimum was recorded in susceptible variety CO 37 (3.89). Among the treatments, T₁ (AC 100% ASM) recorded the maximum productive tillers plant⁻¹ (6.76) and minimum was recorded in T₇ (50% non induced, 3.08).

Number of productive tillers decreased due to increase in water stress. The tolerant variety PMK 2 registered 17.9 and 48.7 per cent reduction over absolute control 100 per cent ASM (T_1) respectively under 75 per cent ASM (T_2) and 50 per cent ASM (T_5). At 75 and 50 per cent ASM conditions PMK 2 induced seedlings registered 4.7, 5 per cent increase respectively over control T_2 (75% ASM) and T_5 (50% ASM), but non induced seedlings registered 35.9, 2.5 per cent reduction over control T_2 , T_5 respectively.

The susceptible variety CO 37 registered 47.5 and 66.2 per cent reduction over absolute control 100 per cent ASM (T_1) respectively under 75 per cent ASM (T_2) and 50 per cent ASM (T_5). At 75 and 50 per cent ASM conditions CO 37 induced seedlings registered 4.8, 11.1 per cent increase over control T_2 (75% ASM), and T_5 (50% ASM) respectively but non induced seedlings registered 30.9 and 25.9 per cent reduction over control T_2 and T_5 respectively.

4.11.3. Panicle length

Significant differences were observed among genotypes, treatments and interactions. Among the genotypes, tolerant variety PMK 2 recorded the maximum panicle length (20.6 cm), followed by Norungan (18.23cm) and minimum was recorded in susceptible variety CO 37 (14.34 cm). Among the treatments, T_1 (AC 100% ASM) recorded the maximum panicle length (22.2 cm) and minimum was recorded in T_7 (50% non induced, 14.64cm).

Panicle length decreased due to increase in water stress. The tolerant variety PMK 2 registered 12.5, 19.6 per cent reduction over absolute control 100 per cent ASM (T_1) respectively under 75 per cent ASM (T_2) and 50 per cent ASM (T_5)

respectively. At 75 and 50 per cent ASM conditions, PMK 2 induced seedlings registered 4.8, 3.5 per cent increase over control T_2 (75% ASM) and T_3 (50% ASM) respectively, but non induced seedlings registered 6.2 and 5.7 per cent reduction over control T_2 and T_3 respectively.

The susceptible variety CO 37 registered 30 and 50.8 per cent reduction over absolute control 100 per cent ASM (T_1) respectively under 75 per cent ASM (T_2) and 50 per cent ASM (T_3) respectively. At 75 and 50 per cent ASM conditions CO 37 induced seedlings registered 10.7, 10.2 per cent increase over control T_2 (75% ASM), and T_3 (50% ASM) respectively but non induced seedlings registered 26.8 and 11.0 per cent reduction over control T_2 and T_3 respectively.

4.11.4. Filled grain percentage

Significant differences were observed among genotypes, treatments and interactions. Among the genotypes tolerant variety PMK 2 recorded the highest filled grain percentage (84.25%), followed by Norungan (80.63%) and minimum was recorded in susceptible variety CO 37 (74.81%). Among the treatments, T_1 (AC 100% ASM) recorded the highest filled grain percentage (90.70%) and lowest was recorded in T_7 (50% non induced, 66.56).

Filled grain percentage decreased due to increase in water stress. The tolerant variety PMK 2 registered 4.3 and 14.1 per cent reduction over absolute control 100 per cent ASM (T_1) respectively under 75 per cent ASM (T_2) and 50 per cent ASM (T_3) respectively. At 75 and 50 per cent ASM conditions PMK 2 induced seedlings registered 2.4, 5.1 per cent increase respectively over control T_2 (75% ASM) and T_3

(50% ASM) respectively, but non induced seedlings registered 7.8 and 3.2 per cent reduction over control T_2 , T_5 respectively.

The susceptible variety CO 37 registered 15.9 and 38.5 per cent reduction over absolute control 100 per cent ASM (T_1) under 75 per cent ASM (T_2) and 50 per cent ASM (T_5) respectively. At 75 and 50 per cent ASM conditions CO 37 induced seedlings registered 6.2 and 20 per cent increase over control T_2 (75% ASM), and T_5 (50% ASM) respectively but non induced seedlings registered 16.9 and 5.0 per cent reduction over control T_2 and T_5 respectively.

4.11.5. 1000 grain weight:

The 1000 grain weight did not differ statistically among treatments. All the treatments are on par with the control. Significant differences were observed in their genotypes. Among the genotypes, norungan recorded the highest 1000 grain wt (28.85 g) followed by PMK 2 (25.54 g), varapukudanchan (25.26 g), nootripattu (24.44 g) and lowest was recorded in CO 37 (22.46 g).

4.11.6. Grain yield

Significant differences were observed among genotypes, treatments and interactions. Among the genotypes, CO 37, recorded the highest grain yield (5.76 g plant⁻¹) followed by PMK 2 (4.08 g plant⁻¹), Norungan (2.18 g plant⁻¹), nootripattu (1.83g plant⁻¹) and lowest was recorded in varapukudanchan (1.48 g plant⁻¹). Among the treatments T_1 (100% ASM) recorded the highest grain yield (4.08 g plant⁻¹), and the lowest was recorded in T_7 (50% Non-Induced, 1.87 g plant⁻¹).

Grain yield decreased due to increase in water stress. The PMK 2 (tolerant variety) and Varapukudanchan (land race) registered 9.4, 21.9, and 22.1, 52.1 per cent reduction over absolute control 100 per cent ASM (T_1), 75 per cent ASM (T_2) and 50 per cent ASM (T_5) respectively. At 75 and 50 per cent ASM conditions PMK 2 and varapukudanchan induced seedlings registered 5.7, 6.1 and 8.5, 13.0 per cent increase over control T_2 (75% ASM) and T_5 (50% ASM) respectively, but non induced seedlings registered 11.0, 14.4 and 36.4 and 64.3 per cent reduction over control T_2 and T_5 respectively.

The susceptible variety CO 37 registered 12.0 and 30.0 percent reduction over absolute control 100 per cent ASM (T_1) under 75 per cent ASM (T_2) and 50 per cent ASM (T_5) respectively. At 75 and 50 per cent ASM conditions CO 37 induced seedlings registered 1.5 and 1.7 per cent increase over control T_2 (75% ASM) and T_5 (50% ASM) respectively but non induced seedlings registered 20.3 and 29.9 per cent reduction over control T_2 and T_5 respectively.

4.11.7. Harvest Index

Significant differences were observed among genotypes, treatments and interactions. Among the genotypes tolerant variety PMK 2 recorded the highest harvest index (44.63), followed by Norungan (42.70) and minimum was recorded in susceptible variety CO 37 (35.29). Among the treatments, T_1 (AC 100% ASM) recorded the highest harvest index (48.20) and the lowest was recorded in T_7 (50% non induced, 32.52).

The tolerant variety PMK 2 registered 7 and 16 per cent reduction over absolute control 100 per cent ASM (T_1) respectively under 75 per cent ASM (T_2) and

50 per cent ASM (T_5) respectively. At 75 and 50 per cent ASM conditions PMK 2 induced seedlings registered 3.2, 4.8 per cent increase respectively over control T_2 (75% ASM) and T_5 (50% ASM) respectively, but non induced seedlings registered 6.0 and 9.0 per cent reduction over control T_2 , T_5 respectively.

The susceptible variety CO 37 registered 22 and 42 per cent reduction over absolute control 100 per cent ASM (T_1) under 75 per cent ASM (T_2) and 50 per cent ASM (T_5) respectively. At 75 and 50 per cent ASM conditions CO 37 induced seedlings registered 7.7 and 13.8 per cent increase over control T_2 (75% ASM), and T_5 (50% ASM) respectively but non induced seedlings registered 17.9, 24 per cent reduction over control T_2 and T_5 .

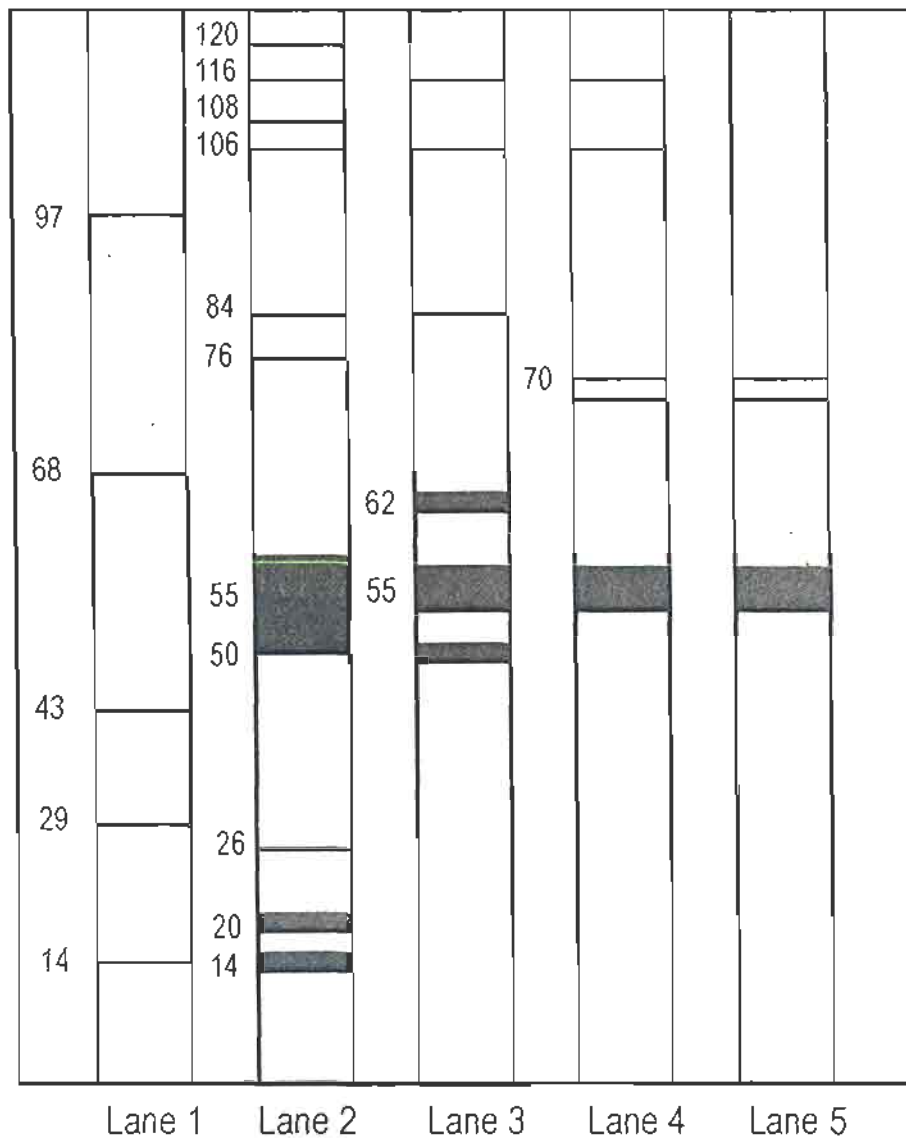
4.12. MOLECULAR MECHANISM OF WATER STRESS TOLERANCE IN RICE GENOTYPES AS INFLUENCED BY INDUCTION RESPONSE TECHNIQUE (SDS-PAGE)

4.12.1. Study of soluble protein profile under water stress in induced and non induced conditions

The results of SDS-PAGE protein profiles displays that there exist detectable differences between absolute control, control, induced and non induced seedlings. Though many minor variations were observed in protein profiles between the above said treatments, prominent detectable variation are taken into consideration. The molecular weight of the bands are approximated based on R_m values.

From the leaf sample, SDS-protein profile was studied and presented in Plate 29 to 34 and Fig. 15 to 20. In CO 37, 75 per cent ASM, there exist a prominent difference at a molecular weight of 55 kDa protein. In induced seedlings the intensity was more. The same was also observed in 50 per cent also. Many minor proteins of 66 kDa also appeared in induced seedlings. A specific protein of 18 kDa was absent in

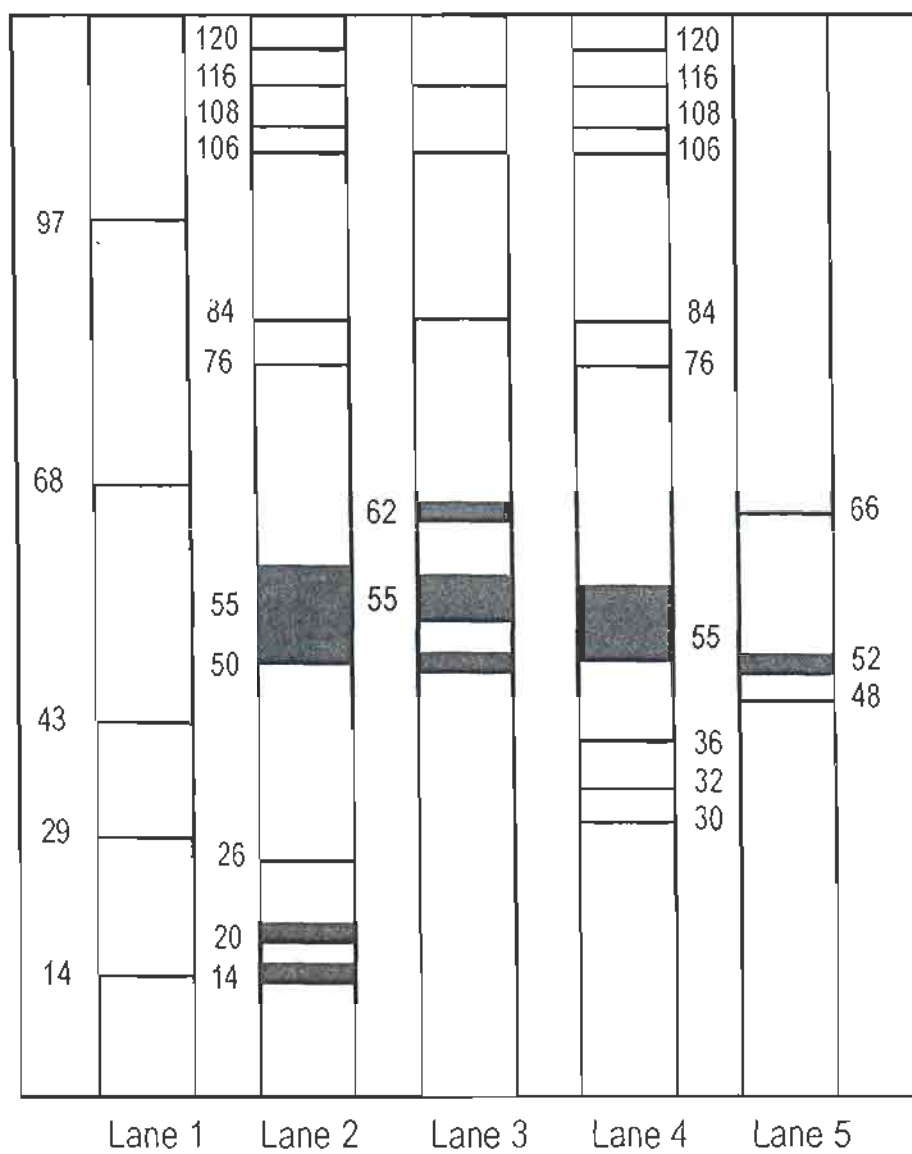
Fig.15. Soluble protein profile (12% SDS-PAGE) of Norungan (75 % ASM)



Lane 1 = Marker Lane 4 = Induced
 Lane 2 = Absolute control Lane 5 = Non induced
 Lane 3 = Control

The molecular marker (kDa) is indicated by Lane 1

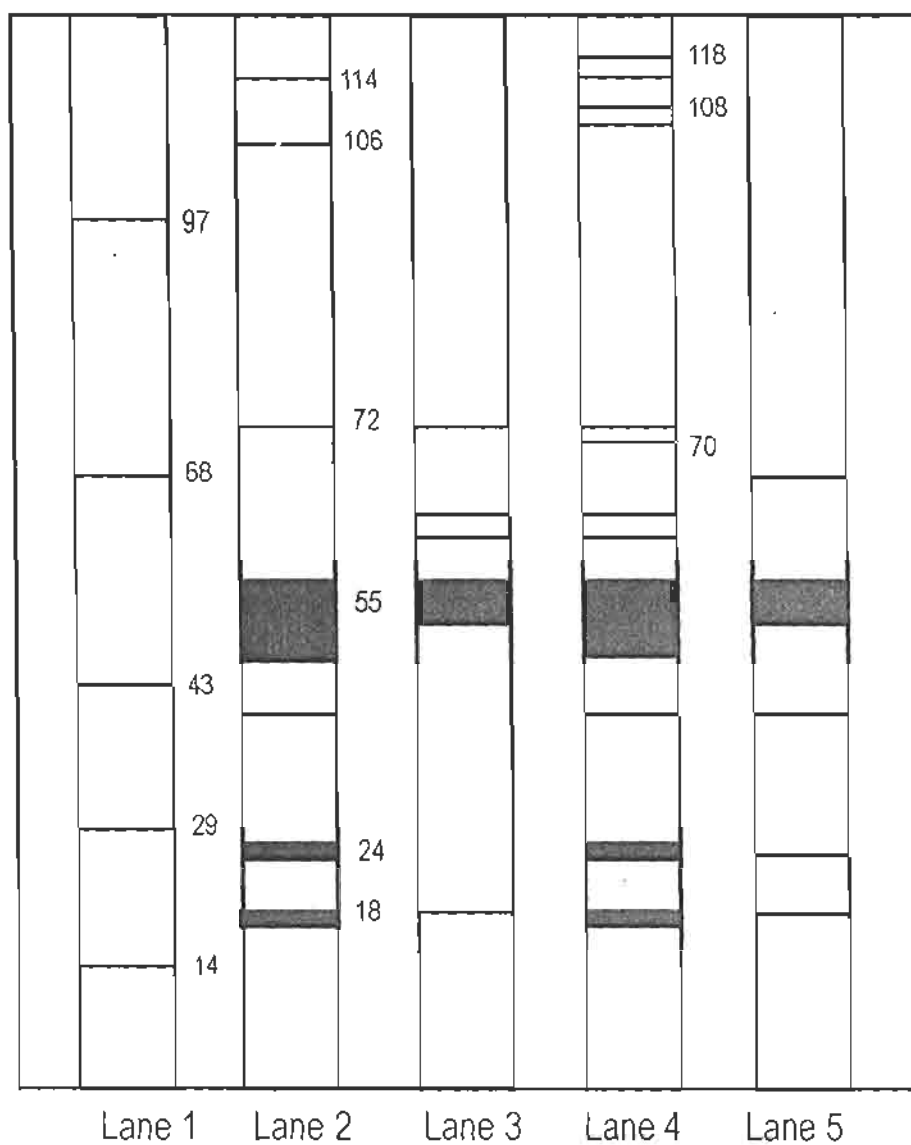
Fig.16. Soluble protein profile (12% SDS-PAGE) of Norungan (50 % ASM)



Lane 1 = Marker
 Lane 2 = Absolute control
 Lane 3 = Control
 Lane 4 = Induced
 Lane 5 = Non induced

The molecular marker (kDa) is indicated by Lane 1

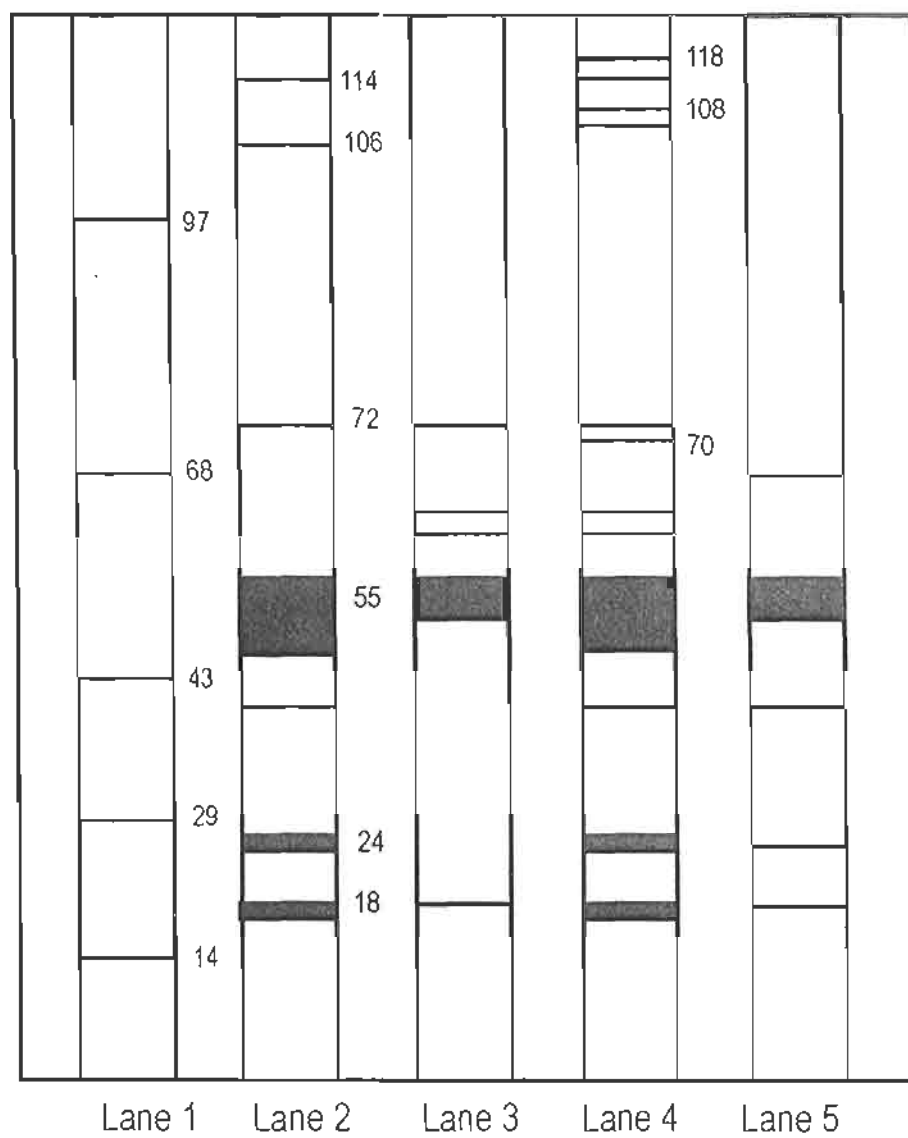
Fig.17. Soluble protein profile (12% SDS-PAGE) of
PMK 2 (75 % ASM)



Lane 1 = Marker	Lane 4 = Induced
Lane 2 = Absolute control	Lane 5 = Non Induced
Lane 3 = Control	

The molecular marker (kDa).is indicated by Lane 1

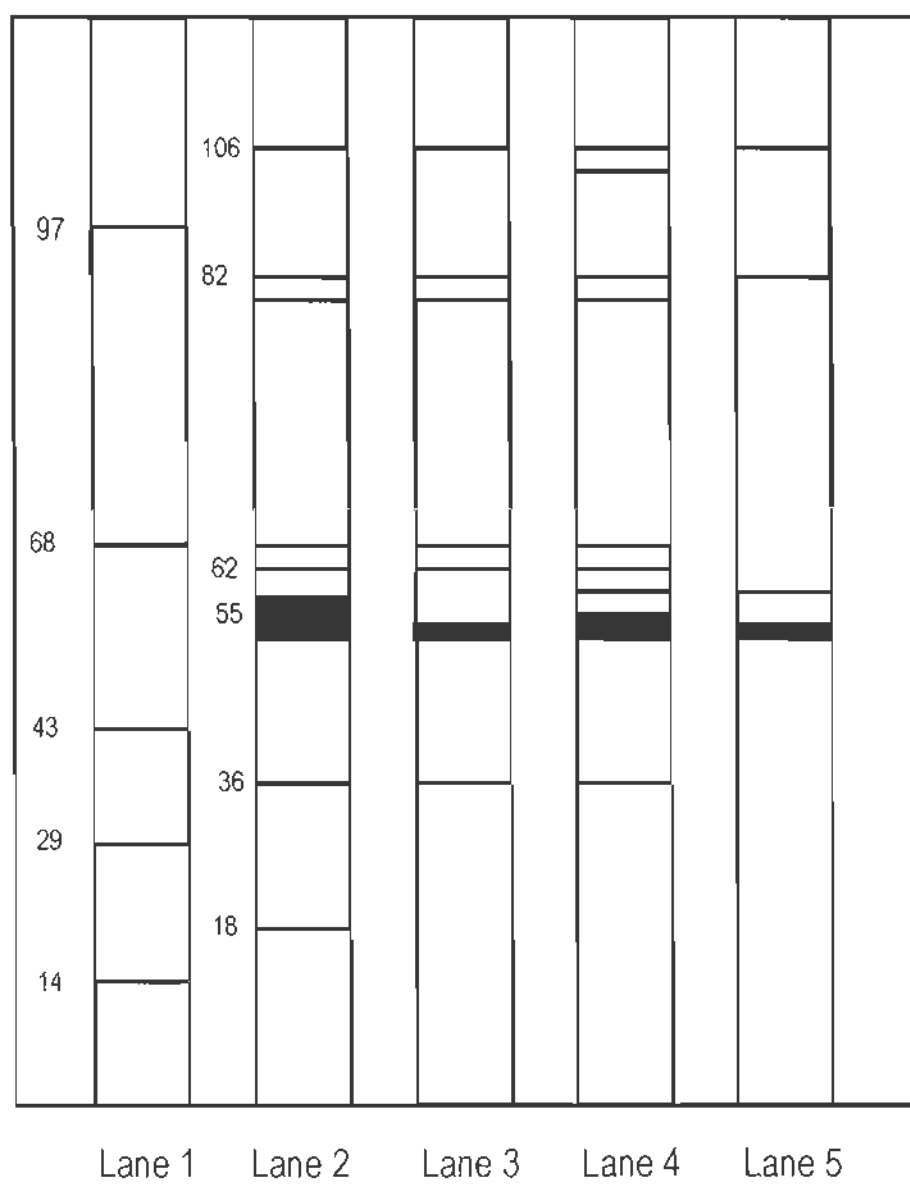
Fig.18. Soluble protein profile (12% SDS-PAGE) of PMK 2 (50 % ASM)



Lane 1 = Marker
 Lane 2 = Absolute control
 Lane 3 = Control
 Lane 4 = Induced
 Lane 5 = Non Induced

The molecular marker (kDa) is indicated by Lane 1

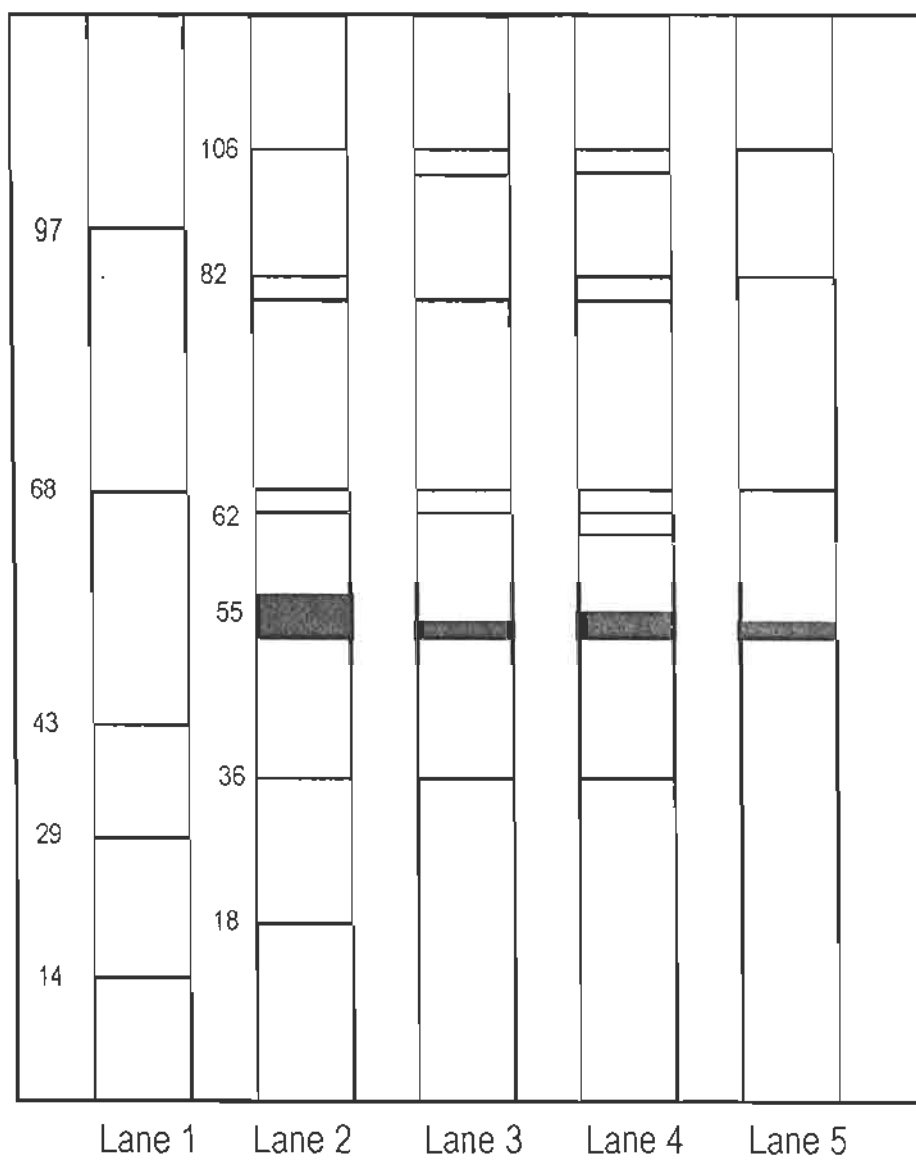
Fig.19. Soluble protein profile (12% SDS-PAGE) of
Co 37 (75 % ASM)



Lane 1 = Marker
Lane 2 = Absolute control
Lane 3 = Control
Lane 4 = Induced
Lane 5 = Non induced

The molecular marker (kDa) is indicated by Lane 1

Fig.20. Soluble protein profile (12% SDS-PAGE) of
Co 37 (50 % ASM)



Lane 1 = Marker	Lane 4 = induced
Lane 2 = Absolute control	Lane 5 = Non induced
Lane 3 = Control	

The molecular marker (kDa) is indicated by Lane 1

all the treatments (control, induced and non induced) is 50 per cent and 75 per cent ASM.

In PMK 2, there was little difference between 50 per cent and 75 per cent ASM in terms of polypeptide profile. In induced seedlings, a specific protein of 18, 24, 70, 108 and 118 kDa was appeared, whereas in non induced and control it was absent. The intensity of 55 kDa was also more in PMK 2, whereas in Norungan there exist a significant difference between 50 per cent and 75 per cent ASM in protein profile. Norungan 50 per cent ASM induced produced more number of bands compared to non induced and control in 75 per cent ASM, The induced seedlings produced a specific protein of 116 kDa which is absent in non-induced, whereas 62 kDa protein was absent in both induced and non induced seedling but present in control plants.

In 50 per cent ASM, induced seedling produced 120, 116, 108, 106, 84, 76, 55, 36, 32 and 30 kDa proteins. The non induced seedling produced only 66, 52 and 48 kDa proteins alone. Comparing control and induced seedlings, 116, 106, 84, 76, 36, 32 and 30 kDa proteins are novel and specific to induced seedling alone.

4.13. ELECTROPHORETIC STUDIES OF ISOZYMES

Isozymes of AOS scavenging enzymes viz., catalase and peroxidase was studied at 8 % native PAGE. the zymogram was given as figure.

4.13.1. Catalase (Plate 38 to 40 and Fig. 24 to 26)

Catalase activity is shown in the plates 38 to 40 and the corresponding zymogram pattern is depicted in fig. 24 to 26. In this, it was observed that most of the treatments shown two isoforms as the maximum number. In PMK 2, the 75 per cent induced and 50 per cent

Zymogram pattern of peroxidase isozyme in rice genotypes

201

Fig.21. PMK 2

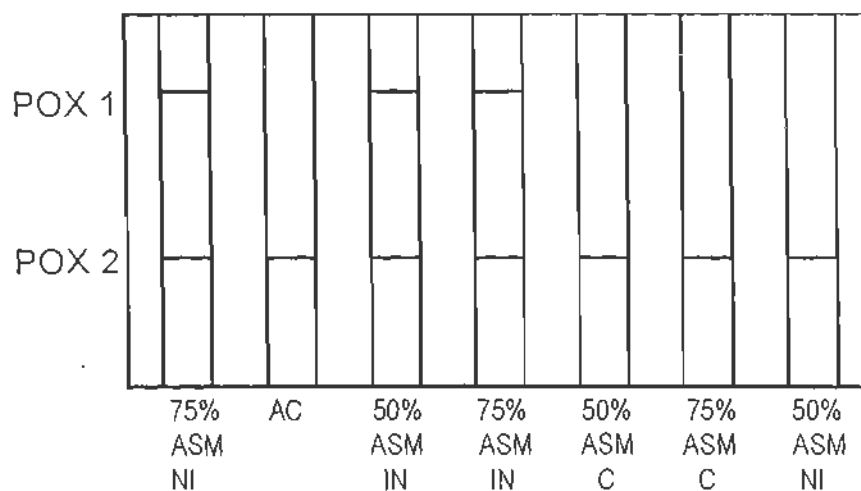


Fig.22. CO 37

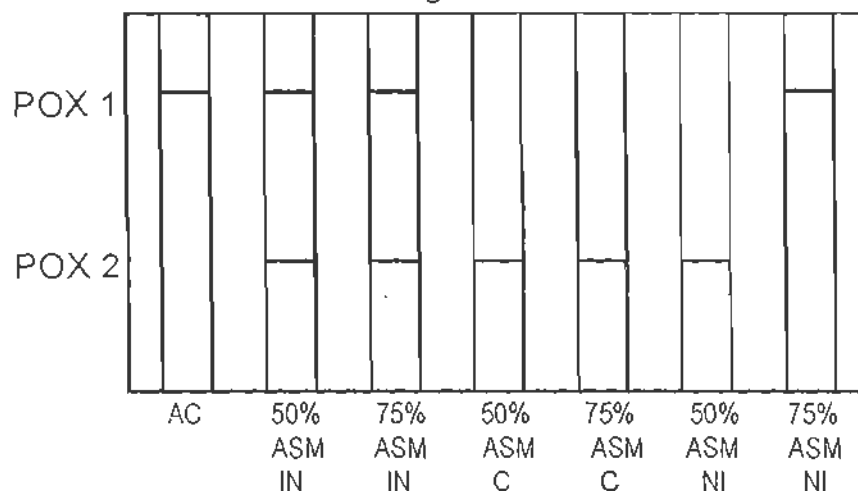
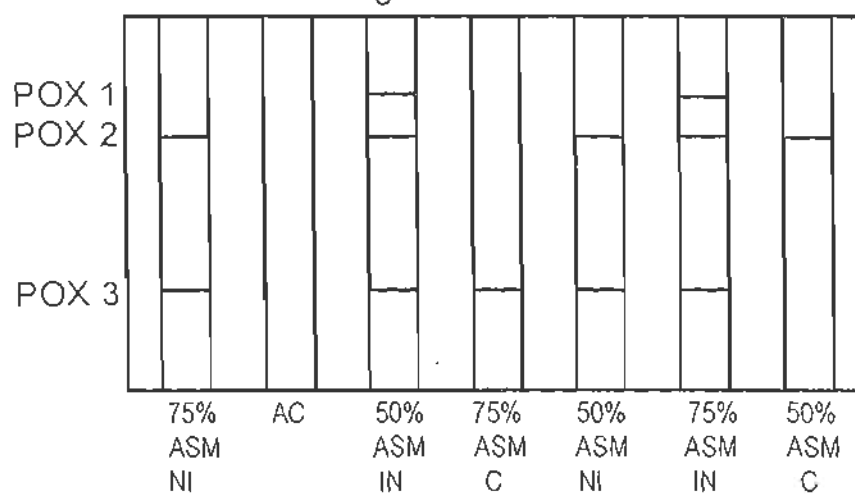


Fig.23. NORUNGAN



C = Control
AC = Absolute Control
NI = Non induced
IN = Induced



Zymogram pattern of catalase isozyme
in rice genotypes

Fig.24. PMK 2

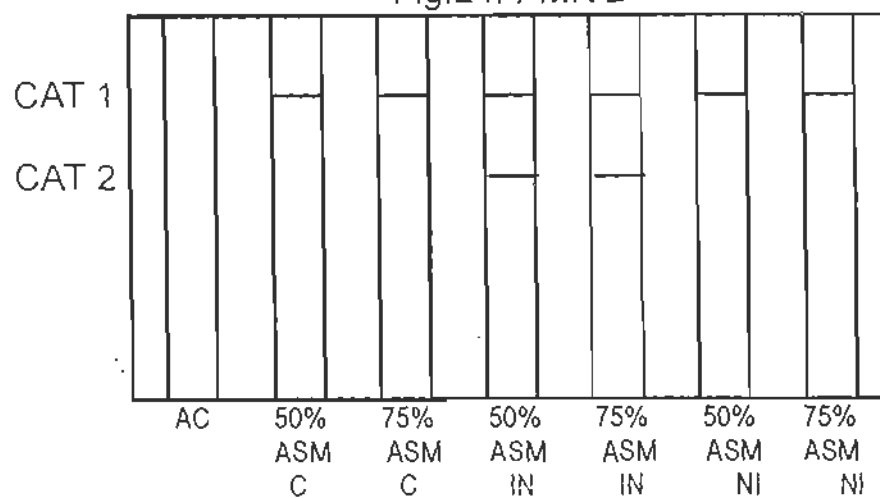


Fig.25. NORUNGAN

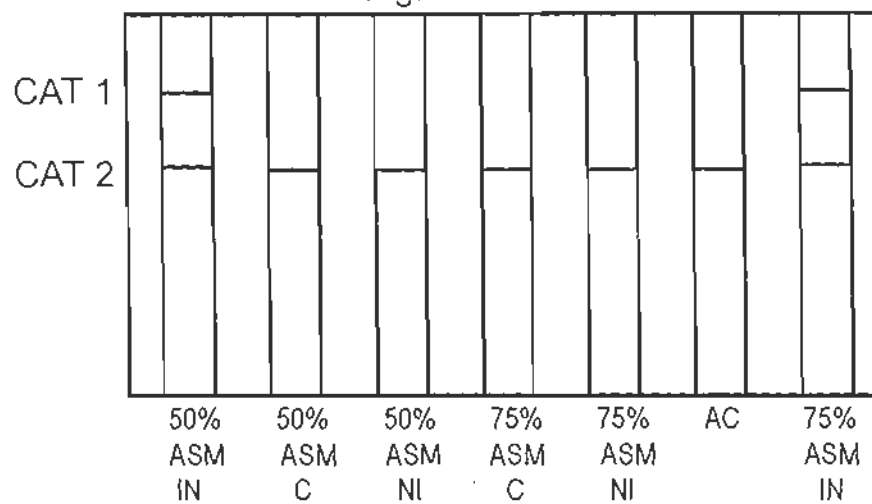
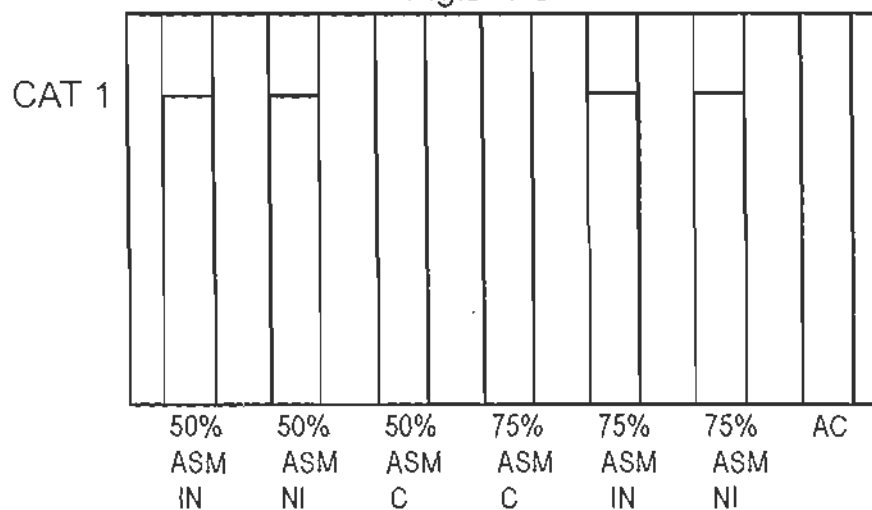


Fig.26. CO 37



induced alone produced maximum of two isoforms, and the others produced one except absolute control, it didn't showed any enzyme activity. In Norungan, the same induced seedling as said above produced two isoforms and the rest of the treatment produced one isoform.

In CO 37, the induced and non induced seedling of 50 per cent and 75 per cent produced one band respectively, whereas others didn't show any enzyme activity. Though the number of isoform was less, the activity of the enzyme was more, it was evidenced by the intensity of the band.

4.13.2. Peroxidase

Peroxidase activity is shown in the plates 35 to 37 and the corresponding zymogram pattern is depicted in fig 21 to 23. In this banding sequence, Norungan under induced conditions (50% and 75%) produced 3 bands, which is the highest among all treatment and genotypes.

In PMK 2, the induced seedlings, (50% and 75%) produced two isoforms and others produced one isoform except 75% NI, which it also produced two isoforms. In CO 37, the induced seedling alone produced 2 isoforms, the rest produced one isoform.

In Norungan, the absolute control did not showed any enzymatic response, whereas 75 per cent and 50 per cent control produced one band respectively. The remaining induced and non induced produced 3 and 2 bands respectively at 50 per cent and 75 per cent ASM.

Discussion

*Chapter V***DISCUSSION**

Currently, about 100 million people depend on upland rice where water deficit is the most important production constraint. The phenomenon of plant adaptation to environment can, in principle be understood in morpho-physiological, biochemical and molecular terms. It is probable that those genotypes originating from locations prone to drought, carry specific adaptive traits which could be exploited in crop improvement programmes. These traits could be either constitutive or inducible. Water stress promotes expression of a wealth of genetic variability and various adaptive traits become important determinants of growth and yield. The existence of adaptive traits whose presence or absence becomes apparent only during stress, raises two questions. (1) can these characters be identified and exploited in crop improvement and (2) can the expression of such trait(s) be used to monitor plant performance.

Efforts to improve productivity of rice under water limited conditions need understanding of the mechanisms so as to identify traits required for productivity improvement programmes. Drought resistance is the manifestation of morpho-physiological, biochemical and molecular mechanisms which allow the crop to survive, grow and maximise yield under water limited conditions.

In the present study, an attempt has been made to elucidate information on water stress tolerance in rice by water stress induction response technique, to circumvent the ill effect of water stress. The results obtained are discussed in this chapter with sufficient support from earlier studies.

5.1. SCREENING FOR WATER STRESS TOLERANCE USING PEG-6000 SIMULATED REDUCED WATER POTENTIAL

Genotypic variation in germination and seedling growth under reduced water potential is critical for its quick establishment ability under water stress condition (Redona and Mackill, 1996). An external water potential of -0.5 MPa is sublethal dose and -1.0 MPa is a lethal dose were selected based on preliminary standardization study. Results showed that increase water potential decreased germination, shoot length, root length, and vigour index. Among the genotypes all water stress tolerant genotypes such as Norungan, Nootripattu Varapukudanchan and PMK2 recorded the highest germination percentage compared to susceptible genotype CO 37. Decreased germination might be due to the additive effect of both water potential and osmotic potential on the inhibition of seed germination as reported by Bernstein (1961). Seedling growth in terms of plumule and radicle length were reduced at decreased water potential. Similar results were reported by Goswami and Baruah (1994). The tolerant genotypes recorded higher germination and seedling growth under reduced water potential which was in conformity with the earlier reports of Goswami and Baruah (1994), Jha and Singh (1997) and Sadasivam *et al.* (2001).

5.2. INDUCTION RESPONSE

Survival and subsequent recovery of seedlings growth, under lethal stress would be higher when they were pretreated with a mild non-lethal stress, compared to the untreated seedling. This was often referred as induction response. This induction response is species specific and the optimum PEG 6000 concentration for induction of stress for rice was -0.5 MPa and lethal dose was -1.0 MPa. In the present study water stress tolerant rice genotypes showed better growth under stress and better recovery growth alleviation of stress, compared to water stress susceptible genotype. Among the genotypes, the drought tolerant land race Norungan was recorded the highest value

of shoot length and root length at the end of water recovery and lowest value was recorded by the susceptible variety CO 37. The primary root of rice always died even in the induced seedling during lethal stress and many secondary roots started growing during recovery growth. The tolerant genotypes were able to put forth many number of lateral roots during recovery was evident. The induced seedling performed better than its control by achieving a fast recovery. It is in accordance with Uma (1992) and Jayaprakash (1998). A large body of current literature shows that pretreatment with non lethal stress, during which stress proteins are synthesized allows the responding organism to tolerate an otherwise lethal stress. The tolerance to lethal stress via induction treatment is again species specific . Soybean seedlings could survive 45°C lethal heat shock with 40°C prior induction for 2 hours (Lin *et al.*, 1984) but tobacco could survive 54°C lethal temperature with 38°C prior induction (Harrington and Alm, 1988). Seedlings could tolerate otherwise lethal stresses with a dramatic increase in the recovery growth with a prior optimum induction treatment. Work by Gill and Singh (1988) has shown that salt tolerant genotypes of rice showed better growth under stress and better recovery growth on alleviation of stress, compared to salt sensitive genotype, and the present study is in accordance with the reported results.

5.3. MORPHOLOGICAL CHARACTERS

5.3.1. Plant height

The plant height showed a linear increasing trend during different growth stages. Irrespective of genotypes, plant height was reduced significantly due to water stress. However, minimum reduction in plant height was recorded in all tolerant genotypes. Most of the tolerant genotypes were traditional upland races. Hence induced seedlings performed better by showing less reduction over its control. The highest plant height was recorded in Norungan (AC 100% ASM) followed by PMK 2 (AC 100% ASM) and lowest was recorded in CO 37 (50% ASM non-induced).

Vijayalakshmi and Nagarajan (1994) reported marginal reduction in plant height of tolerant rice genotypes which had well developed rooting system. Tomar and Prasad (1996) also reported that plant height in rice was associated with thick and deep root system. These observations could be confirmed in the present investigation.

5.3.2. Root characters

Root length being an important morphological parameter showed varied response due to the treatment effects. There was a linear increase in root length towards flowering stage. Drought resistant cultivars were found to show vigorous root development (Simane *et al.*, 1993; Namuco *et al.*, 1993). Water stress reduced mean root length and root shoot ratio (Sorte *et al.*, 1992). In the present study drought tolerant rice genotypes recorded the highest root length and root volume than susceptible genotype. Induced seedling performed better than non induced seedling by showing lesser reduction. Among the genotypes the drought tolerant land race Norungan recorded the longest root length (AC 100% ASM) followed by PMK 2 (AC 100% ASM) and lowest root length was recorded by the susceptible variety CO 37 (50% ASM non induced). Root volume also showed the same trend. Vijayalakshmi and Nagarajan (1994) compared the drought tolerant and drought susceptible rice genotypes for their effect of rooting on productivity under different water regimes. They reported that drought tolerant rice genotypes showed less reduction in root volume than susceptible genotype under increasing water deficit. These observations could be confirmed in the present investigation.

5.3.3. Leaf number

In general the number of leaves per plant showed an increase under 100 per cent ASM at all the stages of growth. The increasing trend was linear upto flowering stage. Leaves in general are considered as an important functional units of

plant which contribute to the formation of yield. Induced seedling performed better than non induced seedling by recording high values. Tolerant genotypes recorded more leaves than susceptible genotypes. Among the genotypes PMK 2 (AC 100% ASM) recorded the more number of leaves followed by Norungan (AC 100% ASM). The susceptible variety CO 37 (50% ASM non induced) recorded the least number of leaves.

The lack of cell expansion due to water shortage would be determined by an increased leaf area rather than the number of leaves (Hsiao, 1973). Reduction in total leaf area under water deficits was attributed to the restricted leaf growth and accelerated leaf senescence (Ludlow and Muchow, 1990). These findings provided a valid support for the result obtained in the present study.

5.3.4. Leaf area

Leaf area (LA) is the fundamental determinant of the rate of photosynthesis. Larger LA development aids in the effective interpretation of light leading to higher drymatter production (Shibles and Weber, 1965).

There was increase in LA linearly towards flowering stage. PMK 2 (AC 100% ASM) recorded the highest LA followed by Norungan (AC 100% ASM) and lowest was recorded by CO 37 (50% ASM non induced). The decline in leaf area might be due to the transport of assimilates from the leaves to the developing sink which later caused senescence of leaves.

During water stress period, the cultivar with a small canopy maintained higher plant water status as compared to a cultivar with large canopy. However, the cultivar with small canopy could not fully recover from stress (Prasertsak and Fukai, 1997).

Tolerant rice genotypes recorded higher in leaf area than susceptible genotype under increased water deficit. Susceptible genotypes of rice responded to water deficit in terms of rapid decline in leaf elongation and greatest leaf death as reported by Lilley and Fukai (1994b) corroborates the present observation.

5.4. GROWTH ATTRIBUTES

5.4.1. Leaf Area Index (LAI)

LAI is an important parameter that can be used to determine the DMP and thereby the crop yield. The early attainment of an optimum LAI is considered to be very essential for better productivity. Significant differences in LAI among different cultivars have been well documented (Patra *et al.*, 1995). Although positive correlation between LAI and yield was not observed in different crops, there were reports by Dingkuhn *et al.*, (1991) in rice. The present study showed that induced seedling performed better than non induced seedling by recording high LAI. Tolerant genotypes recorded highest LAI than susceptible genotypes. The drought tolerant variety PMK 2 (AC 100% ASM) recorded the highest LAI followed by Norungan. The susceptible variety CO 37 (50% ASM non induced) recorded lowest LAI. LAI particularly at reproductive stage have a specific role in deciding drymatter production and grain yield of rice. There was significant reduction in LAI under water stress. Reduction in leaf area was highest in susceptible genotypes. This might be due to rapid decline in leaf elongation rate and also due to greatest leaf death as reported by Lilley and Fukai (1994b). These observations corroborated the present findings.

5.4.2. Leaf area duration

The LAD is the sum of different growth stages mean LAI over time and hence represents time span of active photosynthesis by the leaves. LAD, in general, indicates

that drymatter accumulation is a direct function of leaf area (Power *et al.*, 1967). Ramanujam (1985) pointed out that maintenance of optimum LAI over a longer period i.e. higher LAD was important for maximising yield in crop plants. In rice positive correlation between LAD during grain filling with grain yield ($r = +0.650$) was observed by Chau and Deshmukh (1989). Highest LAD was registered by PMK 2 (AC 100% ASM) followed by Norungan (AC 100% ASM). Longer LAD in AC 100 per cent ASM plants might be due to more functional leaves. Gonzalez and Paez (1996) reported that LAD was reduced with increased water stress. These findings provided a valid support for the result obtained in the present study.

5.4.3. Specific leaf area (SLA)

SLA is a measure of leaf thickness which varies with cultivar, leaf position, growth stage and environment (Murata 1975). These relationship come in handy to explain the degree of growth under each environmental situation in crop plants. The SLA increased markedly during the early part of the vegetative phase. Usha Rani (1979) noted that SLA was inversely related to SLW.

In the present study, tolerant genotypes recorded highest SLA than susceptible genotypes. SLA was found to decline as growth progressed. The higher SLA recorded at early stage might be due to minimum weight of leaves and the decreased SLA at flowering with increased biomass added to the leaves. PMK 2 (AC 100% ASM) registered the highest SLA followed by Norungan (AC 100% ASM). The lowest SLA was registered in the susceptible variety CO 37 (50% ASM non induced).

5.4.4. Specific leaf weight (SLW)

SLW defined as leaf dry weight per unit area has been reported to have a strong positive correlation with leaf photosynthesis in several crops (Bowes *et al.*, 1972; Delaney and Dobrenz, 1974; Dornhoff and Shibles, 1976; Lugg and Sinclair, 1979) Pn showed a strong positive association with SLW at post flowering stage. SLW on the other hand, was significantly and positively associated with leaf thickness. Thus, to a large extent, SLW was found to be dependent on the leaf thickness (Lugg and Sinclair, 1980). SLW was an important feature in the storage of photosynthates and its subsequent translocation to the developing seed. In the present study tolerant genotypes recorded highest SLW than susceptible genotype. Among genotypes, tolerant variety PMK 2 (AC 100% ASM) recorded the highest SLW followed by Norungan (AC 100% ASM) and lowest was recorded by the susceptible variety CO 37 (50% ASM non induced).

5.4.5. Net assimilation rate (NAR)

NAR is the net gain in total drymatter per unit leaf area per unit time. NAR and RGR were considered as important plant traits governing crop growth (Gregory, 1926). He postulated that internal factors largely determined leaf area whereas external factors were primarily responsible for variation in NAR. He evidently showed that NAR for a number of crops grown under uniform conditions was approximately constant. Shibles and Weber (1965) studied the relationship between NAR with increasing leaf area as a parameter of growth. The present study indicated that NAR was high at early stages and declined thereafter. Watson (1958) however suggested that the cause for the decrease in NAR was due to increased leaf area in crop plants, as the mutual shading of leaves would decrease the leaf photosynthesis. Tolerant genotypes recorded highest NAR than susceptible genotypes. Among the tolerant genotypes, PMK 2 (AC 100% ASM) registered the highest

NAR followed by Norungan (AC 100% ASM) and lowest was registered in the susceptible variety CO 37 (50% ASM non induced).

5.4.6. Crop growth rate (CGR)

CGR is the product of LAI and NAR expressing the drymass production per unit land area per unit time. The CGR changes with the age of the crop due to gradual changes in photosynthetic efficiency. In the present study tolerant genotypes recorded highest CGR than susceptible genotypes. Among the genotypes PMK 2 (AC 100% ASM) recorded the highest CGR and lowest was recorded by the susceptible variety CO 37 (50% ASM non induced). The increased CGR due to increased LAI was because CGR had positive association with LAI (Shibles and Weber, 1965). Jayabalan *et al.* (1995) reported a reduction in CGR of rice cultivars due to moisture stress. Zhang *et al.* (1997) reported that greater inhibition of CGR and physiological activities of five rice genotypes under water stress condition. The findings of Jayabalan *et al.* (1995) and Zhang *et al.*, (1997) was in close agreement with the present work.

5.4.7. Relative growth rate (RGR)

The RGR is a complex genetically controlled physiological component of yield (Wallace *et al.*, 1972). It is a derivative of the differences in drymatter accumulation and is not related to the yield, although it has relationships with the total dry matter produced (Krishnamurthy *et al.*, 1976). In the present study, RGR was found to be high at early stages and then declined towards flowering. The decrease in RGR was mainly attributed to the shedding of leaves when the plants advanced towards maturity. Tolerant genotypes recorded highest RGR than susceptible genotype. Among the tolerant genotypes, PMK 2 (AC 100% ASM) recorded the highest RGR followed by Norungan (AC 100% ASM) and lowest was recorded in susceptible variety CO 37 (50%ASM non induced). Water stress has been reported to reduce the

RGR in crop plants (Wallace and Munger, 1965; Seetharani, 1990; Gonzalez and Paez, 1996). The results of the present study was in confirmation with the above findings.

5.5. PHYSIOLOGICAL AND BIOCHEMICAL MECHANISMS OF WATER STRESS TOLERANCE

Adaptation to drought environments is the sum of traits expressed at various levels. In order to exploit metabolic pathways either as components of adaptations or as symptoms, first step is to describe the behaviour of crop species and cultivars with respect to metabolic responses to stress and to interpret the physiological significance of these responses. Metabolic responses might be 'adaptive' i.e. responses which favour growth and yield under stress, 'deleterious' i.e. responses which compound the stress and reduce survival; and 'incidental' i.e. responses which accompany stress and are essentially neutral in their effect.

In the present study, four water stress tolerant rice genotypes Norungan, Nootripattu, Varapukundanchan and PMK 2 and a susceptible genotype CO 37 were subjected to water stress. The results obtained are discussed in this section.

5.6. PHYSIOLOGICAL PARAMETERS

5.6.1. Pigments

5.6.1.1. Total chlorophyll content

Chlorophyll pigments play major role in plant productivity as it is the only pigment which is responsible for photosynthesis. Thus, its destruction under water stress is deleterious to plant productivity. Regardless of genotypes, water stress reduced chlorophyll content. In the present study, total chlorophyll was found to exhibit an increasing trend towards flowering. Total chlorophyll content decreased with increased water stress. Tolerant variety PMK 2 (AC 100% ASM) recorded the

highest total chlorophyll and lowest was recorded in susceptible variety CO 37 (50% ASM non induced). These findings were in conformity with the reports of Sheela and Alexander (1996).

5.6.2. Relative water content

RWC represents the ability of the genotypes to retain tissue water status under stress and the genotypes retaining more tissue water are expected to perform better. Significant reduction in RWC was noted under water stress. The tolerant genotypes however, maintained comparatively higher RWC than susceptible genotypes. This might be due to their low transpirational water loss as evident from their lower transpiration rate. Thangaraj and Sivasubramanian (1990) reported that the genotypes retaining more tissue water as indicated by higher RWC performed better under drought. In the present study, the susceptible genotype CO 37 recorded lowest RWC as compared to PMK 2, Norungan, Varapukudanchan and Nootripattu. The induced seedling performed better over non induced seedling by recording higher RWC over its control. These observations were in conformity with earlier reports (Krishnayya and Murty 1991; Lilley and Fukai, 1994a; and Chauhan *et al.*, 1996).

5.6.3. Transpiration rate

In the present study the tolerant genotypes recorded lower transpiration rate on account of their highest diffusive resistance. Thus, these genotypes might have reduced the water loss. The non induced seedling had high transpiration, compared to induced one. Tolerant variety Norungan recorded the lowest transpiration rate due to water stress tolerance nature and also highest diffusive resistance. Induced seedling indicated a lower transpiration rate by Induction treatment. Similar observations were also reported by Dingkuhn *et al.*, 1989a; and Chauhan *et al.*, (1996).

5.6.4. Leaf diffusive resistance

Data on leaf diffusive resistance revealed that the tolerant genotype PMK 2 registered highest diffusive resistance. Significant decrease in leaf diffusive resistance was noticed from transplanting stage to flowering stage. The induced seedlings recorded highest leaf diffusive resistance when it was compared with non induced seedlings under 75 and 50 per cent ASM. Higher leaf diffusive resistance in response to water stress is a characteristic behaviour of upland genotypes (O'Toole and Cruz, 1980) because of their higher stomatal sensitivity (Dingkuhn *et al.*, 1989a) and is a drought avoidance mechanism. These findings provided a valid support for the result obtained in the present study.

5.6.5. Leaf water potential

Under water limiting condition, genotypes which maintain the highest leaf water potential generally perform better. As expected, the mid-day leaf water potential gradually decreased from the time of creation of stress. Similar observations were reported by O'Toole and Moya (1978), Rao *et al.* (1994), and Lilley and Fukai (1994b). In the present study tolerant genotypes registered highest leaf water potential than susceptible genotype. Among the tolerant genotypes, Norungan recorded the highest leaf water potential and lowest was recorded by susceptible variety CO 37. Most rapid decline in leaf water potential observed in the susceptible variety CO 37 might be because of higher transpirational water loss. This was corroborated by earlier reports (O'Toole and Cruz, 1980; Ekanayake *et al.*, 1990; Lilley and Fukai, 1994c; and Boonjung and Fukai, 1996a).

5.7. BIOCHEMICAL PARAMETERS

5.7.1. Carbohydrate fractions

Carbohydrates are the photosynthetic products in green plants and the ability of plants to accumulate carbohydrates with its partitioning into economically useful parts determine yielding ability. In the present investigation, data showed increased accumulation of sugars while starch accumulation was reduced under water stress. Among the genotypes, tolerant genotype PMK 2 (50% ASM non induced) registered highest carbohydrate fractions and lowest was recorded by susceptible variety CO 37 (AC 100% ASM). Starch content was also high in tolerant variety PMK 2 (AC 100% ASM) and low in CO 37 (50% ASM non induced). The reduction was more in susceptible ones because of more utilization. Similar observations were reported by Sheoran and Saini (1996); Wang *et al.* (1996); and Jha and Singh (1997). These findings corroborated the present findings.

5.8. PROTEINS AND ENZYMES

5.8.1. Soluble protein

Rubisco accounts for about 50 per cent of soluble protein content. Chloroplasts contain approximately half of the total protein in leaves. Martignone *et al.* (1987) reported that soluble protein was the first nitrogenous compound lost under stress situation. In the present study revealed that water stress significantly reduced the soluble protein content. Tolerant genotypes PMK 2, Norungan and Nootripattu showed higher soluble protein content at flowering stage indicating the close association of this parameter with yield, as reported by Reddy and Vora (1985). Soluble protein content was more affected in susceptible variety CO 37 than tolerant genotypes. This observation was in conformity with the reports of Jha and

Singh (1997). The decline was associated with a concomitant increase in free amino acid and decreased NRase activity.

5.8.2. Nitrate Reductase activity (NRase)

The pathway of NO_3 assimilation is considered as the major route of conversion of inorganic N into a biologically useful organic form in plants. The primary step in NO_3 assimilation involves reduction of NO_3 to NO_2 catalysed by the enzyme NRase. Nitrite is subsequently reduced to NH_4^+ by the enzyme Nitrite reductase. These two enzymes reduce NO_3 to the end product NH_4^+ , which is then incorporated into aminoacids. Activity of NRase in plants gives a good estimate of the N status of plants and is very often correlated with growth and yield (Srivastava, 1980). The induced seedling performed better over non induced by recording higher of enzyme activity under water stress. In the present study, NRase activity was found to be reduced to a significant level by water stress and the susceptible genotype CO 37 was most affected. NRase enzyme activity showed its maximum at flowering stage. Among the genotypes, PMK 2 recorded the highest NRase activity and lowest was recorded susceptible variety CO 37. The induced seedling performed better over non induced by recording a less reduction of NRase enzyme activity under water stress. Similar observations were made earlier by Liu *et al.* (1993), Saxena *et al.* (1996) and Jha and Singh (1997). Further, relatively more NRase activity might allow the drought tolerant genotypes in enzymes recovery on subsequent drought relief as suggested by Sairam and Dube (1984).

5.8.3. Ascorbic acid oxidase activity

Levels of oxidised and reduced glutathion, NADPH and ascorbate content in plant cells are regulated by ascorbic acid oxidase. In the present study showed that

ascorbic acid oxidase activity increased with the increased intensity of water stress. Highest activity of this enzyme was noted in CO 37 and lowest activity was in PMK 2. Significant increase in Ascorbic acid oxidase activity was noted from transplanting stage to flowering stage. Higher AAO activity under water stress reduced ascorbic acid content which might be one of the cause for susceptibility to water stress.

5.8.4. Activated oxygen species (AOS) detoxifying enzymes

Decreasing water potential and stomatal closure resulted in activated oxygen species (Sgherri *et al.*, 1993). Increased photorespiration under water stress also elevate glycolate oxidase activity resulting in H_2O_2 production (Mittler and Zilinskas, 1994). Allen (1995) and Willekens *et al.* (1995) reported that activated oxygen species generation under water stress might be responsible for most of the damage caused to cellular components. Shigenaga *et al.* (1994) further reported that superoxide, peroxidase and hydroxyl radicals were highly reactive and were linked to degenerative diseases and ageing. The present study revealed that the AOS scavenging enzymes viz., catalase, peroxidase and SOD were over expressed under the water stress. regardless of genotypes. Further, AOS scavenging activity in drought tolerant genotypes were much higher than the susceptible check CO 37. This might be one of the reasons for the successful establishment of tolerant genotypes under water stress. These results were in conformity with the findings of Dhindsa and Matowe (1981) who reported that drought induced damage was negated with increasing activities of SOD and catalase. It was interesting to note that regardless of genotypes, the activity of AOS scavenging enzymes increased with the progress of water stress to a certain level and then started declining. Decline in activity of these enzymes during water stress started much earlier and more intensely in CO 37. This

observation indicated that these enzymes degraded at a higher rate in CO 37 under dehydration, while their synthesis might have been inhibited (Zhang and Kirkam 1994),. Ranjita *et al.* (1994) also reported similar observations

5.9. AMINO ACIDS

5.9.1. Proline

Proline accumulation under water stress may occur in different ways *viz.*, stimulation of synthesis from glutamic acid perhaps due to loss of feed back inhibition of the synthesis of the intermediate Δ^1 -pyroline-5-carboxylate; inhibition of proline oxidation, impaired incorporation of free proline into protein and reduced export of proline via phloem. Reasonable hypothesis based on the possible role of proline accumulation under water stress has been advanced as a nitrogen store, energy store, NH_3 -detoxification product and cytosolic osmoregulation. Results of the present study indicated that tolerant genotypes recorded highest proline accumulation than susceptible genotype. Among the genotypes PMK 2 (50% ASM non induced) recorded that highest proline content followed by Norungan (50% ASM non induced) and lowest was recorded in susceptible variety CO 37. Proline accumulation increases with increase in water stress. The increased proline production in tolerant genotypes may be due to, increased activity of pyrroline-5-carboxylase reductase and decreased level of its oxidative enzyme proline oxidase as suggested by Rus-Alvarez and Guerrier (1994). It was suggested that organic acids of oxidative respiration were the direct sources of proline accumulation in plants under stressful conditions. proline accumulation may also due to breakdown of proline rich protein or shift in metabolism (Singh and Singh, 1991). These observations could be confirmed in the present investigation.

5.10. Other metabolites

5.10.1 Ascorbic acid

Ascorbic acid is a part of AOS scavenging ascorbate peroxidase - glutathion reductase system. In the present study ascorbic acid content was reduced under water stress and was associated with the increase in ascorbic acid oxidase activity. Lowest ascorbic acid content was recorded in CO 37 which might have reduced its AOS scavenging ability under water stress and thus, AOS might have accumulated leading to susceptibility during water stress.

5.10.2. Total phenols

Diverse group of phenolic compounds are found in all plant parts. Phenols are known to regulate a range of growth and development processes in plants. Accumulation of total phenolics were observed in all the genotypes under water stress, highest accumulation being recorded in PMK 2 (50% ASM induced) followed by Norungan (50% ASM induced) and lowest was recorded in CO 37 (AC 100% ASM). Similar results were reported by Ashraf *et al.* (1994).

5.11. Total Drymatter Production (TDMP)

The TDMP was observed to increase as growth progresses with the result of increase in stem girth, thickness of leaves, root length and root volume. Due to treatments given, dry matter accumulation in rice cultivars decreased as leaf rolling and crop canopy to air temperature difference increased under moisture stress condition (Turner *et al.*, 1986) Simane *et al.* (1993) reported that the rate of TDMP varied in drought resistant and susceptible cultivars. The present study showed that tolerant genotypes recorded highest TDMP than susceptible genotype.

Among the tolerant genotypes PMK 2 (AC 100% ASM) registered the highest TDMP and lowest was registered by CO 37 (50% ASM non induced). Lilley and Fukai (1994b) reported that water stress reduced biomass production in rice genotypes and the degree of reduction depended upon the severity of moisture stress. Chauhan *et al.* (1996) reported that cultivars differed in their ability to produce drymatter under stress. They noted that 40.3 per cent and 67.3 per cent reduction in dry matter accumulation due to moisture stress in improved upland and traditional upland genotypes respectively. These observations were confirmed by the present investigation.

5.12. YIELD AND YIELD COMPONENTS

5.12.1. Tiller production

The number of tillers plant⁻¹ was found to be significantly affected by water stress irrespective of genotypes. However induced seedlings had more tillers and the non induced seedlings had the lowest number. Water stress tolerant variety PMK 2 showed highest tillers plant⁻¹ followed by Norungan during induction and lowest was recorded in CO 37. Upland adapted genotypes recorded lower tiller number per unit area. However, these genotypes were less affected by water stress. These observations were in confirmity with the reports of Vijayalakshmi and Nagarajan (1994). On the other hand, the unproductive tillers were found to be increased by water stress.

5.12.2. Panicle length

The panicle length showed a significant reduction due to water stress. Tolerant genotype PMK 2 was found to show least reduction due to water stress. The tolerant genotypes had fairly a long panicle under stress. It was in accordance with Saxena and Pandey (1981).

5.12.3. Filled grain percentage

Water stress affects pollen performance. Maurya and O'Toole (1986) found large genotypic variation in filled grain percentage during dry season. Reduction in the leaf water potential at anthesis caused poor panicle exertion (O'Toole and Namuco, 1983; Cruz and O'Toole ; 1984; Ekanayake *et al.*, 1989) and this increased the percentage of sterile spikelet because of pollination abnormalities. The number of filled grains showed a significant decline due to waterstress in all the genotypes. The yield reduction was due to decrease in the filled grains (Balasubramanian and Saktharam Rao, 1977). In the present study the induced seedling had high filled grain per cent and low ill filled grains however it was reverse for non induced one. This findings are inaccordance with earlier reports.

5.12.4. 1000 grain weight

The 1000 grain weight which was yet another important yield component, which showed significant reduction under water stress irrespective of the genotypes. Among the genotypes, induced one performed better over non induced. Tolerant genotypes showed a least decrement in 1000 grain weight due to stress, showing its tolerance nature, but it was reverse for susceptible genotype. The above finding was on par with the observations of Srivastava (1980).

5.12.5. Yield

The grain yield was found to be affected by water stress irrespective of genotypes (Yang *et al.* 1995a). Among the genotypes evaluated, PMK 2 induced showed least depression followed by Norungan. Yield depression mainly depended on the stage of growth as indicated by Pearson and Bernstein (1959). Fukai *et al.* (1991) reported that close relationship of grain yield under water stress with grain number, as grain weight was relatively stable across environments. Under upland condition

tolerant genotypes maintained stable yield under the adverse soil moisture regime and was linearly related to root density at depth of 25 cm (Liu *et al.*, 1993). Vijayalakshmi and Nagarajam (1994) reported that tolerant rice genotypes having well distributed rooting system had more stable grain yield under drought due to their ability to maintain a high leaf water potential at anthesis. Cruz and O'Toole, 1984; Ekanayake *et al.*, 1989; 1990 and Jayabalan *et al.* (1995) also reported that reduction in grain yield was less in tolerant genotypes under drought.

5.12.6. Harvest Index

The fraction of total dry matter produced by a crop which is harvested as yield is referred as harvest index (Donald, 1968). In the present study the harvest index showed a reduction due to water stress irrespective of genotypes, but induced ones had a low reduction compared with non induced. The genotype which recorded high yield resulted in the highest harvest index. Harvest index had a consistent association with grain yield in rice (Reuben and Katuli, 1990). Water stress reduced harvest index (Singh and Patel, 1995). Genotypes having greater tolerance to waterstress recorded higher number of grains, and grain weight per panicle, grain yield per plant and harvest index under drought (Saxena *et al.*, 1996). Thus the results of the present study suggested the possibility of increasing the existing yield level of rice is by employing this simple, cost effective and environment friendly technology.

5.13. MOLECULAR MECHANISMS OF WATER STRESS TOLERANCE (SDS-PAGE).

5.13.1. Study of protein profiles in water stress condition under induced and non induced condition

The results of SDS-PAGE protein profile displayed that qualitative and quantitative differences in proteins profile between induced and non-induced seedlings.

The observation of new protein (24 kDa) in PMK 2 induced seedling revealed that, this was a specific protein responsible for plants to drought tolerance. The same was reported by Djanaguiraman (2000) as "Osmotin". This was responsible in providing osmotic adjustment to the cells either by facilitating the accumulation of solutes or by providing certain metabolic attractions in the cell, which may be helpful in osmotic adjustment.

Appearance of 108 and 118 kDa protein were specific to PMK 2. These proteins might be constitutive of the tolerant genotypes as they appeared only in tolerant genotypes (PMK 2 and Norungan). An another group of protein (66 kDa) appeared in induced seedling alone. As such, they might be a LEA protein (Djanaguiraman, 2000). These proteins might have played a role in reducing cellular damage during water stress as suggested by Dure *et al.* (1989), and also maintenance of protein or membrane structure, sequestration of ions, binding of water and as molecular Chaperons (Blackman *et al.* 1991).

Another LEA protein, called dehydrin, RAB or D-11 has been identified as induced gene product in response to many stress conditions (Close, 1996).

5.14. ISOZYME

The focus of present investigation is to understand the mechanism of drought tolerance, at biochemical level by the antioxidant enzymes like catalase and peroxidase.

5.14.1. Catalase

There was a clear variation in intensity and banding pattern of catalase enzyme in induced and non-induced seedling. The isoform CAT 2 was specific to induced

seedlings of PMK 2 and Norungan. In CO 37 CAT 1 was specific to induced and non induced seedling. Presence of more number of isoform makes the induced seedling to survive under stress condition. The tolerant genotypes produced more isoforms proving its tolerance nature (Djanaguiraman, 2000).

5.14.2. Peroxidase

Differences in peroxidase isozymes were noticed among the genotypes both in intensity and banding pattern. The isoform POX was not expressed in the non-induced seedling. The reduction in isoform was also evidenced in susceptible genotypes. The appearance of specific isoform in specific genotypes was also observed. From this experiment, peroxidase appeared to be highly sensitive to water stress. Th tolerant cultivar (PMK 2 and Norungan) produced more isoforms comparing susceptible genotype (CO 37).

It has been reported that under stress condition, free radicals and H_2O_2 were produced (Kaberichaudhuri and Choudhuri, 1993) which may cause degradation of membranes and many cellular macromolecules. The enzymes peroxidase and catalase acted as scavenging enzyme destroying free radicals and H_2O_2 (Gango Padhyal *et al.*, 1996).

Thus presence of these enzyme in higher quantities was responsible for tolerance and the decline of isoforms in susceptible and non induced seedling was due to utilization of these enzymes for the accumulation of free radicals and H_2O_2 (Singha and Choudhuri, 1990).

With this scenario, it was confirmed that there existed clear cut polymorphism in isozyme pattern between tolerant and susceptible genotypes. These enzymes could be used as a biochemical marker for evaluating the genotypes for drought tolerance in rice. This conclusion was in accordance with the earlier report of Subal Maibangsa (1998).

Summary

SUMMARY

Water stress is the most important, serious abiotic factor, which limits rice productivity. Despite the fact that studies in drought stress have been carried out for a long time, the mechanism of water stress tolerance of plants is not yet fully understand. The present investigation was carried out with the following objectives:

1. To study the physiological, biochemical and molecular mechanisms of water stress tolerance in rice genotypes through induction response technique.
2. To identify parameters closely related to water stress tolerance.
3. To develop/identify suitable water stress tolerant genotypes in rice.

Fifteen genotypes viz., Norungan, Nootripattu, Varapukudanchan, PMK 1, PMK 2, IR 20, ADT 36, ADT 39, ASD 16, ASD 18, TPS 1, TPS 2, TKM 9, TKM 10 and CO 37 were collected From Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore and Agricultural Research Station, Paramakudi were used for these study. The results of the various experiments are summarized below:

Norungan, PMK 2 and CO 37 were used for fixing sublethal and lethal dose for drought stress. It was inferred that out of 3 concentration (-0.50, -0.75 and -1.0 MPa) - 0.5 MPa was found to be sublethal and -1.0 MPa as lethal.

The effect of induction was assessed by using -0.5 MPa as induction dose and -1.0 MPa as lethal dose in above said fifteen varieties. It was found that Norungan showed good response followed by PMK 2, Nootripattu and Varapukudanchan.

Varieties showing high degree of tolerance in terms of high germinability under drought stress were identified in the laboratory as best germinator by normal method. Besides high germination they showed minimum reduction in root length and shoot length under water stress. Norungan and PMK 2 were identified as best germinators.

Under pot culture, investigation were concentrated to increase the drought tolerance by induction response technique. It was associated with yield improvement. In general, for all the characters induced seedling performed better over non induced seedling showing its acquired tolerance. It was found that the per cent decrease in grain yield due to drought was low in PMK 2, followed by Norungan. This indicated that the variety PMK 2 was tolerant to drought stress. In depth studies on growth, physiological and biochemical basis indicated that the drought had a significant reducing effect on shoot height. On the other hand, the root length was found to be slightly decreased due to drought irrespective of the varieties. TDMP was found to be affected by drought. The number of tillers and leaf area, leaf number and root volume were reduced much in susceptible variety namely CO 37.

All the biometric observation were found to be affected by drought. LAI, LAD, SLA, SLW, NAR, CGR and RGR were found to be reduced. The tune of reduction was low in PMK 2, whereas high in CO 37.

The total chlorophyll content were found to be reduced due to drought in almost all the varieties. PMK 2 showed comparatively less reduction than Norungan, Nootripattu, Varapukudanchan and CO 37.

The decrement in transpiration due to drought was low in PMK 2 and Norungan. The same trend was observed for RWC, Leaf water potential and Leaf diffusive resistance.

Higher amount of total sugar and reducing sugars were found in induced seedling than with non-induced seedling. PMK 2 and Norungan had more carbohydrate fractions than the susceptible variety namely CO 37, whereas starch content reduced due to drought in all the genotypes.

The drought tolerant variety PMK 2 had higher soluble protein and nitrate reductase enzyme activity particularly at flowering stages. The AOS enzymes namely catalase, peroxidase and superoxide dismutase were found to increase due to drought stress in all the varieties. The increase was more in induced seedlings than non induced seedlings.

The proline, total phenols and ascorbic acid oxidase enzyme increased due to drought in all the varieties. The increment was more in induced seedling compared to non-induced seedlings.

In drought stress situation the ascorbic acid content was found to be affected. Stress shock proteins were synthesized in tolerant genotype (PMK 2), which were responsible for its survival and higher yield. Presence of isoforms of catalase and peroxidase in genotype PMK 2 might be responsible for its water stress tolerance.

The water stress was found to affect the yield components *viz.*, the number of productive tillers, filled grain percentage, panicle length, thousand grain weight. Apart from these the TDMP and harvest index were reduced due to water stress. The decrease was lower in tolerant genotype (PMK 2) compared to susceptible control (CO 37).

From the present study, it was inferred that, induction response had increased the drought tolerant in tolerant genotypes namely PMK 2, Norungan, Nootripattu and Varapukudanchan. The susceptible namely CO 37 had performed well, when it was induced because during induction, the seedlings were well preconditioned for the ensuing drought situation. The above said desirable characters might be responsible for the high water stress tolerance and a significant increase in the yield of induced plant than the non induced ones. This induction Response Technique appears to be a simple and viable technology for increasing the water stress tolerance of rice.

Plates

INDUCTION RESPONSE OF RICE SEEDLINGS TO WATER STRESS (*Norungan, Nootripattu & Varapukudanchan*)

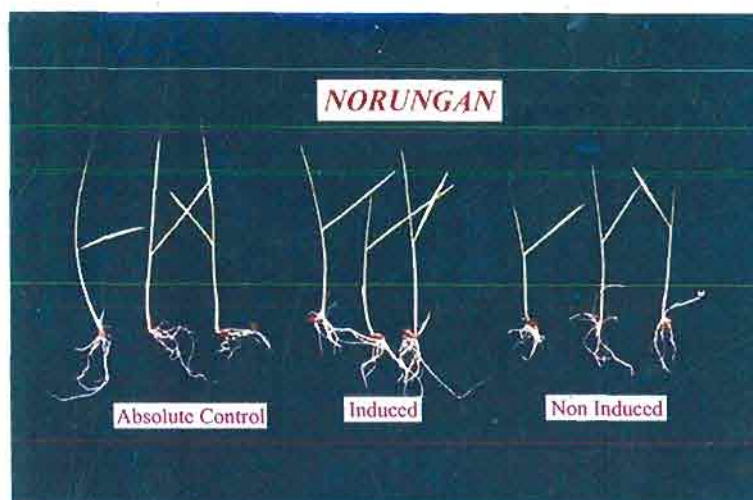


Plate 1.

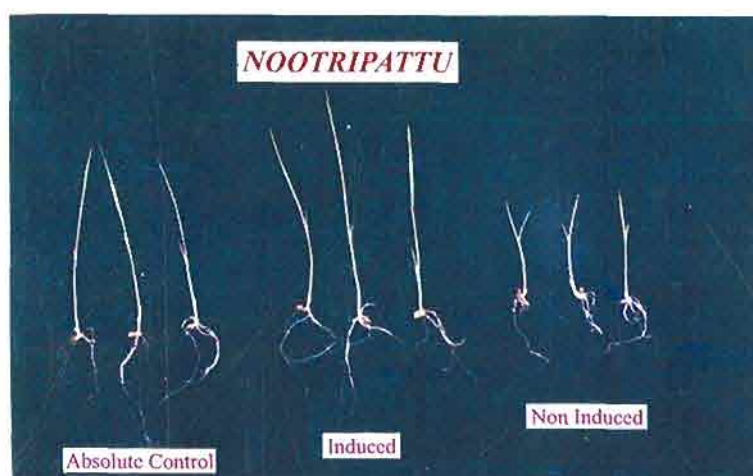


Plate 2.

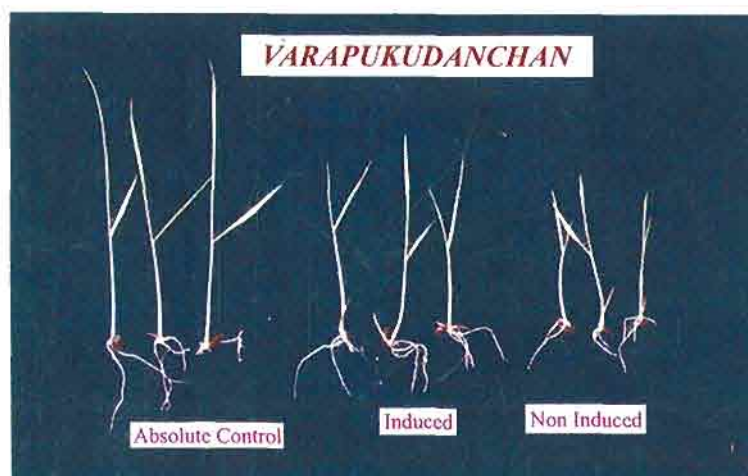


Plate 3.

Induced : 0.5 MPa $\rightarrow$ -1.0 MPa
(16 hrs.) (48 hrs.)

Non Induced : -1.0 MPa
(48 hrs.)

INDUCTION RESPONSE OF RICE SEEDLINGS TO WATER STRESS (PMK 2 & CO 37)

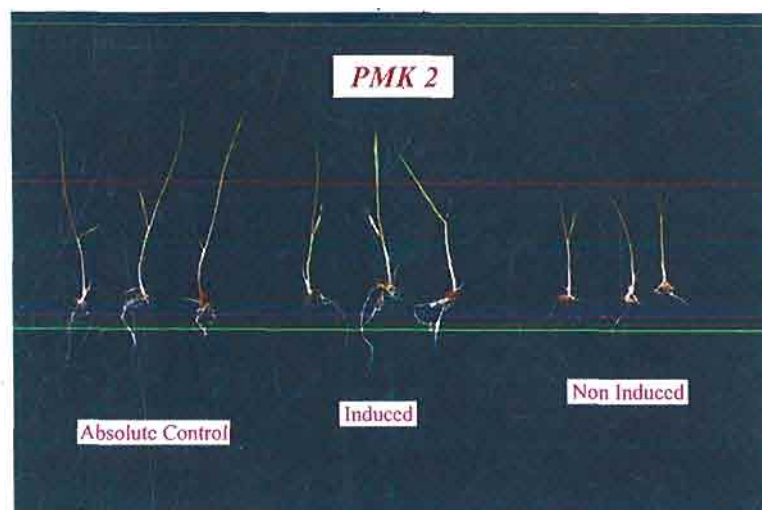


Plate 4.

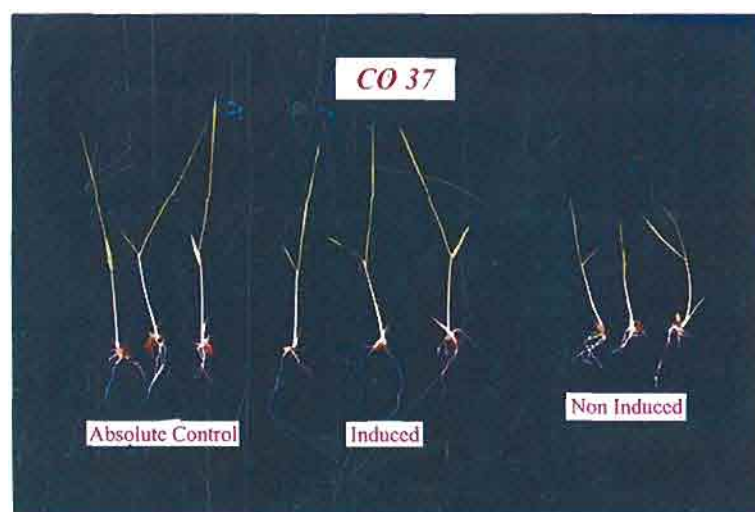


Plate 5.

Induced : -0.5 MPa → -1.0 MPa
(16 hrs.) (48 hrs.)

Non Induced : -1.0 MPa
(48 hrs.)

RICE GENOTYPES IN THE GLASS HOUSE CONDITION



Plate 6.

MEASUREMENT OF LEAF WATER POTENTIAL USING PRESSURE CHAMBER (Soil Moisture Equipment Corp., Santa Barbara, CA 93105, U.S.A.)



Plate 7.

MEASUREMENT OF LEAF DIFFUSIVE RESISTANCE AND TRANSPIRATION RATE IN THE GLASS HOUSE USING STEADY STATE POROMETER (LICOR 1600)



Plate 8

EFFECT OF WATER STRESS ON ROOT LENGTH OF INDUCED AND
NON INDUCED RICE GENOTYPES AT PANICLE INITIATION STAGE
(*Norungan*, *Nootripattu* & *Varapukudanchan*)

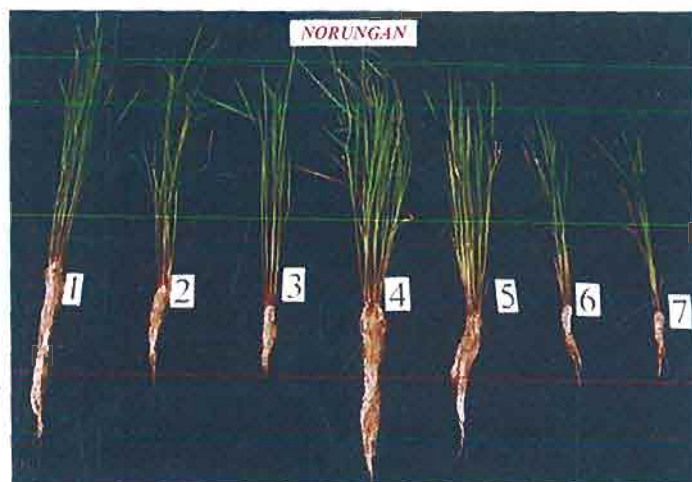


Plate 9.

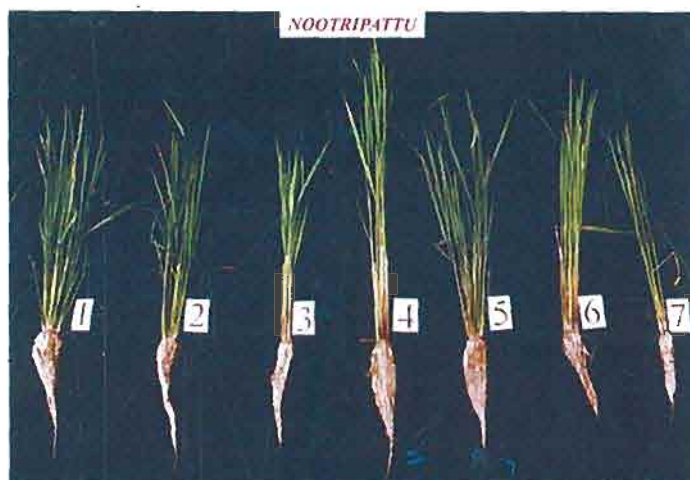


Plate 10.

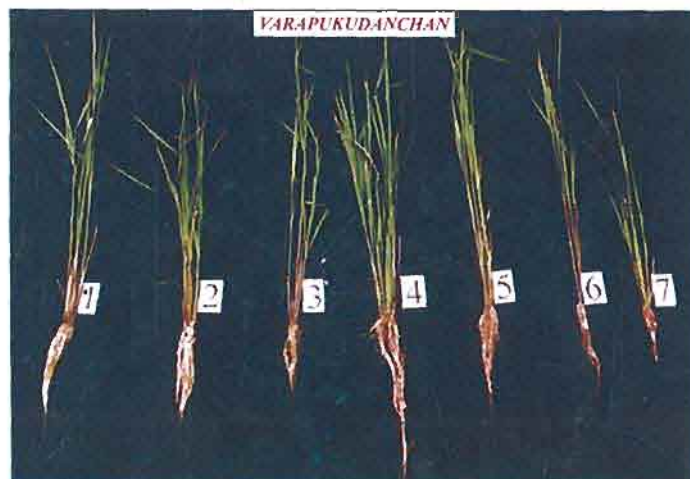


Plate 11.

1 - Absolute Control 100% Available Soil Moisture
2 - 75% Available Soil Moisture
3 - 50% Available Soil Moisture

4 - 75% Available Soil Moisture Induced
5 - 50% Available Soil Moisture Induced
6 - 75% Available Soil Moisture Non Induced

EFFECT OF WATER STRESS ON ROOT LENGTH OF INDUCED AND
NON INDUCED RICE GENOTYPES AT PANICLE INITIATION STAGE
(PMK 2 & CO 37)

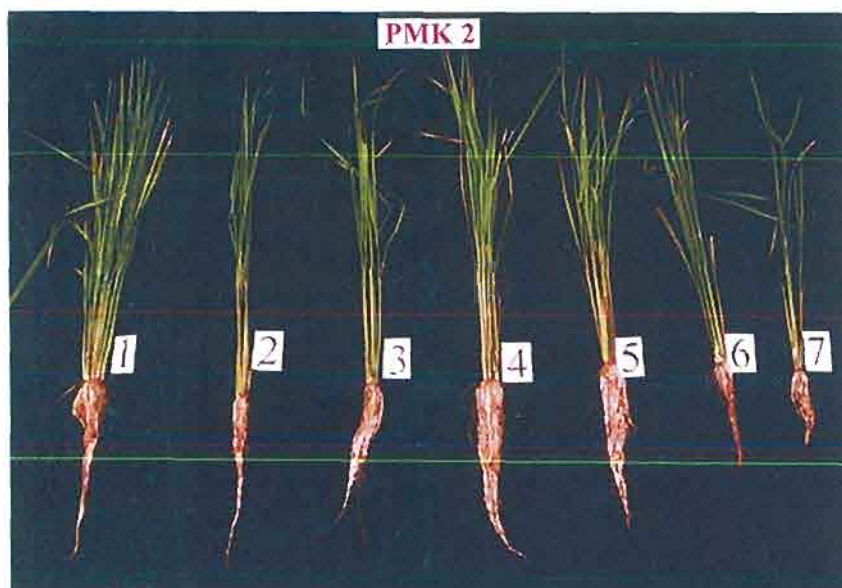


Plate 12.



Plate 13.

1 - Absolute Control 100% Available Soil Moisture
2 - 75% Available Soil Moisture
3 - 50% Available Soil Moisture

4 - 75% Available Soil Moisture Induced
5 - 50% Available Soil Moisture Induced
6 - 75% Available Soil Moisture Non Induced
7 - 50% Available Soil Moisture Non Induced

EFFECT OF WATER STRESS ON ROOT LENGTH OF INDUCED AND
NON INDUCED RICE GENOTYPES AT PANICLE INITIATION STAGE
(PMK 2 & CO 37)

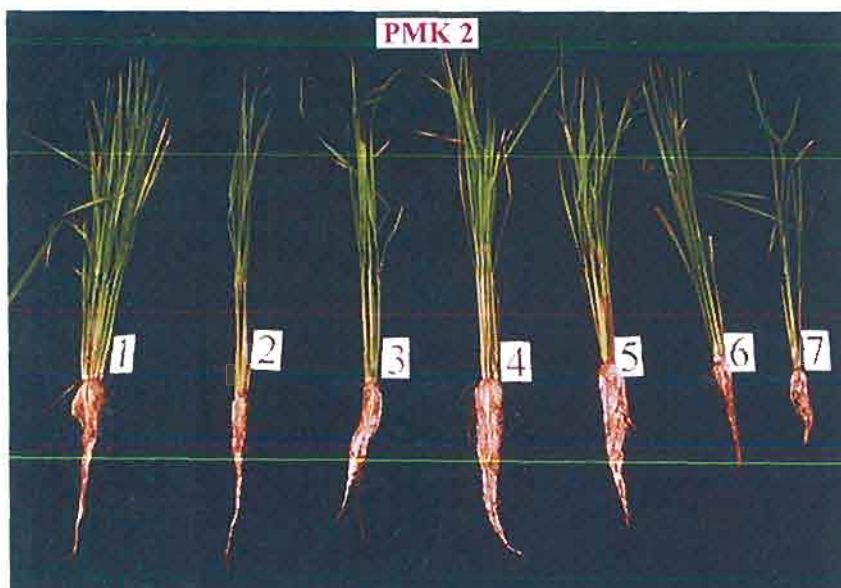


Plate 12.



Plate 13.

1 - Absolute Control 100% Available Soil Moisture
2 - 75% Available Soil Moisture
3 - 50% Available Soil Moisture

4 - 75% Available Soil Moisture Induced
5 - 50% Available Soil Moisture Induced
6 - 75% Available Soil Moisture Non Induced
7 - 50% Available Soil Moisture Non Induced

EFFECT OF WATER STRESS ON PLANT HEIGHT OF NORUNGAN SEEDLINGS AT PANICLE INITIATION STAGE

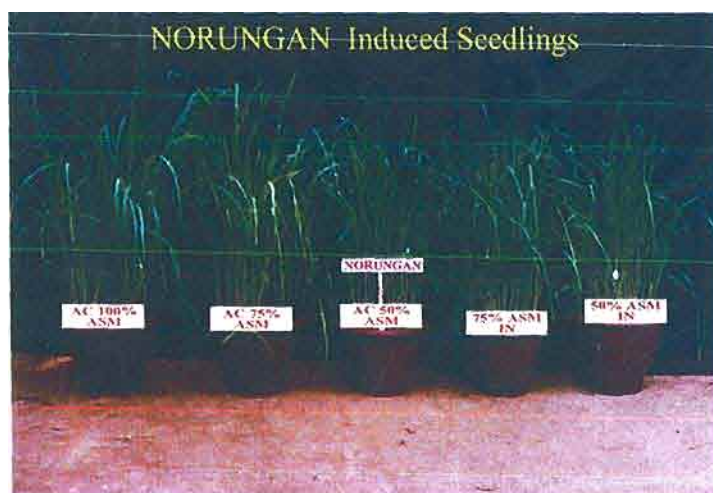


Plate 14.

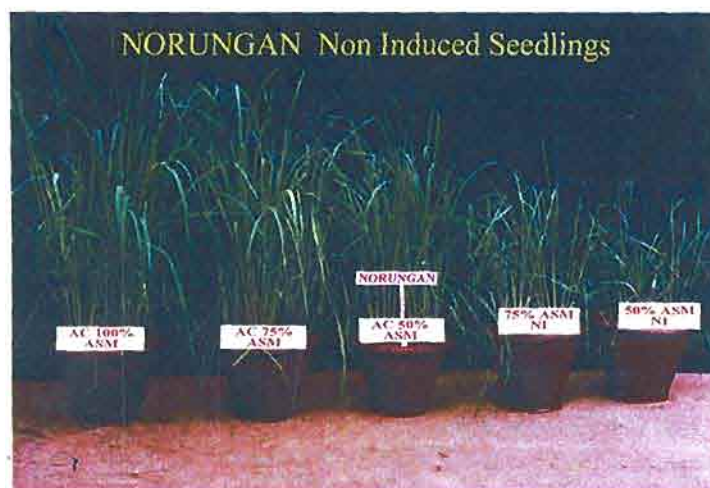


Plate 15.

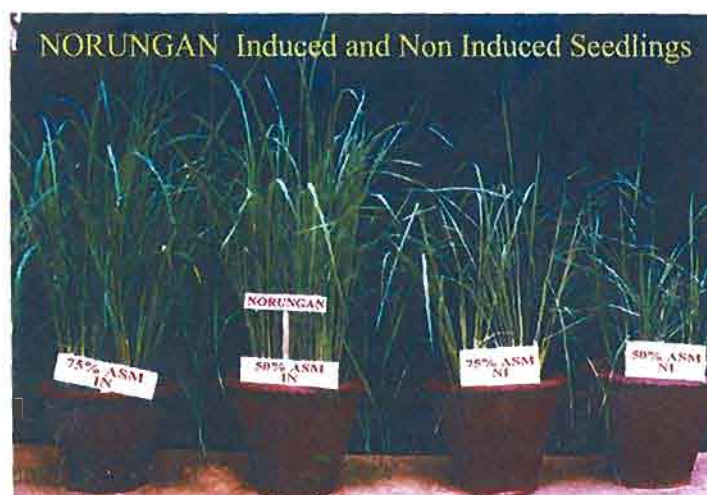


Plate 16.

EFFECT OF WATER STRESS ON PLANT HEIGHT OF • NOOTRIPATTU SEEDLINGS AT PANICLE INITIATION STAGE



Plate 17.

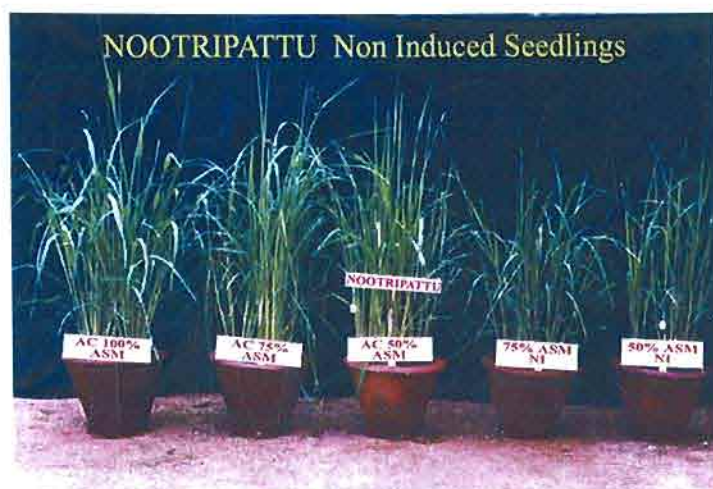


Plate 18.

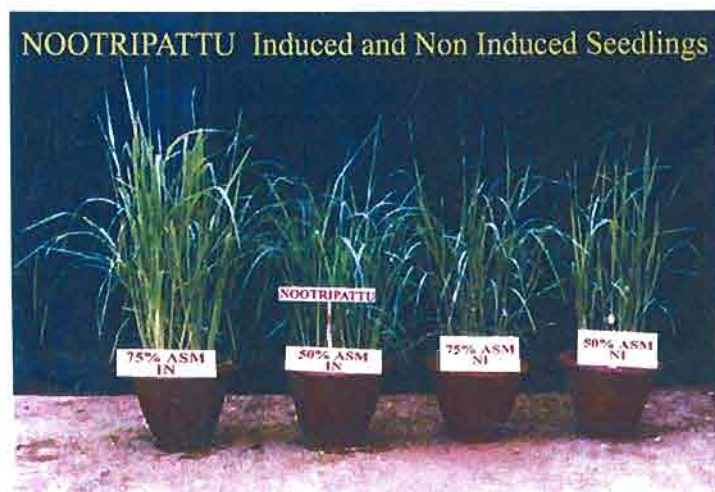


Plate 19.

EFFECT OF WATER STRESS ON PLANT HEIGHT OF VARAPUKUDANCHAN SEEDLINGS AT PANICLE INITIATION STAGE



Plate 20.



Plate 21.



Plate 22.

EFFECT OF WATER STRESS ON PLANT HEIGHT OF PMK 2 SEEDLINGS AT PANICLE INITIATION STAGE

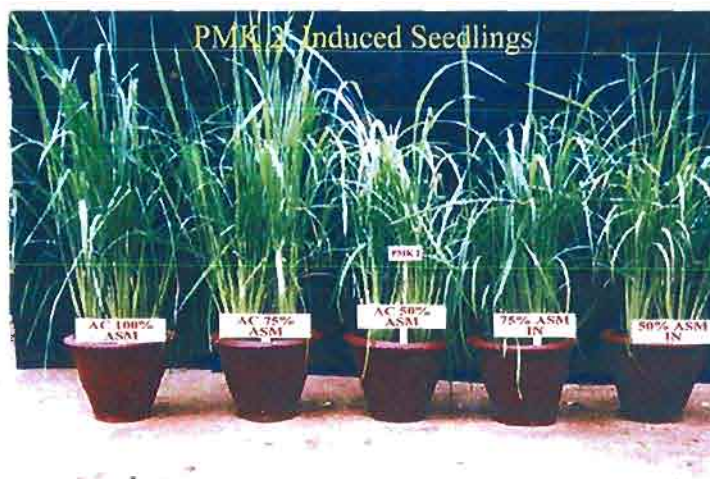


Plate 23.

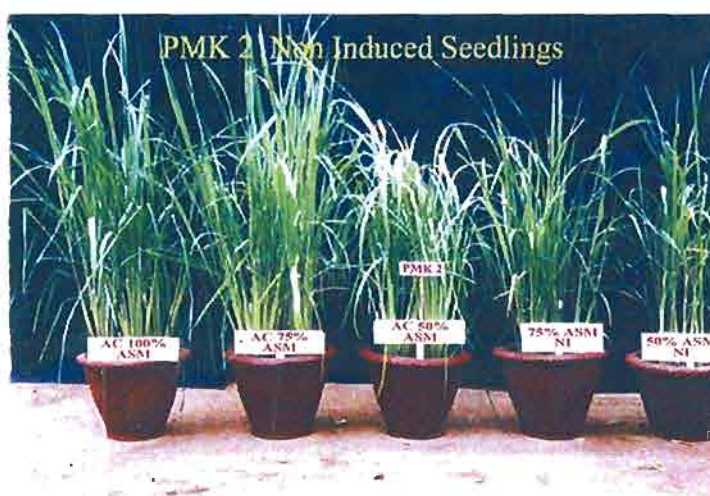


Plate 24.

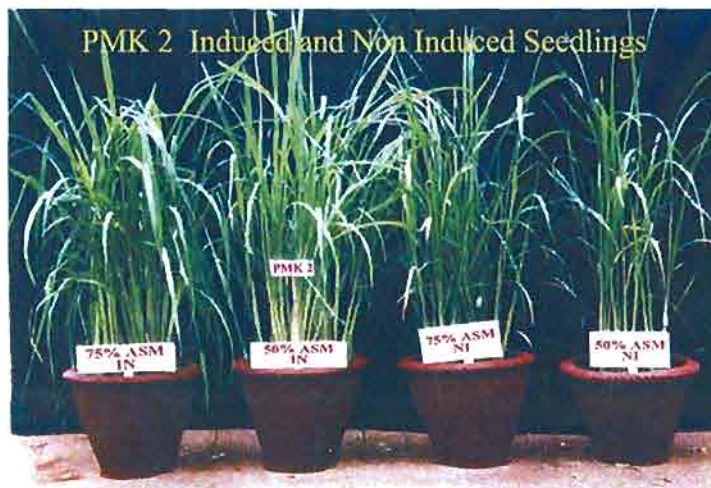


Plate 25.

EFFECT OF WATER STRESS ON PLANT HEIGHT OF CO 37 SEEDLINGS AT PANICLE INITIATION STAGE

CO 37 Induced Seedlings



Plate 26.

CO 37 Non Induced Seedlings



Plate 27.

CO 37 Induced and Non Induced Seedlings



Plate 28.

Soluble protein profile (12% SDS-PAGE) of Norungan (75% ASM)

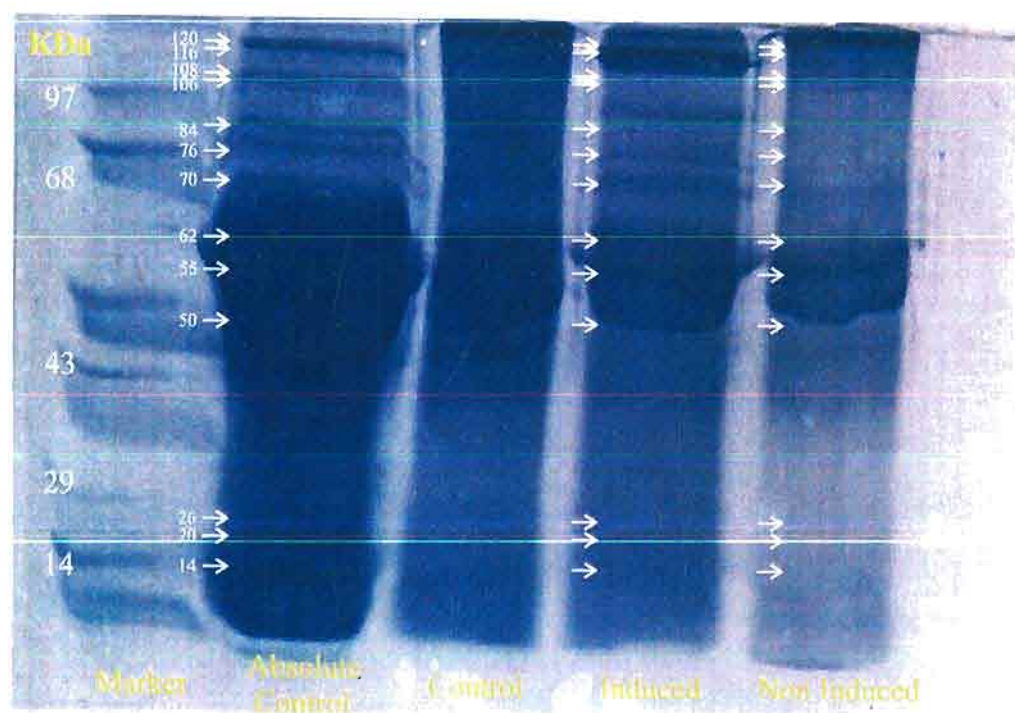


Plate 29.

Soluble protein profile (12% SDS-PAGE) of Norungan (50% ASM)

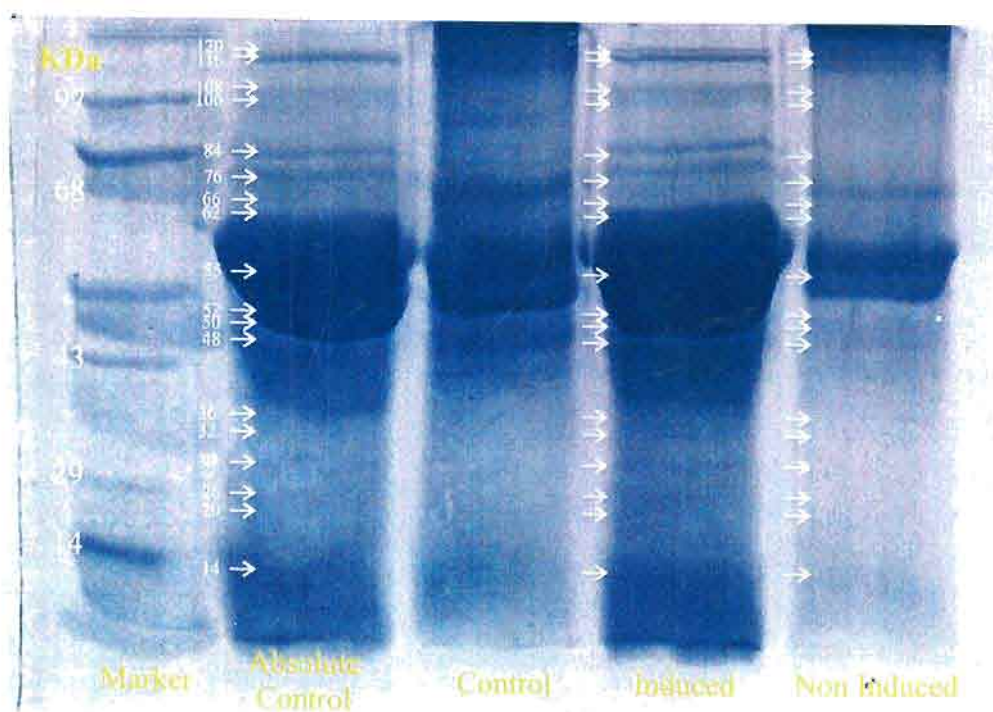


Plate 30.

Soluble protein profile (12% SDS-PAGE) of PMK 2 (75% ASM)

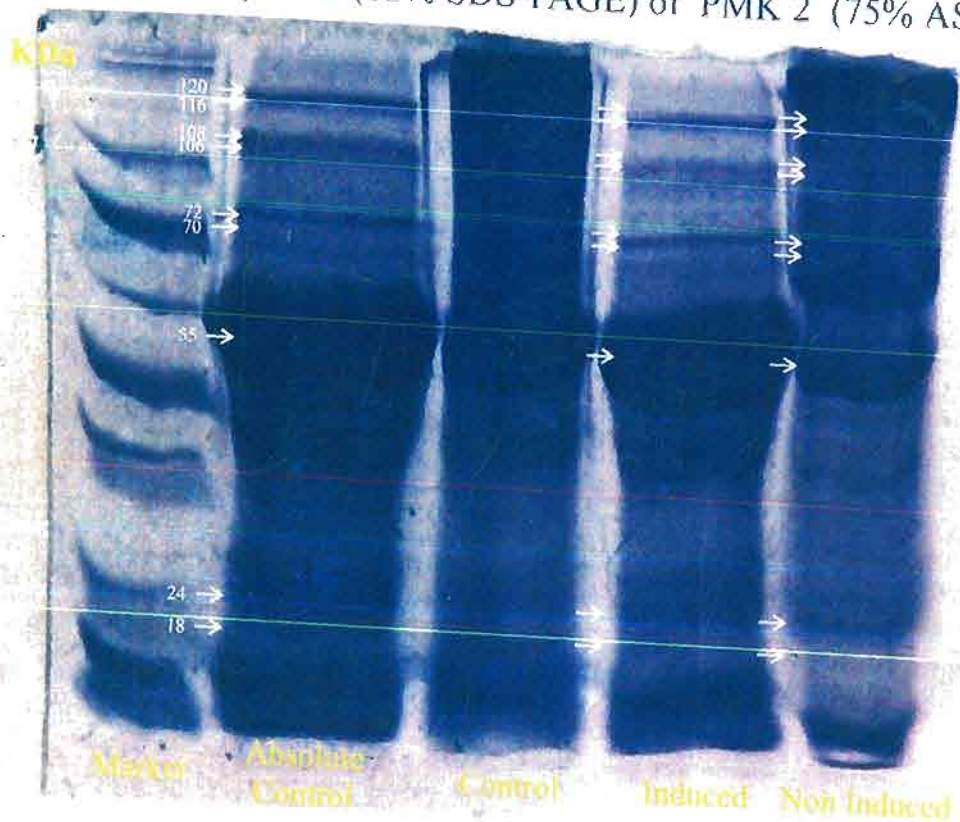


Plate 31.

Soluble protein profile (12% SDS-PAGE) of PMK 2 (50% ASM)

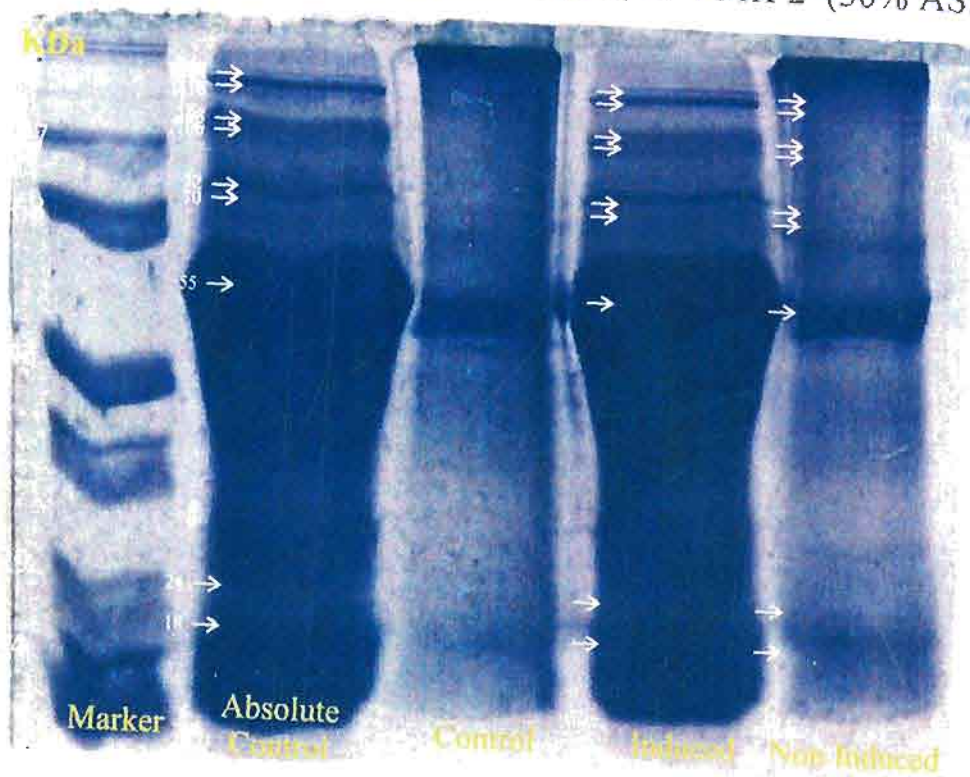


Plate 32.

Soluble protein profile (12% SDS-PAGE) of CO 37 (75% ASM)

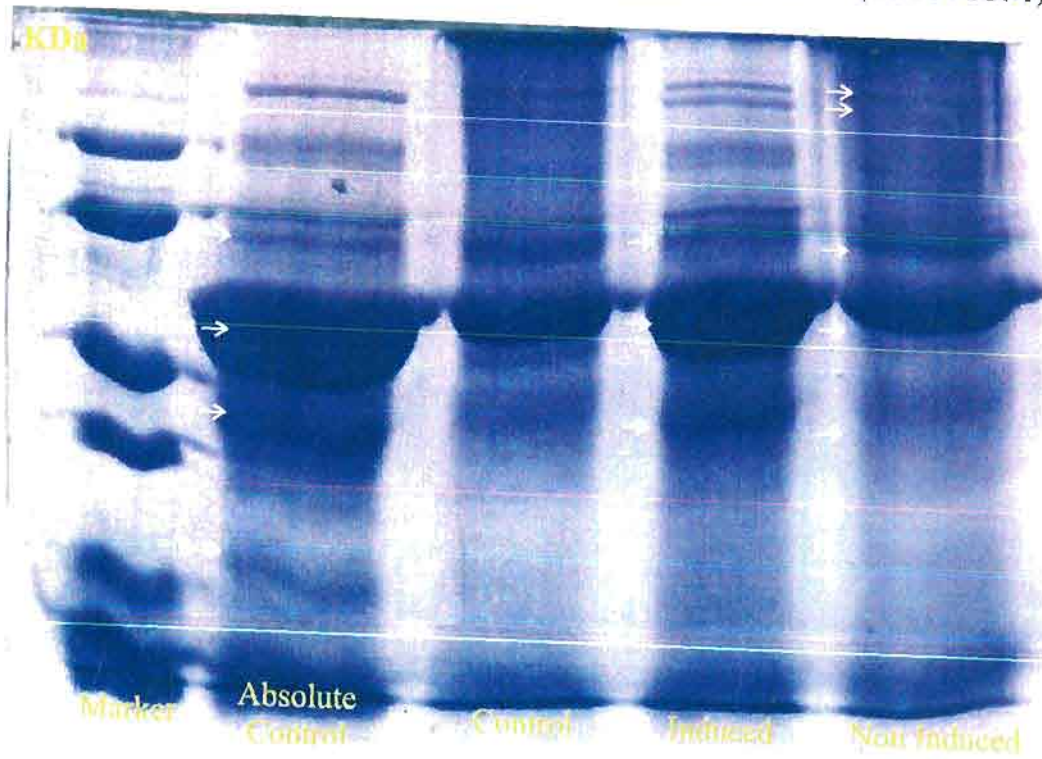


Plate 33.

Soluble protein profile (12% SDS-PAGE) of CO 37 (50% ASM)

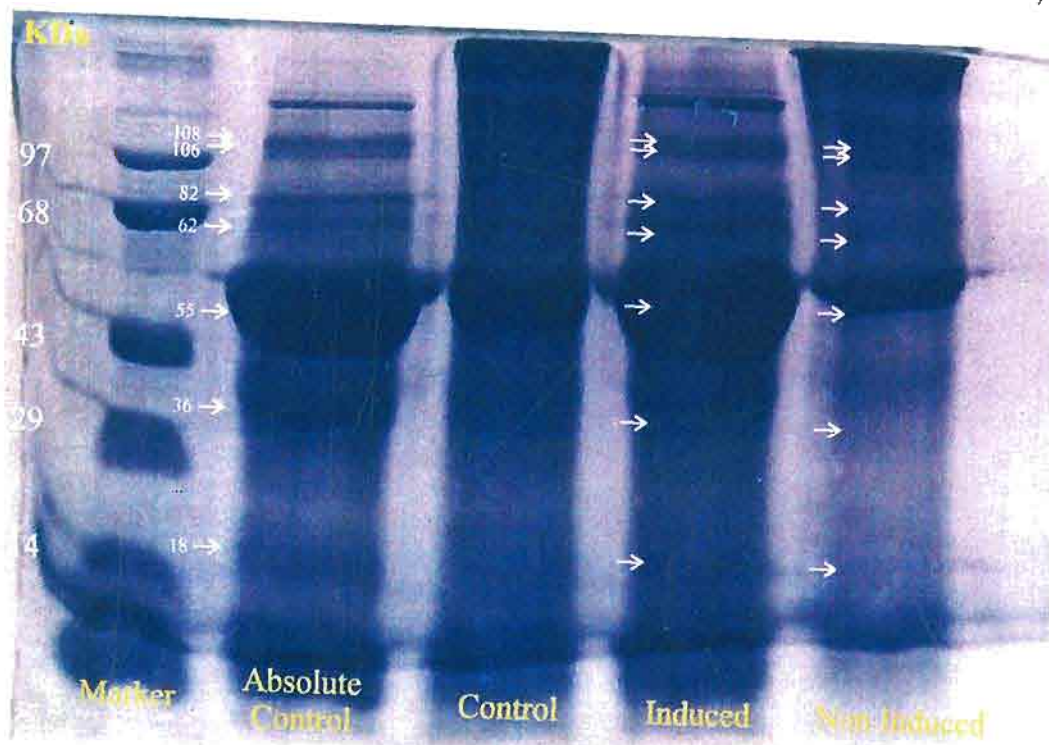


Plate 34.

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