

**EFFECT OF SEED PRIMING ON GERMINATION, GROWTH AND YIELD OF
RICE UNDER SALT STRESS CONDITION**

Thesis submitted in part fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY (AGRICULTURE) IN SEED SCIENCE AND TECHNOLOGY
to the Tamil Nadu Agricultural University, Coimbatore – 641 003

By

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I.D.No. 09-813-003

**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE – 641 003**

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CERTIFICATE

This is to certify that the thesis entitled “**EFFECT OF SEED PRIMING ON GERMINATION, GROWTH AND YIELD OF RICE UNDER SALT STRESS CONDITION**” submitted in part fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) IN SEED SCIENCE AND TECHNOLOGY** to the Tamil Nadu Agricultural University, Coimbatore, is a record of *bonafide* research work carried out by Mrs. N. PUNITHAVATHI under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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(N.PUNITHAVATHI)

Abstract

ABSTRACT

EFFECT OF SEED PRIMING ON GERMINATION, GROWTH AND YIELD OF RICE UNDER SALT STRESS CONDITION

By

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**Degree : Doctor of Philosophy (Agriculture) in
Seed Science and Technology**

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A study was conducted with rice varieties TNAU Rice TRY 3 and I.W.Ponni to standardize suitable seed priming treatment and to study its effect on germination, growth and yield of rice under sodic and saline stress environments.

To standardise a suitable seed priming treatment for rice, the seeds of TNAU Rice TRY 3 and I.W.Ponni were primed with CaCl_2 , CaSO_4 , ZnSO_4 , FeSO_4 , *Pseudomonas fluorescens*, *Azophos* and Pungam leaf extract at 0.5 and 1.0 % each and with GA_3 , IBA at both 10 and 20 ppm concentrations for 12 and 18h soaking durations. The results revealed that seed priming with *Azophos* 1.0%, ZnSO_4 1.0 %, GA_3 20ppm, *Pseudomonas fluorescens* 1.0%, CaSO_4 1.0 % and FeSO_4 1.0% for 18h could be recommended as suitable priming treatments for enhancing germination and vigour of rice.

The best performing treatments from the standardisation experiment were further evaluated in combination by imposing sodicity stress levels of 25 and 50 mM with NaHCO_3 and salinity stress levels of 50, 100 and 150 mM with NaCl along with untreated control. The results of the investigation revealed that, with increasing concentration of the salts, the germination percentage, seedling growth and vigour index were drastically decreased.

Between two varieties, TNAU Rice TRY 3 showed high degree of tolerance with high germination and seedling vigour under both stress conditions.

The performance of the priming treatments varied with stress levels. Regarding sodicity, 50 mM stress level had an adverse effect on seed germination showing 30 and 33 mean per cent reduction over control in both TNAU Rice TRY 3 and I.W.Ponni varieties, respectively.

The seeds primed with 1 % mixture of $KCl + CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + *Azophos* 1 % + *Pseudomonas fluorescens* 1 % recorded 14 and 15; 15.3 and 14.5; 36 and 44; 37 and 27 and 46 and 47.2 per cent mean increase over control, respectively for seed germination, root length, shoot length, dry matter production and vigour index of TNAU Rice TRY 3 and I.W.Ponni.

The same trend was also observed under salinity stress condition. At higher salinity level of 150 mM the reduction in germination from 94 to 66 % and 92 to 62 %; root length from 20 to 8.8 cm and 19.1 to 7.4cm; and shoot length from 14.3 to 7.4 cm and 14.1 to 6.6 cm were recorded in both varieties, respectively.

Since the results of above experiment revealed the severe impact on germination and seedling growth at 25mM sodicity as well as at 150mM salinity among various levels of sodicity (0, 25 and 50mM) and salinity (50,100 and 150mM) tested. Hence, the stress levels were further refined and fine tuned as (0, 14, 16 and 18 mM of sodicity and 125, 150 and 175mM of salinity) for evaluating the performance of seed priming treatments on alleviating the effect of stresses.

The seed quality and vigour could be maintained under 18 mM sodicity level and 100 mM salinity level in both the varieties, respectively. Above which seedling vigour were drastically reduced. To assess the impact of different priming treatments on mitigating the adverse effects of sodicity and salinity stress, a field study was conducted under both soil conditions. TNAU Rice TRY 3 and I.W.Ponni were imposed with seed priming treatments along with foliar spray of 0.5% $ZnSO_4$, 0.5% $FeSO_4$, 2% DAP and 2 % cowpea pulse sprout extract at active tillering and panicle initiation stages.

Under sodicity condition, the seeds primed with 1% mixture of $CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + *Azophos* 1% along with 0.5 % foliar spray of $ZnSO_4$ found to record seed yield of 6253 and 5263 kg ha⁻¹ in TNAU Rice TRY 3 and I.W.Ponni, respectively which accounted 15.8 and 14.9 per cent increase over control (5396 and 4580 kg ha⁻¹ in TNAU Rice

TRY 3 and I.W.Ponni, respectively). Whereas, in salinity condition the seeds primed with 1% mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1% + *Pseudomonas fluorescens* 1% along with 2 % cowpea pulse sprout extract recorded higher seed yield of 6088 and 5027 kg ha⁻¹ in TNAU Rice TRY 3 and I.W.Ponni, respectively, and it was 15.1 and 13.6 per cent increase over control which recorded the seed yield of 5290 and 4424 kg ha⁻¹.

The biochemical constituents such as proline content, chlorophyll, chlorophyll stability index and soluble protein content were improved by priming cum foliar spray treatments. The similar results were also observed in accelerating the activity of enzymes viz., nitrate reductase, catalase and peroxidase.

Therefore, it is concluded that seed priming with 1 % mixture of CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos1% along with 0.5 % foliar spray of ZnSO₄ under sodicity condition and 1% mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos1% + *Pseudomonas fluorescens* 1% along with 2 % cowpea pulse sprout extract spray under salinity condition at active tillering and panicle initiation stages effectively enhanced the overall efficiency of the crop and improved the yield in both tolerant and sensitive varieties of rice grown under salt stress conditions.

Introduction

CHAPTER I

INTRODUCTION

Rice is grown in more than 154 million hectares in the world in a wide range of ecosystems under varying temperatures and water regimes in India and it occupies an area of 44 million hectares. While the population of rice consumers is increasing at a rate of 1.8 per cent annually, the population grows at a rate of 1.5 per cent every year. Hence, the rice requirement by the year 2025 would be about 125 million tons (Mahendra Kumar *et al.*, 2009).

A total of 800 million hectares of land throughout the world are salt affected either by salinity (397 million hectares) or by sodicity (434 million hectares). In Asia alone, 21.5 million hectares of land area is thought to be salt affected, of which 12 million hectares is due to saline and the remaining 9.5 million hectares is due to alkaline / sodic conditions. In India, approximately 8.6 million hectares of agricultural land is affected by varying degrees of salt related problems and of which about 3.4 million hectares is under sodic soils. The problems of soil sodicity, salinity and of poor quality water are likely to increase in near future. (Chandan sahi *et al.*, 2006). The estimates indicate that the salt affected soils will constitute nearly 13 million hectares area in the country by 2025 (CSSRI, Vision).

Soil salinity has become a severe threat to ensure food security in the developing world. Increasing salinity had significant impact on food production and more agricultural lands are expected to become salt affected due to climate change effect (Rengasamy, 2006). Cereals contribute mainly to food production and growing grain crops on saline soils require adoption of different strategies for sustainable crop production.

Rice is susceptible to salt stress (Munns and Tester, 2008) particularly during the early seedling stage (Li and Xu, 2007). Salinity affects the seed germination by creating osmotic stress due to reduced water uptake or through ionic imbalance due to toxic effects of sodium (Na^+) and chloride (Cl^-) ions (Hosseini *et al.*, 2003). Salinity also upsets plant hormone level and reduces the utilization of seed reserves (Ahmad and Bano, 1992). Salinity induced stress inhibited seed germination constraints to achieve uniform seedling stand in rice (Almansouri *et al.*, 2001) and ultimately diminishes economic yield and quality of produce (Ali *et al.*, 2004). Rice is sensitive especially at young seedling stage, where varying degree of mortality occurs at 50 mM NaCl and about 50% of 14 days old seedlings may die in most

salt sensitive varieties within ten days of salinity stress (Flowers and Yeo, 1981). Efficient strategies are required for effective utilization of saline lands for crop growth. Improvement of salinity tolerance in crop species is one potential strategy in overcoming salinity problems in agriculture (Flowers, 2004; Yamaguchi and Blumwald, 2005). Development of salt tolerant plants through conventional breeding programs is very slow due to the complexity of salt tolerance and lack of reliable traits for selection (Yamaguchi and Blumwald, 2005). Nonetheless, exogenous application of osmolytes, osmoprotectants or plant hormones through foliar or seed is a good option to alleviate the adverse effects of salinity stress on crops (Ashraf *et al.*, 2008).

Higher production and productivity of crop is possible only through use of good quality seeds and proper management practices. Good quality seeds imply vigour, uniformity and structural soundness besides its genetic and physical purity.

The physiological treatments of seeds have not been widely exploited in contrast to the pervasive uptake of crop protectant applied to the seeds. An invigourtion treatment should bring about qualitative improvement in the seed, which should persist after the treatment is withdrawn and the treatments are basically physiological in nature.

To provide higher quality seeds, many researchers have developed new technologies called “Seed Enhancement Techniques”. The main objective of this technique is to optimize the application of seed treatment products by improving the technical quality of seeds. In the last two decades, seed priming, an effective seed invigouration method, has become a common seed treatment to increase the rate and uniformity of emergence and crop establishment in most vegetable and flower crops especially in advanced countries.

Seed priming is a controlled hydration process that involves exposing seeds to low water potentials that restrict germination, but permits pregerminative physiological and biochemical changes to occur (Heydecker and Coolbear, 1977; Bradford, 1986; Khan, 1992). Upon rehydration, primed seeds may exhibit faster rate of germination, more uniform emergence, greater tolerance to environmental stresses, and reduced dormancy in many species (Khan, 1992).

Heydecker (1973) used different terms depending upon the method adopted for priming, namely (i) hydropriming - soaking the seeds in water, (ii) osmopriming - soaking the seeds in osmotic solution, (iii) halopriming - soaking the seeds in salt solutions, (iv) biopriming - coating the seeds with biological agents like bacteria and (v) solid matric priming - mixing the seeds with an organic or inorganic carrier and water for a specific period of time. The moisture content of the

matrix is brought to a level just below which is required for radicle or plumule protrusion. Seed water potential is regulated by the matric potential of the seed. During priming, water is largely held by the carrier, but seeds can imbibe water from the carrier only till the equilibrium is reached.

Several literatures (Murungu *et al.*, 2004; Basu *et al.*, 2005; Rashid *et al.*, 2006; Windauer *et al.*, 2007; Afzal *et al.*, 2008) revealed that seed priming could advance germination, improve the initial quality characteristics, improve field emergence, better establishment, crop stand and increase yields in many diverse environments.

The causes for the invigouration effect might be due to biochemical and molecular changes that happen within the seed as exposing them to various management techniques (Sunitha and Bradford, 2001)

Seed priming, a controlled hydration process followed by re-drying is pragmatic approach to counteract the salinity effects in many crops because of its simplicity, low cost and effectiveness (Wahid *et al.*, 2007; Afzal *et al.*, 2011)

Priming treatments are being used to shorten the time between planting and emergence and to protect seeds from biotic and abiotic factors during critical phase of seedling establishment. Such earlier and synchronized emergence often leads to uniform stands and improved yield (Farooq *et al.*, 2006b; Afzal *et al.*, 2006; Afzal *et al.*, 2011).

Many crops are susceptible to seed and seedling decay caused by soil-inhabiting fungi or by pathogens carried on the seed. Biological seed treatments may provide an alternative to chemical control of many soil and seed borne pathogens. Biopriming, a seed treatment system that integrates the biological and physiological aspects of enhancing growth, disease control and increase in yield, involves coating the seed with biological agents and incubating the seed under warm, moist conditions. Seed may be planted moist or dried for storage.

Excessive and continuous use of chemical fertilizers coupled with pesticides and fungicides have damaged the soil health which causes deleterious effects on crop cultivation and productivity. Now-a-days, the chemical fertilizers are replaced by environment friendly biofertilizers. Most of the biofertilizers manufactured in India are solid carrier based and generally suffer from shorter shelf life, poor quality, high contamination and low field performance (Hedge, 2002). At present, the carrier based biofertilizers are replaced by liquid formulations which are easy to use as it spreads well, mixed uniformly and does not require sticker agent (Nethery, 1991). Rice and Olsen (1992) suggested that liquid formulations were

an effective method for seed inoculation of biofertilizer than carrier based inoculant application. Research information on the use of liquid biofertilizers as seed treatment, especially seed biopriming is very scanty and need further investigations about its efficacy in different crop seeds.

For optimal growth and development, 17 essential elements are required by crop plants. These minerals, when required in relatively high amounts are called macronutrients or, in trace amounts as micronutrients. While micronutrients are required in relatively smaller quantities for plant growth, they are as important as macronutrients. If any element is lacking in the soil or not adequately balanced with other nutrients, growth suppression or even complete inhibition may result (Mengel *et al.*, 2001). Micronutrients often act as cofactors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants. Most importantly, micronutrients are involved in the key physiological processes of photosynthesis and respiration (Marschner, 1995; Mengel *et al.*, 2001) and their deficiency can impede these vital physiological processes thus limiting yield gain.

The availability of micronutrients in saline soils depends on the solubility of micronutrients, the P^H and redox potential of the soil solutions and the nature of binding sites on the organic and inorganic particle surfaces. Thus, salinity can differently affect the micronutrient concentrations in plants depending on crop species and salinity level (Oertli, 1991). Micronutrient deficiencies are very common under salt stress owing to high pH (Zhu *et al.*, 2004).

Foliar application might be better than soil application because ion imbalance and uptake problem happened under saline soil condition. Advantages of foliar sprays might be due to (1) application rates are much lower than those of soil application; (2) a uniform application is easily obtained; and (3) response to the applied nutrient is almost immediate, so deficiencies can be corrected during the growing season (Singaraval *et al.*, 1996; Savithri *et al.*, 1999; Ali *et al.*, 2003; Johnson *et al.*, 2005 and Sultana *et al.*, 2001). Soil or foliar application of the three micronutrient Zn^{+2} , Fe^{+2} , Mn^{+2} partially alleviates the adverse effects of salinity on yield and yield components of salt stressed plants (Zayed *et al.*, 2011).

According to Manoharan *et al.* (2001), foliar application of $ZnSO_4$ (0.5 %) could increase the grain yield significantly over control. According to Kamaraj and Krishnaswamy (2003), foliar spraying of 0.5 per cent $ZnSO_4$ recorded maximum seed set per cent, seed yield and seed quality. According to Kumar and Singh (1997) foliar spray of 0.5 per cent $ZnSO_4$

have favourable effect in pollen germination, tube elongation and in decreasing the number of ruptured pollen which results in better fertilization, higher seed set and increased seed yield.

In barley seed priming with Zn improved germination and seedling development (Ajouri *et al.*, 2004). In maize, priming in 1% ZnSO₄ solution (for 16 h) substantially improved crop growth, grain yield and grain Zn content (Harris *et al.*, 2007).

Since research on seed priming under sodic soil condition is very negligible, the present study was conducted with an aim to explore the effects of different priming treatments on seed germination and productivity of rice varieties under both sodic and saline soil stress environments. Keeping the research gap in priming under stress environments a study was conducted with the following objectives,

1. To standardize a suitable seed priming treatment.
2. To study the effect of priming treatment under stress condition.
3. To determine the biochemical and physiological changes on plant growth induced by priming under salt stress.
4. To study the effect of seed priming along with foliar spray on seed yield under salt stress environment.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) is one of the world's most important cereals for human consumption providing up to 80 per cent of the daily energy intake which serves as the staple food for more than one-third of the world's population (Khush, 1997). Rice is grown under various soil and climatic conditions and is extremely sensitive to different abiotic stress factors especially salinity, sodicity, drought and submergence (Grover, 1999). Though rice is considered as a salt sensitive crop (Flowers *et al.*, 1985), it is one of the most widely grown crops in coastal areas frequently inundated with saline sea water during high tidal period (Akbar *et al.*, 1972; Maas and Hoffman, 1977 and Flowers and yeo,1995). These widespread soil problems especially salinity and sodicity impair normal growth and limits the realization of yield potential of modern rice varieties (Greenland, 1984).

2.1. Soil salinity

Salinity is one of the major abiotic stresses that adversely affect crop productivity and quality. About 20% of irrigated agricultural land is adversely affected by salinity (Flowers and Yeo, 1995). A salt affected soil is defined as one that has been adversely affected to the extent that it is no longer suitable for the growth of most crops by the presence of action of soluble salts. This group of soils includes both saline and sodic soils. Soil salinity and sodicity problems are present in nearly every irrigated area of the world and also occur on non irrigated crop lands. The problem of soil salinity is further increasing because of the use of poor quality water for irrigation and poor drainage. In clay soils, improper management of salinity may lead to soil sodicity whereby sodium binds to negatively charged clay causing clay swelling and dispersal that makes the soil less fit for crop growth. Thus, virtually no land is immune from salinization. Therefore, for sustaining life on earth, control of these problems and finding new ways to utilize these extensive saline and sodic soils and water resources, at least for agricultural purposes are vital and urgent. Reclamation, or at least minimizing the effect of salinity and or sodicity, is important and necessary.

Plants are classified as glycophytes and halophytes according to their capacity to grow on high salt medium. Most of the grain and vegetables crops are glycophytes and are highly susceptible to soil salinity even when the soil EC is $< 4 \text{ dSm}^{-1}$. High salt concentrations primarily decrease the osmotic potential of soil solution creating a water stress in plants. Secondly, they cause severe ion toxicity, since Na^+ is not readily sequestered into vacuoles as in halophytes. Finally, the interactions of salts with mineral nutrition may result in nutrient imbalance and deficiencies. The consequence of all these can ultimately lead to plant death as a result of growth arrest and molecular damage (McCue and Hanson, 1990).

Several mechanical and chemical methods have been devised to reclaim the salt affected soils but they are either expensive or not readily feasible. However, the use of plant species that can tolerate high salt levels is important for sustainable crop production on such soils. Therefore, one of the modern approaches to the exploitation of saline or sodic soils is the improvement of salt tolerance of cultivated species (Nobel, 1983).

Presowing seed invigouration treatments are numbered many and all are claimed to have invigourative effect for enhancing the germination, emergence, field stand, growth, development and productivity of many crops. Since literature on the influence of priming on rice seed quality under salt affected condition is negligible, the literatures available on the influence of this technique in different crops are reviewed here under.

2.2. Effect of seed priming on physiological seed quality parameters.

Among various plant growth processes, seed germination and early seedling growth are considered critical for raising a successful agriculture crop, as they indirectly determine the crop stand and density and affect consequently the yield of the crop (Gelmond, 1978). The salinity effect is generally concentration dependent and differs among different species. Adverse effect of salinity on growth and development of plant has been reported by Munns and Termaat (1986).

Salt stress effect is more harmful during early stages of germination and seedling growth (Kingsbury and Epstein, 1986). Salinity adversely affects seed germination, seedling growth and different metabolic activities in plants (Narayana and Rao, 1987).

Rice is very sensitive to salinity at early seedling stage. Salt injury symptoms first manifest on the first leaf, followed by the second and then on the growing leaf (Akbar, 1975). The inhibition of seed germination and seedling growth of rice which were normally observed under salinity stress might be attributed to the inhibition of the hydrolysis of endosperm reserves (Dubey, 1983) and translocation of food reserves from endosperm to embryonic axis (Sheoron and Garg, 1978).

Germination of rice was found to be affected very severely due to salt stress induced by sodium carbonate (Vijayaraghavan, 1994). The exposure of plants to salinity results in metabolic perturbances and lowered physiological processes which ultimately reflects in growth inhibition (Amzallag, 1997).

Misra *et al.* (1997) found that the effect of salinity in rice varieties on seed germination, shoot and root length, seedling vigour and increase in the root: shoot length ratio in the laboratory was relatively greater in variety Jaya than in Damodar.

Root and shoot length were found to be decreased significantly by saline irrigation of EC 6 and EC 10 dSm⁻¹ as compared to control. Length of root and shoot decreased perhaps due to accumulation of ions near the root surface (Afria and Narnolia, 1999) in wheat. Salinity ultimately diminishes economic yield and quality of produce (Ali *et al.*, 2004).

Rice is comparatively tolerant during germination, active tillering and towards maturity and is sensitive during early seedling and vegetative stages. (Lafitte *et al.*, 2004).

2.2.1. Hydro priming

2.2.1.1. Rice

Seed priming is one of the presowing seed management techniques, where the seeds are partially soaked and subsequently dried back for invigourative effect that expresses on field emergence and extended upto yield (Austin *et al.*, 1969; Berrie and Drennan, 1971; Cor leto and Mallik, 1974). Hegarty (1970) also opined that priming would improve the velocity of germination and seedling emergence even under sub-optimal environmental conditions. However, Burgass and Powell (1984), Basu and Pal (1979), Perl (1979), Rao *et al.* (1987) and Savino *et al.* (1979) suggested that short pre-hydration treatments (upto 1h) had little effect on either germination rate

or longevity. Increasing the durations of pre-hydration or priming reduced the mean time to germination and also the mean seed longevity.

Seed priming is a simple and low cost technique in which controlled hydration of seeds followed by redrying is done to break dormancy, improve germination and stand establishment (Afzal *et al.*, 2009).

The beneficial seed priming as halo (treating with salt solutions), hydro (treating with water), osmotic (treating with high molecular compounds) and solid matrix priming (priming the seed using nontoxic solid media), depending upon the variations in practicing the treatment and also the type of chemical used for priming.

Harris (1999) surveyed the influence of priming in farmer's field and opined that hydro priming of rice for 10h was farmer friendly and modification of the treatment for overnight also had good effect on farmer's field.

Seed priming techniques was effective for better germination and seedling establishment in direct seeded-rice under controlled conditions when soaking seeds in aerated distilled water for 48h and also alternate soaking of seeds in tap water at $27 \pm 3^{\circ}\text{C}$ for 24 h and then dried back to original moisture content (Farooq *et al.*, 2006). They revealed that seed priming techniques promoted germination, yield, and grain quality of rice.

2.2.1.2. Other cereals and millets

In sweet corn, presowing hydration improved early emergence (Mark and Luther, 1987) increased the plant size at an early (2 to 4 leaf) vegetative stage and improved plant stand (Bennett and Waters, 1987).

According to Basra *et al.* (2003), wheat seeds were subjected to hydropriming for 6, 12, or 24h and matriconditioning with gunny bags or sugarcane press mud for 12 or 24h. Early emergence was recorded in hydroprimed seeds. However, maximum emergence per centage was recorded for hydropriming and matriconditioning with gunny bags for 24h including control. The best priming treatment was found to be hydropriming for 24h followed by matriconditioning with gunny bags for 24h. Hydroprimed seeds had lesser electrical conductivity (EC) of seeds lechates than control. Matricondiotioning with gunny bags or press mud resulted in increased electrical conductivity (EC) than control. Hydropriming for 12 or 24h reduced the germination

time and increased the seedling vigour under present experimental conditions. However, Giri and Schillinger (2003) noted that none of the seed priming agents including water improved field emergence and subsequent grain yield in deep planted winter wheat.

Orzeszko-Rywka and Podlaski (2003) primed maize seeds for 17h and found that priming increased the final emergence, leading to a 14 per cent increase in crop stand in one season but in another season, there was a little effect of priming on growth, time to flowering and maturity, or yield of plants that had emerged on the same day from primed or non-primed seed.

In barley, Rashid *et al.* (2006) reported that seed priming had effective influence on earlier germination, better establishment and increased yields in many diverse environments. Grain yield increase due to priming was up to 53 per cent with the optimum duration of priming that was between 12 and 16h and the response to priming was better in low potential environments than under better conditions.

Afzal *et al.* (2008) reported that hydropriming of maize hybrid seed cv. Monsanto 7878 failed to improve the germination and behaved similarly to the non-primed seed. This treatment also did not improve root and shoot lengths. However, very effective in reducing the days to 50% emergence, mean emergence time, dry weight and α -amylase activity.

Ananthi (2008) hydroprimed seeds of hybrid maize COH (M) 5 for various duration from 8 to 48h and reported that 10h hydroprimed seed increased the germination, root and shoot length, drymatter production and vigour index. Early germination and reduction in days to 50% germination was also observed due to this treatment.

Moradi and Younesi (2009) reported that hydropriming improved the per centage and mean emergence time of sorghum seeds at sub-optimal temperature of 15°C. Seed treatment for 12 and 24h had a positive statistically significant effect on per centage and speed of emergence. Nevertheless priming for 36h failed to improve emergence per centage and mean emergence time.

2.2.1.3. Pulses

Harris *et al.* (1999) surveyed the influence of priming in farmer's field and opined that hydro priming of seeds for 24h in chickpea was farmer's friendly and modification of the

treatment for overnight also had good effect on farmer's field of Rajasthan, Gujarat and Madhya Pradesh.

Kaur *et al.* (2003) observed that priming chickpea seeds with water caused early emergence of germination under salt stressed conditions. Priming with water increased the length and biomass of roots and shoots of salt stressed chickpea seedlings as compared to non-primed seeds.

2.2.1.4. Oilseeds

Dhedhi *et al.* (2007) reported that in summer groundnut hydropriming resulted in higher germination, speed of emergence, per cent field emergence and ultimately better crop establishment and in turn increase in pod yield. They also reported hydro priming for 16h followed by dressing with thiram at 0.25 per cent was more effective in low vigour seed.

Avila *et al.* (2008) reported that canola rape seeds hydrated in water up to 60h was effective in the low vigour lot compared to pre-osmotic conditioning.

2.2.1.5. Vegetables

Rapid imbibitions resulting from placing seeds into direct contact with water found to cause injury in lima bean, whereas slow hydration with water vapour did not and this injury appeared to occur relatively early in imbibition (Pollock, 1969).

Heydecker (1973) found that 20, 15 and 10°C were equally effective for the hydro priming of onion seeds and however, a longer priming period was required at the lowest temperature. Onion seed primed at 10°C exhibited the higher rate of germination.

Soaking of melon seeds in water for 24-36h enhanced germination, plant growth and fruit quality (Muminov, 1973). Heydecker and Coolbear (1977) reported that the priming may also leach germination inhibitor from the vegetable seeds.

Coolbear and Grierson (1979) demonstrated that hydro priming did not affect the DNA content of tomato (*Lycopersicon esculentum*) seeds. However, after drying back and re-imbibition, the primed seeds commence S-phase DNA synthesis in half the time of the unprimed seeds.

Daniel *et al.* (1984) primed lettuce seed (*Lactuca sativa* L cv. Minetto) in water at 15°C in the dark for various periods of time and reported that priming for 20h in distilled water

improved the germination upto 86 per cent. They also reported that cell division occurred at 21h in water prior to radicle protrusion.

Anuradha *et al.* (1995) revealed that the hydration of freshly harvested cabbage seeds for two days at low temperature (10°C) had increased the emergence per centage, speed of emergence and days to 50 per cent emergence than the control.

Gurusinghe *et al.* (1999) expressed that hydro primed seeds of tomato has underwent an advancement of radical meristem cells into the S and G₂ phases of the cell cycle, increasing the per centage of nuclei having a 4C DNA content.

The priming study carried out with carrot indicated that seeds gave rise to decreased number of normal seedlings compared to untreated seeds due to heavy pathogen infection. However, the priming resulted in faster and uniformity of germination (Tylkowska and Van den Bulk, 2001).

Lin *et al.* (2005) indicated that priming improved emergence per centage, mean emergence time and seedling growth of treated bitter gourd seeds. Primed seeds also showed lower peroxidation, as indicated by the accumulation of malondialdehyde (MDA) and total peroxide, and higher total anti-oxidation activities (TAA) than non-primed seeds. The seeds receiving slow post-hydration drying treatment exhibited faster emergence and better seedling growth than the seeds receiving fast post-hydration drying treatment and the non-primed control.

Venkatasubramaniam and Umarani (2007) revealed that for tomato seeds, hydropriming for 48h (in double the volume of seed) was optimum whereas, for chilli and egg plant seeds, sand matric priming at 80% WHC of sand for three days was the best in terms of rate and uniformity of germination.

Abila (2008) recorded the highest values for per centage of plumule protrusion and germination of bitter gourd due to hydro priming for 24h. She also reported that sand matric priming at 60% WHC for 48h found optimum. In the case of ash gourd, hydro priming for 20h recorded higher plumule protrusion and germination followed by sand matric priming for 36h.

Nirmala and Umarani (2008) compared the different priming viz., hydro priming, halopriming and osmopriming and expressed that for okra, sand matric priming (3h in 60%

WHC of sand) was found to be the best, while for beetroot, hydropriming (12h in water at double the volume of seed) was optimum.

Moosavi *et al.* (2009) revealed that both hydro and osmopriming for 3h in amaranthus cultivars of two genus viz., Amont, Trigin, Mercado and Plainsman increased antioxidant enzymes activities. It was suggested that higher activity of antioxidant enzymes could increase tolerance of primed seeds to environmental stresses such as salinity.

2.2.2. Halopriming

Several osmoticum have been used for seed priming. Inorganic salts such as KNO_3 , K_3PO_4 and a chemically inert compound are materials most commonly used to adjust osmotic potential. Salts are easier to aerate, less costly and may provide a nutritional effect to seeds. A mixture of various salts in the solution is a common recommendation for many plant species. Osmotic agents may be combined with seed protectant or growth regulator or micronutrients (Dastor and Mone, 1958). Osmoconditioning, osmopriming or halopriming are synonymous seed priming methods used to describe the soaking of seeds in aerated low-water potential solutions to control water uptake and prevent radicle protrusion (Bray, 1995).

2.2.2.1. Rice

Sinha (1969) suggested that presoaking of rice seeds with 75ppm naphthalene acetic acid (NAA) and indole acetic acid (IAA) each with one molar solution of potassium dihydrogen phosphate resulted in greater production of drymatter.

Geetha (1992) found that seeds primed with KNO_3 , Na_2PO_4 and $\text{Na}_2\text{H}_2\text{PO}_4$ registered increased seed quality parameters and resultant seed quality.

Osmoconditioning, osmopriming, or halopriming synonymous seed priming methods are used to describe the soaking of seeds in aerated low-water potential solutions to control water uptake and prevent radicle protrusion Bray (1995).

Nagaraj (1996) reported that seeds primed with KCl , CaCl_2 increased the seed quality parameters.

Usha Thomas *et al.* (2000) reported that seeds of upland rice variety MattaTriveni (PTD-45) primed with one per cent KCl for 15h registered an appreciable increase in plant height, leaf area index and drymatter production at 30 DAS, 60 DAS and at harvest.

Reddy *et al.* (2001) reported that soaking of rice seeds in KMnO_4 for 24h recorded higher germination in direct sown flooded rice.

Anuradha and Seetarama Rao (2002) revealed that the seeds of rice soaked in 0.54M brassinolide and 150mM sodium chloride for 24h showed increased germination and plant stand.

Kalita *et al.* (2002) found that nutripriming with 4% monoammonium phosphate resulted in the highest number of tillers and greater grain yield of direct-sown summer rice.

Ruan *et al.* (2002) reported that osmopriming with CaCl_2 and $\text{CaCl}_2 + \text{NaCl}$ improved seedling vigor and stand establishment in rice under flooded soil.

Basra *et al.* (2005) found that priming with polyethylene glycol 8000 accelerated the germination of coarse and fine rice.

Basra *et al.* (2006) suggested that priming with ascorbate 10 ppm concentration improved the germination and early seedling growth in both coarse and fine rice types.

Seed priming techniques was effective for better germination and seedling establishment in direct seeded-rice under controlled conditions when soaking seeds in aerated distilled water for 48h and also alternate soaking of seeds in tap water at $27 \pm 3^\circ\text{C}$ for 24h and then dried back to original moisture content (Farooq *et al.*, 2006). They revealed that seed priming techniques promoted germination, yield and grain quality of rice. They also reported that osmohardening in the presence of KCl and CaCl_2 solution with $\psi_s = -1.25 \text{ MPa}$ for 48h get recorded better germination and yield.

Farooq *et al.* (2007) reported that rice seeds primed with 30 ppm salicylate registered prompt and most uniform germination and emergence, earlier synchronized and enhanced germination improvement in root length, leaf score and seedling fresh and dry weight was also observed.

Yari *et al.* (2010) found that priming of wheat seed using polyethylene glycol (PEG10%) and distilled water improved speed of germination.

Liela yari *et al.* (2012) primed three rice cultivars Fajer, Sherodi and Taramds primed by soaking in CaCl_2 solutions at 0.5% and 1% and distilled water for 12, 24 and 36h at three temperature levels (20, 25 and 30°C). Maximum seed germination per centage was recorded in cv. Sherodi when the seeds primed with CaCl_2 1%. All seed priming treatments resulted in lower mean germination time than that of control and the seed priming for 24h at 25°C temperature was suitable for all cultivars.

2.2.2.2. Other cereals and millets

Grzywnowicz-Gazda (1982) reported that soaking of spring barley seeds in B, Mn, Mo, Zn, Fe and Mg either individually or in combination for 24h increased the trace elements concentration in the grain. The seed treatment was also found to increase the germination capacity, growth and drymatter production of barley seedlings when compared with untreated control.

Amarjit *et al.* (1988) primed maize seed in solutions of either 2.5% K_2HPO_4 or 2.5% $\text{K}_2\text{HPO}_4 + \text{KNO}_3$ and found that the results accelerated germination at a chilling temperature and the effect of priming was largely retained after seeds had been dried back.

Selvaraju (1992) reported that sorghum seeds treated with KH_2PO_4 2%, DAP 2%, micronutrient mixture shows increased seed quality parameters.

Harris (1999) soaked maize seeds for 8h in distilled water and in 200 ppm of NaCl, KCl, and $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ to alleviate the adverse effects of salt stress on maize at germination stage and found that $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ proved to be more effective, since the seeds primed with this salt had significantly higher final germination, rate of germination and fresh and dry weights of plumules and radicles than those treated with other salts or distilled water. He also reported that halopriming increased the concentration of Na^+ , K^+ and Ca^{2+} significantly in all germinating seeds of maize.

Ashraf *et al.* (2002) reported that number of grains per spike and grain yield per plant, 1000-grain weight and number of spike per plant decreased significantly under salt stress (0, 100 and 200 mol m^{-3}) in two spring wheat cultivars, Barani-83 (salt sensitive) and SARC-1 (salt tolerant) but a more adverse effect of salt was observed on Barani-83 than on SARC-1 with respect to yield attributes. However, application of GA_3 (100 mg l^{-1}) caused a slight decrease in grains per spike and increase in thousand grain weight in both the cultivars.

Kulkarni and Chittapur (2003) reported that pre-sowing seed treatment with water, mineral solution viz., CaCl_2 , ZnSO_4 , cobalt sulphate, K_2SO_4 , CuSO_4 , sodium molybdate, boric acid and MnSO_4 or growth regulators viz., ascorbic acid, kinetin, benzyl adenine, gibberellic acid and cycocel alone and in combination was found to speed up germination process, increased the germination rate and seedling vigour, the resistance for water and salinity stress and increased the crop yields in sorghum.

Pegah *et al.* (2008) reported that maize seeds when treated with urea-1.2 Mpa or PEG-1.2 MPa increased seed quality parameters.

Yari *et al.* (2010) found that priming of wheat seed by using polyethylene glycol PEG 10% and distilled water improved speed of germination.

2.2.2.3 Pulses

Sathiyamoorthy and Vivekanandan (1998) reported that soybean seeds soaked in KNO_3 (1.0%), NaCl (0.5%) and DAP (0.025%) for 12h were effective for better development of root system, dry matter production and seed yield.

Ramamohan and Saran (1999) reported that soaking of blackgram seeds in KNO_3 and CaCl_2 increased the germination and growth.

The seed germination and seedling vigour of blackgram cv.VBN 3 seed could be improved by soaking the seeds in 0.5% KNO_3 for 4h duration (Surulirajan, 2007).

In chickpea Johnson (2004) reported that priming seeds in aqueous solution of 0.5 g^{-1} (approximately equivalent to 40 g ha^{-1}) molybdenum improved the vigour of the seed.

Sasthri and srinathi (2010) reported that cowpea seeds primed with FeSO_4 0.5% increased the initial germination and the seed yield by 10.0 and 28.0%.

Hosseini Sadeghi *et al.* (2011) reported that soybean seeds osmoprimed with PEG 6000 –1.2 MPa for 12h duration registered increase in germination percentage, germination index and seed vigour and decrease in mean germination time.

. 2.2.2.4. Oilseeds

Sunflower seeds soaked in distilled water or 0.1M KNO₃ or FeSO₄ or ZnSO₄ solution for 12h increased the emergence and the seed and oil yield were the highest with ZnSO₄ soaking (Ullah and Hussain, 1989).

Farooq *et al.* (2006) reported in sunflower for seedling elongation priming of seeds in H₂O₂, NaCl and GA₃ were the best, while for shoot and root dry weight, priming of seeds in salicylic acid and H₂O₂ were promising.

Mavi *et al.* (2006) found that improvement in plumule length was observed due to earlier germination induced by NaCl priming.

Sunflower seeds were hydro primed for 24 h, matriprimed for 24 and 48h, osmoprimed with 0.5% KNO₃ for 12 h and 0.1% NaCl for 12 h. Hydropriming and osmopriming with NaCl resulted in early 50 % emergence, increased plant population, achene yield and achene proteins, but plant height and achene oil contents were not affected significantly by different seed priming (Mubshar *et al.*, 2006).

. 2.2.2.5. Vegetables

Daniel *et al.* (1984) primed lettuce seed (*Lactuca tiva* L cv. Minetto) in aerated solutions of 1 per cent K₃PO₄ or water at 15°C in the dark for various periods of time and reported that priming for 20h in 1 per cent K₃PO₄ or distilled water improved the germination upto 86 per cent. They also reported that cell division occurred at 21h in water and at 27h in 1% K₃PO₄ prior to radicle protrusion.

Furutani *et al.* (1986) found that onion seeds primed for 8 days at 10°C in -1.1 MPa of mannitol or NaCl reduced the durations for 50 per cent germination by 46 per cent and decreased the speed of germination by 32 per cent. Primed onion seeds with 9 per cent moisture stored at 10°C maintained a higher germination rate than untreated seeds and did not loss viability during 18 months of storage (Dearman *et al.*, 1986).

Alvarado *et al.* (1987) found that primed tomato seeds in KNO₃ solution at 15°C germinated more rapidly as compared to seeds primed in PEG 8000 solution.

Primed muskmelon seeds obtained after 40 DAA (immature) and 60 DAA (fully mature) in 0.3M KNO₃ for 48 h at 30°C and in deionized water or PEG 8000 solutions of

0 to 1.2 MPa at 15, 20, 25 and 30°C and found that priming treatment improved their germination per centage under stress conditions which were equal or exceed that of control seeds of 60 DAA, while 60 DAA seeds exhibited only modest improvements due to priming (Welbaum and Bradford, 1991).

Cantliffe (1991) revealed that lettuce seeds primed in one per cent K_3PO_4 for 20h in the dark with the addition of 100ppm of cytokinin reduced thermodormancy, and increased germination per centage.

Lanteri *et al.* (1993) found that in pepper seeds, DNA synthesis was induced only after 10 days of priming in the solution of PEG or $KNO_3 + K_3PO_4$ at an osmotic potential of -1.1 MPa.

Cavallaro *et al.* (1994) primed tomato seeds in aerated solution of $KNO_3 + KH_2PO_4$ at -1.0 MPa or PEG 6000 at -0.8 MPa in a dark room at 18 ± 1^0C for 6 and 8 days decreased the mean time for seedling emergence compared to unprimed seeds.

Mauromicale *et al.* (1994) primed the summer squash seeds in aerated solution of $KNO_3 + K_2HPO_4$ at 3 per cent for 2 days and found that priming improved the seedling emergence (97%) and was followed by $KNO_3 + K_2HPO_4$ 2 per cent for 4 days (85%). An average per cent of seedling emergence of primed seeds was 93 per cent as compared to 72 per cent of untreated seeds.

Anuradha *et al.* (1995) revealed that hydration of freshly harvested cabbage seed for two days at low temperature (10°C) increased the emergence per centage, speed of emergence and days to 50 per cent emergence than control.

Yongqing *et al.* (1996) reported that addition of 10µM GA_{4+7} to the osmotic priming solution triggered replicative DNA synthesis of fresh priming seeds and further enhanced the germination process in tomato.

Demir and venter (1999) haloprimered the watermelon seeds with KNO_3 at 3% for 6 days at 20 °C and found that priming decreased mean emergence time and increased seedling weight and hypocotyl length.

Orzeszko-Rywka and Podlaski (2003) gave clear evidence that priming of sugar beet seed with water for 24h and air-dried had the best effect on the course of germination.

Venkatasubramaniam and Umarani (2007) standardized the best priming methodology for tomato, brinjal and chilli as i) hydropriming in double the volume of water (48h), ii) sand matric priming in 80 per cent water holding capacity (3 days), iii) osmopriming in -1MPa PEG (3 days) and iv) halopriming with 5 per cent NaCl (24h).

Nethaji (2006) observed that the best methodology for priming radish and mustard seeds were i) hydropriming for 12h in double the volume of water, ii) osmopriming treatments in – 1MPa PEG for 1 day and iii) halopriming in 3% KNO₃ upto 24h and these primed seed recorded better performance in physiological and biochemical parameters viz., per centage of radicle protrusion and germination, seedling length, speed of germination, vigour index and amylase activity.

2.2.3. Biopriming with biocontrol agents

Bio-priming is a process of biological seed treatment that refers to combination of seed hydration (physiological aspect of disease control) and inoculation (biological aspect of disease control) of seed with beneficial organism to protect seed. It is an ecological approach using either bacteria or selected fungal antagonists against the soil and seed-borne pathogens. Biological seed treatments may provide an alternative to chemical control of crop diseases.

2.2.3.1. Millets and Rice

Callan *et al.* (1990) observed that *sh2* sweet corn seed bioprimed and coated with *Pseudomonas fluorescens* AB254 increased bacterial population from 10 to over 10,000 fold, depending on initial inoculum level. It also provided protection against damping off as good as or better than seed treatment with Metalaxyl. Bio priming with *Pseudomonas fluorescens* AB254 enhanced the ability of this biocontrol agent to protect *sh2* sweet corn seeds from attack of *Phythium* sp. in cold to warm soils. The effects of bio priming on both seed physiology to relieve chilling injury and bacterial growth to provide pathogen control may be involved in this response.

The term 'bio-prime' was introduced by Callan *et al.* (1991) who used it to describe a method of infecting maize seeds with a strain of *Pseudomonas fluorescens* and reported that inoculation of seeds with biocontrol agents in combination with priming has, in several cases, been reported to enhance and stabilize the efficacy of biocontrol agents .

Introduction of biopriming with novel stain of *Pseudomonas fluorescens* introduced to the seeds, stems and leaves of maize revealed that seeds retained a greater colonization frequency than roots in the plants grown in both soil and nutrient solution (Fisher *et al.*, 1993).

Niranjan Raj *et al.* (2004) reported that seed bio priming with *Pseudomonas fluorescens* isolate enhanced the growth of pearl millet plants and induced the resistance against downy mildew. The time required for flowering was also advanced by 5 days with 22% increase in grain yield and 20 to 75% resistant to downy mildew.

Sudharalingam (2005) reported that seeds of hybrid rice ADTRH 1 when treated with organic priming with panchakavya, coconut water and vermiwash increased the germination.

Singh and Singh (2008) reported that biopriming with *T.harzianum* and *P.fluorescens* reduced the disease incidence significantly in sorghum.

Chandra Nayaka *et al.* (2010) reported that biopriming of maize seed with novel strain of *Trichoderma harzianum* controlled the toxigenic *Fusarium verticilliodes*, a fungal pathogen causing pre and post- harvest losses and also capable of producing Fumonisin. Bio priming with *Trichoderma harzianum* could also increase the seed germination, field emergence, vigour index, yield and thousand seed weight in comparison with the control.

2.2.3.2. Pulses

Vidhyasekaran and Muthamilan (1995) revealed that biopriming chickpea seeds with *Pseudomonas fluorescens* increased rhizosphere population, controlled chickpea wilt disease and increased the yield in the two field trials.

Mohamedy *et al.* (2006) reported that biopriming cowpea seeds with *Trichoderma harzianum* caused a highly significant reduction in root rot incidence under field conditions. Furthermore, fresh pods yield was highly increased when compared with fungicide treatment. Moreover, population density of *T. harzianum* cfu in rhizosphere soil of cowpea plants was increased as the highest propagules counts were recorded.

Begum *et al.* (2010) indicated that in soybean seeds, all biopriming treatments significantly reduced pre and post emergence damping off compared to hydro primed and non-primed seed controls. In general, biopriming with *P.aeruginosa* was the most effective treatment for controlling pre and post emergence damping off, with reduction in disease incidence and enhancement of seed germination and healthy seedling stand.

2.2.3.3. Vegetables

Singh (2003) reported a improved method for seed biopriming with *Trichoderma harzianum* and *Pseudomonas fluorescens*, which involves a pre-sowing hydration treatment to improve seedling establishment. In this technique, the seeds were first coated with the suspension of *Trichoderma* powder prepared by mixing 10g *T. harzianum* + 10g FYM powder + 5g gum arabica in 50ml water for 1kg seed. Treated seeds were then placed on plastic sheet as a heap and covered with moist sacks and incubated under warm (27 to 32°C) and moist conditions until just prior to radical emergence (24 to 48 h after treatment). This has been tested in rice, wheat, chickpea, lentil, pigeon pea, tomato, brinjal, capsicum, cabbage, cauliflower and chilli.

Mohamedy (2004) reported that biopriming of okra seed with *Trichoderma harzianum* at 1.25 and 2.5mg/litre reduced the growth of all the pathogens by more than 72.5%. They also reported that under field conditions biopriming seed treatments with *Trichoderma harzianum* and *Bacillus subtilis* reduced the pre-emergence damping off by 68.4% and the post-emergence at 45 and 60 days after sowing by more than 64.4%.

Jensen *et al.* (2004) demonstrated that biopriming carrot seed with the biocontrol strain *Clonostachys rosea* isolate IK726 makes it possible to prime seeds infected with pathogenic *Alternaria* spp. without risking adverse effects on seedling establishment. This is particularly interesting for organic farmers, because it is difficult to produce high quality disease free seed organically.

Kaymak *et al.* (2008) suggested that biopriming with PGPR was more consistent in improving germination per centage and rate of radish (*Raphanus sativus* L.) seeds under high saline conditions.

Mohamedy and Baky (2008) reported that biopriming and seed coating pea seeds with *Trichoderma harzianum* or *Bacillus subtilis* stimulated the vegetative growth and significantly increased the yield of early and total green pods. It also resulted with the highest values for pea pod quality, namely pod length, diameter, number of seeds/pod and chemical contents of pods (i.e., TSS, total carbohydrates and protein) in two seasons.

Mougy and Kader (2008) reported that biopriming feba bean seeds with anyone of the strains of *Trichoderma viride*, *Trichoderma harzianum*, *Bacillus subtilis* and *Pseudomonas fluorescens* showed a higher significant reduction on disease incidence than seed that was not primed. There was a greater reduction of disease incidence at the pre-emergence stage of plant growth rather than at the post-emergence stage.

2.2.4. Bio priming with liquid biofertilizers

First report on liquid inoculants for seed inoculation of *Rhizobium* was published from Holland (VanSchreven *et al.*, 1953). The liquid inoculum was as effective as peat based inoculant when the number of rhizobia per seed was increased 2.5 times (Burton *et al.*, 1965).

Application of liquid suspension either directly to the soil or to the seeds is the simplest method of inoculation which was used in numerous green house and field experiments (Albrecht *et al.*, 1981; Reynders and Vlassak, 1982; Smith *et al.*, 1984; Millet and Feldman, 1986; Fallik *et al.*, 1988). If the inoculant formulation favours the dormant state of the organisms i.e. dehydrated condition, precoating of the seeds with the *Azospirillum* was recommended and number of cells must be obtained on every seed after several months of storage (Fages, 1994).

High cell count, zero contamination, longer shelf life, greater protection against environmental stresses, and convenience of handling are the major advantages of liquid inoculants over the conventional carrier based inoculants and this liquid inoculant technology can be considered as a breakthrough in the field of biofertilizer technology (Hedge, 2002).

Biofertilizers manufactured in India presently are carrier based and they suffer from short shelf life, poor quality, high contamination and unpredictable field performances (Hedge, 2002). So, as an alternate, liquid inoculant formulation with a good field performance that uses low cost materials and easily attainable by small producers could overcome many problems associated with processing solid carriers (Singleton *et al.*, 2002).

2.2.4.1. Other cereals, millets and vegetables

The performance of liquid formulations of *Azospirillum* and phosphobacteria was found to increase the rhizosphere population, plant biometric observations and yield of maize and tomato under field conditions (Kanimoli *et al.*, 2004).

Gomathy *et al.* (2007) inoculated maize seeds with liquid formulation of phosphobacteria which increased the cob height, cob yield, cob grain weight and plant nutrient content.

Thamizh vendan and Thangaraju (2007) inoculated the tomato seeds with liquid formulation of *Azospirillum* which enhanced the plant height, biomass, nitrogen uptake of plants, available nitrogen content of soil and yield of tomato.

Gomathy *et al.* (2009) reported that 1% inoculum showed better results followed by 1.5% inoculum for the optimization of liquid phosphobacteria required for maize seeds.

Zortia and Canigia (2009) inoculated the wheat seeds with liquid formulation of *Azospirillum brasilense* and reported that the crop exhibited more vigorous vegetative growth, with both greater shoot and root drymatter accumulation. The inoculation increased the number of harvested grains and grain yield.

2.3. Foliar spray with minerals on crop performance

2.3.1 Foliar spray with micronutrients

Micronutrients play a vital role in enhancing the productivity of crops. Additions of micronutrients increase the yield and quality of crops.

Putteswamy *et al.* (1975) revealed that foliar application of micro nutrient solution “Navaras” at different growth stages such as tillering, flag leaf, grain filling and mid anthesis increased rice plant height, number of panicles plant⁻¹, grain weight and grain yield over NPK alone.

Kanwar and Randhawa (1976) reported that foliar application of micronutrient mixtures increased rice crop yield over control. Shivananje *et al.* (1976) reported that foliar application of micronutrient mixture “Navaras” at 0.25 % thrice increased plant height, 1000 grain weight and grain yield of rice.

Dey and Chattopadhyay (1978) observed that 1.0 % ZnSO_4 as foliar application on 40th day after transplanting resulted in higher rice yield when compared with no Zn.

Kumar *et al.* (1979) reported that application of 5 kg Zn ha⁻¹ through foliar spray significantly increased the rice grain yield by 17 % over the untreated control.

Mahapatra and Gupta (1979) observed that foliar application of MnSO_4 and ZnSO_4 increased grain yield by 12 per cent and 21 per cent respectively over control. Premkumar *et al.* (1979) found that foliar application of ZnSO_4 , MnSO_4 and sodium borate @ 5.5 and 2.5 kg ha⁻¹ both single and in combination increased the grain and straw yield in sandy loam soil.

Jayaram Reddy *et al.* (1980) reported that foliar application of micronutrient mixture Zimag increased yield and number of productive tillers hill⁻¹ in clay loam soil over NPK alone. Muthuvel *et al.* (1981) also reported that enhancement of grain and straw yields of rice due to foliar application of zinc solution @ 0.75 %.

Singh and Chatterjee (1980) observed that foliar application of micronutrient mixture Agromine @ 1.25 kg ha⁻¹ increased the grain yield (14.1 q ha⁻¹) of rice over control (12.7q ha⁻¹).

Samui and Dasgupta (1982) reported that foliar applications of Zn, B and Mo increased rice yield over control. Nampoodiri and Ramasubramanian (1982) obtained higher grain yield with 0.5 % zinc sulphate as foliar spray.

Ramakrishna Reddy *et al.* (1983) reported that foliar application of zinc sulphate at 10 kg ha⁻¹ increased the grain yield by 1361 kg ha⁻¹ over NPK application. Gupta and Ram Kala (1983) reported that foliar application of ZnSO_4 recorded the highest grain and straw yields than the soil applied chelated zinc.

Prasad *et al.* (1983) concluded that the foliar feeding of ZnSO_4 was better than soil application in enhancing the rice yield. Sanchez (1983) observed that foliar application of zinc @ 1.5 kg ha⁻¹ as zinc chelate significantly increased the grain and straw yield of rice.

Ramakrishna Reddy *et al.* (1984) found that foliar application of 10 kg ZnSO₄ ha⁻¹ increased the number of productive tillers, number of grains per panicle and grain and straw yield of rice.

Application of 0.2 % zinc sulphate as foliar spray at flowering stage significantly increased the grain yield (Misra and Reddy, 1985). Velu and Savithiri (1985) obtained the highest straw and grain yields at 2.0 % foliar spray of ferrous sulphate, which was comparable with soil application.

Devarajan *et al.* (1987) reported that foliar application of ZnSO₄ at 0.5 % along with 120 kg N as zincated urea increased the grain yield (4456 kg/ha). Bollu Rajendra Prasad and Singh (1987) reported that foliar application of chelated zinc and manganese registered the highest dry matter and straw and grain yield than inorganic treatments. Ilangoan and Palaniappan (1987) found that foliar application of zinc sulphate increased the grain yield during kharif and summer seasons.

According to Govind Reddy *et al.* (1988), foliar application of zinc at 0.2 % increased rice grain yield over control. An increase in yield of rice due to the foliar application of micronutrients based fertilizers over control was reported by Swamy *et al.* (1990).

Oertli (1991) reported that the availability of micronutrients in saline soils depends on the solubility of micro nutrients, pH and redox potential of the soil solution and the nature of binding sites on the organic and inorganic particle surfaces. Thus, salinity can differently affect the micronutrient concentrations in plants depending upon crop species and salinity level.

Rattan and Shukla (1991) found that application of Zn as ZnSO₄ · 7H₂O / Zn-EDTA or Zn-DTPA increased dry matter and grain yield of rice. Li and Zhu (1991) reported that B additions significantly increased the grain yield and yield attributing characters such as plant height, 1000 grain weight and effective tillers.

Bansat and Nayyar (1992) observed an increase in rice grain yield with foliar spray of zinc. Application of 0.5 % zinc sulphate as foliar spray thrice at 15, 25 and 35 DAT increased the grain yield during Navarai season (Paramasivam *et al.*, 1992).

In a sandy clay loam soil at West Bengal, foliar application of 5 to 6 kg Zn + 3.0 kg Cu + 0.5 kg Mo ha⁻¹ along with NPK produced higher rice grain yield of 7.17 t ha⁻¹ (Rafey *et al.*, 1992). Application of 20 kg zinc sulphate ha⁻¹ as soil application and foliar

application of zinc sulphate 5 kg ha⁻¹ increased the grain yield (Srivastava *et al.* 1992). Srivastava *et al.* (1992) reported that foliar application of ZnSO₄ or Zn-EDTA increased rice grain yield over control. Savithiri *et al.* (1992) reported that application of 25 kg ZnSO₄ ha⁻¹ increased the grain yield in the Thaladi season i.e., 17.6-33.7 % over control.

Durairaj (1993) reported that the combined foliar application of 20 ppm humic acid and 25 ppm ZnSO₄ gave the highest yield of paddy. Prasad *et al.* (1994) observed that foliar application of Fe-chelates and FeSO₄ increased the dry matter over control.

Savita Tripathi *et al.* (1995) found that application of NPK supplemented foliar spraying of various mixtures of elements including Fe, Mn, Mg, Mn, Zn, Cu, B, Mo, Ca and S (Sat Rite SF, Borocol BSF-12 of Micnelf MS-12) increased the grain yield of rice.

Foliar application of 0.5 % zinc sulphate spray at 45 days after transplanting increased the grain and straw yields (Chauhan, 1995). Khanda and Dixit (1995) observed that foliar application of ZnSO₄ increased grain and straw yield by 2.5 and 4.2 %, respectively. Two sprays of 1% ferrous sulphate at 40 and 55 days after transplanting along with recommended dose of NPK fertilizers increased the grain yield during *kharif* season (Tandon, 1995).

Foliar spray of 0.5 % zinc chelate during panicle initiation produced more grain and straw yields comparable with application to nursery and during transplanting (Revathi *et al.* 1996).

Sakal *et al.* (1996) reported that the grain and straw yields of five rice crops in rice-wheat cropping sequence varied from 171.6 to 238.0 and 254. 3 to 353.0 q ha⁻¹ due to B application and maximum yield was recorded when borax at 16 kg ha⁻¹ was applied to soil.

The average response of rice for manganese and copper application was found to be 4.7 and 4.4 q ha⁻¹ respectively under calcareous soil (Sakal *et al.* 1996).

Islam *et al.* (1997) observed an increase in rice yield by 15 % due to B application @ 3 kg ha⁻¹.

Binod Kumar and Singh (1997) reported that foliar application of 0.2% ZnSO₄ increased grain and straw yield at active tillering stage over control.

Subbiah and Mitra (1997) reported that foliar application of Zn (0.5 %), B (1 ppm) and Mo (0.1 %) recorded higher yield over control in a micronutrient deficient soil.

Jayaraj and Chandrasekharan (1997) reported that foliar application of 0.5 % zinc sulphate at panicle initiation, boot leaf and 50 % flowering accumulated more dry matter leading to more grain and straw yields during *kharif*. Spraying of 0.2 % zinc sulphate at 20 and 30 DAT recorded the highest grain yield in rice (Rajendra Prasad *et al.*, 1997).

Application of micronutrient combinations either in chelated or non-chelated forms of Fe, Mn, Zn and Cu gave greater biological and grain yields than individual applications of the micronutrients (Modaihsh, 1997). Binod Kumar *et al.* (1998) reported that better results in rice were obtained by spraying with 0.5 % zinc sulphate at third and fifth week after transplanting.

Jalali (1998) reported that three foliar sprays of 1.0 % zinc sulphate applied at 40, 50 and 60 DAT were significantly effective in increasing the rice yield. Foliar application of 0.5 % zinc sulphate at 20 and 50 DAT increased the yield (Mathew, 1998). Five foliar sprays of 1.0 % ferrous sulphate starting from three weeks after transplanting at 7 days interval produced more straw and grain yields of rice (Singh *et al.*, 1988).

Foliar application of 0.5 % zinc sulphate at 30 and 45 DAT increased the grain and straw yields (Sharma *et al.*, 1999). Gangiah and Prasad (1999) found that application of NPK plus two foliar application of Fe solution increased straw and grain yield over control.

Application of 0.5 % zinc sulphate as foliar spray at 50 % flowering and at 10 days after first spray increased the grain yield 5.78 % over control (Kamaraj, 2001). Marchezan *et al.* (2001) observed that foliar application of micronutrients at tillering and flowering stage increased the yield of rice. Sakal and Singh (2001) observed that foliar spray of 2 % FeSO₄ supplemented with 0.2 % citric acid solution increased grain yield over control.

Sankaran *et al.* (2001) reported that foliar application of 0.5 % ZnSO₄ increased the grain yield over control.

Singh *et al.* (2002) found that foliar application of Zn as ZnSO₄ increased the DMP of rice significantly over control. Application of recommended dose of NPK fertilizers along with 10 t FYM ha⁻¹ + 45 kg ha⁻¹ ZnSO₄ produced maximum rice grain yield (Jadhav *et al.*, 2003).

Kalyan Singh *et al.* (2003) reported that foliar application of 1.0 % FeSO₄ increased the grain yield of rice.

Zhu *et al.* (2004) reported that micronutrient deficiencies are very common under salt stress owing to high pH. Soil fertility is an important factor, which determines the growth of plant. Soil fertility is determined by the presence or absence of nutrients i.e macro and micronutrients, which are required in minute quantities for plant growth. Micronutrients also enhances plant productivity, leaf area and grain yield as result of enhancing the enzymatic system of plants. The factors that affect the contents of such micronutrients are organic matter, soil pH, lime content, soil salinity and others.

Natarajan (2004) reported that the treatment with MnSO_4 @ 25 kg ha⁻¹ and CuSO_4 @ 5 kg ha⁻¹ with recommended dose of NPK in the thaladi season increased the grain yield of rice.

Yong Fang *et al.* (2007) reported that foliar application of zinc, selenium and iron increased the yield of rice.

Maralian Habid (2009) showed that foliar application of Zn and Fe increased seed yield of wheat and its quality compared with control. Among treatments, application of (Fe + Zn) recorded the highest seed yield and quality.

Zayed *et al.* (2011) found that dry matter production, leaf area index and chlorophyll content (SPAD value) as well as plant height and various yield attributes were significantly higher in rice cv.Sakha101 moderately salt tolerant variety when received the micronutrient application.

2.3.2 Foliar spray with pulse sprout extract

There is an amazing increase in nutrients in sprouted seeds when compared to their dried embryo. In the process of sprouting, the vitamins, minerals and protein increase substantially with corresponding decrease in calories and carbohydrate content. The increase in protein availability is of great significance. It is a valuable indicator of the enhanced nutritional value of a food when sprouts. The remarkable increase in sodium content supports the view that sprouts offer nutritional qualities. The infinite increase in ascorbic acid derives from their absorption of atmospheric elements during growth (Chavan and Kadam, 1989).

Sprouting grains causes increased activities of hydrolytic enzymes, improvements in the contents of total proteins, fat, certain essential amino acids, total sugars, B-group vitamins and

a decrease in dry matter, starch and anti-nutrients. The increased contents of protein, fat, fibre and total ash are only apparent and attributable to the disappearance of starch. However, improvements in amino acid composition, B-group vitamins, sugars, protein and starch digestibilities, and decrease in phytates and protease inhibitors are the metabolic effects of the sprouting process (Chavan and Kadam, 1989).

Subbarao *et al.* (2001) expressed that priming seeds with sodium molybdate 0.5 g^{-1} improved the seed yield of rice fallow pulses.

Vijayalakshmi, (2009) reported that spraying of 2 % cowpea seed extract during active tillering and grain formation stage recorded the maximum values for panicle length , number of seeds panicle⁻¹ and 1000 seed weight in rice.

2.4. Effect of salinity/sodicity on physiological and biochemical parameters.

2.4.1. Physiological parameters

2.4.1.1. Chlorophyll Content

Chlorophyll content and photosynthetic function were inversely proportional to salinity level (Ota and Yasue, 1962), (Garg and Garg, 1985) reported a marked reduction in chlorophyll content with the increasing levels of salinity.

Krishnamurthy *et al.* (1987) reported the reduction in chlorophyll content due to salt stress in rice. Ashraf *et al.* (1988) reported that salinity reduced significantly leaf chlorophylls and also the protein and carbohydrate contents in different plant parts of mung bean.

Nieves *et al.* (1991) reported a decrease in chlorophyll content when plants were grown in saline conditions. Total chlorophyll and chlorophyll a were higher in both susceptible and tolerant cultivars of rice and chlorophyll b was higher only in salt tolerant rice cultivars grown in saline medium than compared to control and chlorophyll a/b was lower in salt tolerant and high in susceptible cultivars grown in saline medium (Peiris and Anoma Ranasinghe, 1993).

Sodicity also showed its adverse effect on chlorophyll 'a' and 'b' content and the reduction in chlorophyll 'a' and 'b' contents with increasing soil sodicity was found at all stages

of crop growth. Increasing ESP and reduced chlorophyll 'a' and 'b' contents most at 60 and 90 DAS, respectively in lentil (Tewari and Singh, 1991).

The chlorophyll content decreased beyond 0.6 per cent NaCl in sunflower and 0.4 per cent in case of mung bean (Saha and Gupta, 1993).

Chlorophyll pigment is responsible for photosynthesis. Thus, its destruction under salt stress is deleterious to plant productivity. Salinity caused a major decline in the chlorophyll.

Khavari-Nejad and Mostofi (1998) suggested that the total contents of chlorophyll (a+b) and chlorophyll 'a' decreased in tomato cultivars when treated with 100mM NaCl.

Salinity decreased the total chlorophyll content in rice (Pushpam and Rangasamy, 2000) pearl millet (Albassam, 2001) and maize (Demiroglu *et al.*, 2001)

Badr and Albassam (2001) reported that salinity (0, 25, 50, 100 mM NaCl) decreased the amount of chlorophyll 'a' and 'b' and total chlorophyll content in leaves of pearl millet however, application of nitrate (2 and 10 mM) increased the chlorophyll 'a', 'b' and total chlorophyll content under salinity.

Sahoo *et al.* (2001) found decreased accumulation of chlorophyll content in the leaves of both salt sensitive (Ratna) and salt tolerant (Geta) cultivars of rice with increased levels of salinity from control (0 mM NaCl) to 25, 50, 100, 200 mM NaCl. The trend was more pronounced in the susceptible cultivars than tolerant cultivars.

Ashraf *et al.* (2002) reported that total chlorophyll and its fractions 'a' and 'b' contents decreased with increased salinity (0, 100 and 200 mol m⁻³ NaCl) in two spring wheat cultivars, Barani-83 (salt sensitive) and SARC-1 (salt tolerant). However, foliar application of GA₃ (100 mg l⁻¹) enhanced both the pigments in Borani-83 but, total chlorophyll in both the lines.

El-Tayeb (2005) found that Barley seeds presoaked with 1mM salicylic acid (SA) under salinity (0, 50, 100, 150, 200 mM NaCl) increased the photosynthetic pigment like chlorophyll 'a', 'b' and carotenoids in shoots and roots of 15 days old seedlings compared to seedlings treated with NaCl alone.

Mannan *et al.* (2009) reported that in soybean salt tolerant (AGS313) and salt-susceptible (Shohag) varieties of soybean, the proline accumulation was increased and chlorophyll 'a', 'b' and total chlorophyll were decreased in leaves with increased salinity level (100 mM).

Farahbakhsh and Shamsaddin (2011) primed maize seeds with 0.0, 0.5 and 1.0 M NaCl and tested at salinity levels of 0, 4, 8 and 12 dsm⁻¹. They observed that increase in salinity reduced the shoot dry weight and chlorophyll content. Whereas, 0.5M NaCl priming registered higher seedling dry weight and chlorophyll content.

2.4.1.2. Chlorophyll stability index

Chlorophyll stability index has been used as an indicator of stress tolerance in rice as reported by Michael Gomez and Rangasamy (2002) and Yogameenakshi *et al.* (2003).

2.4.1.3. Sodium and potassium ions content

In saline soils, availability of P decreases due to precipitation of applied phosphorus, higher retention of soluble phosphorus and antagonism due to excess Cl⁻ and SO₄⁻ restricted root growth in tomato plant (Chabbra *et al.*, 1976).

The maintenance of higher concentrations of nitrogen, phosphorus, potassium and lower concentration of sodium in the salt stressed plants are essential to overcome nutrient imbalance and carry out their normal physiological processes. This phenomenon has also been observed in wheat (Garg *et al.*, 1990) grown under saline water irrigation.

The common salt NaCl is often the most abundant salt in saline soils. This compound in higher concentrations causes water deficit, ion toxicity, ion imbalance or a combination of these factors. A major part of the NaCl induced growth inhibition is caused by excess sodium ions. There is a natural tendency in all the cells to accumulate potassium and exclude Na ions for maintaining favourable K⁺/Na⁺ ratios. Presence of higher concentrations of Na⁺ in the growth medium upsets this balance. Excess Na⁺ may compete with K⁺ in membrane transport and when accumulated in the cytoplasm, it inhibits many enzymes (Parker *et al.*, 1997).

Specific effects of salt stress on leaf senescence have been related to the accumulation of toxic ions (Na⁺ and Cl⁻) or to K⁺ and Ca⁺⁺ depletion (Yeo and Flowers, 1982). Salt-tolerant cultivars of rice accumulate less Na, Cl, Zn and proline and more K at root and shoot levels than salt-sensitive varieties (Fischer, 1996).

Varshney *et al.* (1998) observed that salinity caused a significant increase in Na content of shoot while K remained almost unaltered in three chickpea cultivars. Besides K/Na ratio, Ca, Mg and total N contents also decreased. However, chickpea cultivar ICC 4948 having the highest K/Na ratio was the most tolerant cultivar compared to ICC 4951 and ICC 6098.

Jumberi *et al.* (2002) reported that Na concentration in the shoots of the vegetable crops was higher with higher ESP in sodic soil.

Barley seeds presoaked with 1 mM salicylic acid under salinity (0, 50, 100, 150 and 200 mM NaCl) increased accumulation of potassium, calcium, phosphorus and decreased the accumulation of sodium in both shoots and roots of 15 days old seedlings with increased salinity level (El-Tayeb, 2005).

Ndayiragije and Lutts (2006) reported that exogenous application of putrescine (1 and 10 mM) in rice in presence of NaCl (0, 150 and 300 mM) decreased the Na⁺ and Cl⁻ accumulation and increased the K⁺ and CO₂⁺ accumulation compared to control plants.

2.4.2. Biochemical parameters

2.4.2.1. Soluble protein

Saha and Gupta (1998) observed a drastic reduction in the level of soluble protein content due to salinity in mung bean plants.

Salt stress significantly decreased soluble protein content after exposure to 50, 100 and 150 mM NaCl and the effect was aggravated with time from 42 to 72 hr in *Phaseolus vulgaris* (Fusun *et al.*, 2004).

2.4.2.2. Nitrate reductase activity (N R'ase)

The effect of salt stress on nitrate reductase activity may be attributed to inhibition of enzyme induction. It has been reported that stress causes a shift of ribosomes from the polymeric to the monomeric form in maize seedlings (Hsiao, 1970). Although, sodium and potassium ions are essential for the synthesis and activity of nitrate reductase, their salts are strong inhibitors (Hewitt, 1975). Limited substrate availability in the leaves, resulting from inhibition of NO₃⁻ uptake (Trogisch *et al.*, 1989; Lacuesta *et al.*, 1990), is another reason for lower activity of nitrate reductase under salt stress.

Rao and Gnanam (1990) found that in sorghum nitrate reductase activity is known to be highly sensitive to salt stress.

Khan (1996) found that nitrate reductase (NR) and nitrite reductase activities were substantially declined in leaves and roots of two soybean genotypes grown under varied amount of NaCl and Na₂CO₃ salts (0-12 dSm⁻¹). Sodium carbonate proved more inhibitory than NaCl to both the enzymes and further, leaves showed higher levels of nitrate reductase and nitrite reductase activity than roots, however, the salt induced inhibition was higher in leaves.

Richharia *et al.* (1997) reported that NaCl salinity level of 7 and 14 dsm⁻¹ significantly inhibited NRase activity Campbell (1999) reported that salinity may strongly affect the overall nitrate assimilation process because nitrate is required to induce nitrate reductase, the key enzyme of nitrogen assimilation process.

Badr and Albassam (2001) reported that the activities of nitrate reductase, nitrite reductase and glutamate synthetase were reduced under salinity (0, 25, 50 and 100 mMNaCl) but, among then glutamate synthetase activity was less affected in pearl millet However, application of nitrate (10 mM) in irrigation solution partially restored the activities of above enzymes.

A sharp reduction in the activity in the activity of nitrate reductase and nitrogenase in shoots and roots of two maize cultivars (cv. 323 and cv. 324) was noticed under different salinity levels (-0.2, -0.6, -1.0 and -1.6 MPa). However, *Azospirillum* inoculation at seedling stage stimulated nitrate reductase and nitrogenase activity in both shoots and roots of both cultivars of maize (Abd El-Samad Hamidia *et al.*, 2004).

2.4.2.3. Proline accumulation

Accumulation of free proline under stress conditions has been taken as criteria to screen genotypes for drought and salinity tolerance. Lutts *et al.* (1996) reported that salt-resistant cultivars accumulate lower amounts of free proline than salt sensitive ones in rice.

Singh and Singh (1999) reported that the proline content increased with increase in salinity levels (0, 4, 8 dSm⁻¹) in shoots of tolerant genotypes (SG-11 and DHG-84-11) compared to susceptible genotypes (Pusa-256 and Phule G-5) in chickpea.

Lin and kao (2000) found that proline accumulation is considered as a contributor to NaCl inhibited root growth.

Sahoo *et al.* (2001) found that salinity levels at 0, 25, 50, 100, 150 and 200 mM NaCl significantly enhanced the rate of proline accumulation in the leaves of both salt sensitive (Ratna) and salt tolerant (Geta) cultivars of rice with increased salinity and the trend was more pronounced in the tolerant than the sensitive cultivar.

Anuradha and Seetarama Rao (2002) found that the rice seedlings subjected to salinity stress showed increase in proline content and further supplementing NaCl (150 mM) with brassino steroids at 0.5, 1.0, 3.0 μ M still enhanced the proline content.

Filiz *et al.* (2004) reported that free proline in seedlings of IR 28 rice cultivar increased under salt stress (120 mM NaCl), however, 24-epibrassinolide (3 μ M) seed treatment caused significant decrease in free proline content.

Ayliffe *et al.* (2005) noted the presence of proline and demonstrated the importance of accumulation and degradation of proline in the mechanisms of tolerance to abiotic stress namely drought and salt.

2.4.2.4. Anti oxidants

An important consequence of salinity stress in plants is the excessive generation of reactive oxygen species (ROS) such as super oxide anion (O_2^-), H_2O_2 and the hydroxyl radicals ($OH^\cdot$) particularly in chloroplast and mitochondria (Mittler, 2002; Neill *et al.*, 2002). Plants under stress produce some defense mechanisms to protect themselves from the harmful effect of oxidative stress. ROS scavenging is one of the common defense responses against abiotic stresses (Vranova *et al.*, 2002).

Irfan Afzal *et al.* (2006) reported that two wheat varieties Auqab 2000 (salt tolerant) MH-97(salt sensitive) were given hydropriming and halopriming treatment with 50mM $CaCl_2$ ascorbate priming 50 mg l^{-1} and found that halopriming increased super oxide dismutase and catalase activities in both cultivars under stress.

Primed seeds had less lipid peroxidation and higher super oxide dismutase (SOD) and catalase (CAT) activities than non-primed rice seeds. Amylase activities and starch breakdown were also hastened in primed seeds (Evangelina *et al.*, 2012).

Ijaz Ahamed *et al.* (2012) they reported that maize hybrid seeds primed with 20 mg⁻¹ of ascorbic acid, salicylic acid and hydrogen peroxide registered improved germination speed shoot and root growth and higher antioxidant enzyme activity.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present investigation was carried out primarily for screening the priming treatments, standardization of soaking durations and treatment concentrations to mitigate the sodicity and salinity stress and to understand the physiological and biochemical means of sodicity and salinity tolerance in rice. An attempt was also made to alleviate the sodicity and salinity stress with seed priming combined with foliar spray of nutrients. The research work was carried out during 2010-2012 through laboratory and field experiments. A brief account of the materials used and methodologies followed in different experiments in the present study are presented below.

3.1. MATERIALS

Genetically pure rice seeds of two varieties viz., TNAU Rice TRY 3 and Improved White Ponni obtained from the Department of Plant Breeding and Genetics, ADAC&RI, Trichy formed the basic materials for the study. The bio-control agent *Pseudomonas fluorescens* obtained from the Department of Plant Protection, ADAC&RI, Trichy and liquid bio-fertilizer *Azophos* obtained from the Department of Agricultural Microbiology, TNAU, Coimbatore were used for this study.

The laboratory experiments were carried out in Seed Science and Technology laboratory, Department of Plant Breeding and Genetics, ADAC&RI, Trichy while the field experiments were carried out at Research farm of Department of Plant Breeding and Genetics, ADAC&RI, Trichy and Krishi Vigyan Kendra, Sikkal, Nagapattinam districts.

Salt affected soils are classified as non-saline / non-sodic soils with pH < 8.5, ESP $\leq 15\%$ and EC $\leq 4 \text{ dSm}^{-1}$, saline soil with pH - 8.5, ESP $\leq 15\%$ and EC $> 4 \text{ dSm}^{-1}$ and sodic soils with pH > 8.5, ESP > 15% and EC $\leq 4 \text{ dSm}^{-1}$ (USDA, 1954).

3.2. METHODS

3.2.1. Standardization of concentration and soaking duration for seed priming treatments in rice.

To standardize the concentration and soaking duration of the priming agents on effectiveness of germination and seedling growth of rice seeds of two varieties viz., TNAU

Rice TRY 3 and I.W.Ponni, solutions of various priming agents were prepared as detailed below:

Treatment details:

T ₀ : Control	T ₁₁ : GA ₃ 20 ppm
T ₁ : Hydropriming	T ₁₂ : IBA 10 ppm
T ₂ : Halopriming with CaCl ₂ 0.5%	T ₁₃ : IBA 20 ppm
T ₃ : Halopriming with CaCl ₂ 1.0%	T ₁₄ : <i>Pseudomonas fluorescens</i> 0.5 %
T ₄ : CaSO ₄ 0.5%	T ₁₅ : <i>Pseudomonas fluorescens</i> 1.0%
T ₅ : CaSO ₄ 1.0%	T ₁₆ : Azophos 0.5%
T ₆ : ZnSO ₄ 0.5%	T ₁₇ : Azophos 1.0%
T ₇ : ZnSO ₄ 1.0%	T ₁₈ : Pungam leaf extract 0.5%
T ₈ : FeSO ₄ 0.5%	T ₁₉ : Pungam leaf extract 1.0%
T ₉ : FeSO ₄ 1.0%	
T ₁₀ : GA ₃ 10 ppm	

Soaking duration : D₁- 12 h D₂- 18 h

Varieties : V₁ – TNAU Rice TRY 3 V₂- I.W.Ponni

Initially, the rice seeds were dried to bring down the moisture content to less than 13 per cent and then cleaned with the help of suitable sieves and winnowed to obtain uniform sized seeds.

The seeds were surface sterilized with 10% ethanol and soaked in double the volume of priming agents' solution for 12 and 18h durations. For hydropriming water was used for soaking the seeds. The unprimed seeds formed the control.

After soaking, the seeds were removed from respective priming solutions and dried under shade at room temperature to bring back to original moisture content. The primed seeds were evaluated for the following seed and seedling characters along with unprimed seeds.

The experiment was carried out with four replications in Factorial Completely Randomised Design (FCRD).

3.2.1.1. Germination

The germination test was conducted by following the procedure outlined in ISTA (1999) using paper (Between papers) medium. Four replicates of 100 seeds each were

germinated in a seed germinator maintained at $25 \pm 2^\circ\text{C}$ temperature and $95 \pm 3\%$ RH. After fourteen day, the seedlings were evaluated and the normal seedlings were counted and expressed in percentage.

3.2.1.2. Speed of germination

Four replicates of twenty five seeds each were used to test the speed of germination of seeds from different treatments. The seeds showing radicle protrusion were counted daily from third day after sowing until fourteenth day. From the number of seeds germinated on each day, the speed of germination was calculated using the following formula and the results were expressed in number (Maguire, 1962).

$$\text{Speed of germination} = \frac{X_1}{Y_1} + \frac{X_2 - X_1}{Y_2} + \dots + \frac{X_n - X_{n-1}}{Y_n}$$

X_1 - Number of seeds germinated at first count

X_2 - Number of seeds germinated at second count

X_n - Number of seeds germinated on n^{th} day

Y_1 - Number of days from sowing to first count

Y_2 - Number of days from sowing to second count

Y_n - Number of days from sowing to n^{th} count

3.2.1.3. Root length

At the time of germination count, ten normal seedlings were selected at random from each replication and used for measuring the root length of seedlings. Root length was measured from the point of attachment of seed to the tip of primary root. The mean values were calculated and expressed in centimetre.

3.2.1.4. Shoot length

The seedlings used for measuring root length were also used for measuring shoot length. The shoot length was measured from the point of attachment of seed to tip of the leaf and the mean values were expressed in centimetre.

3.2.1.5. Drymatter production

After measuring the root and shoot lengths, ten normal seedlings in each replication were shade dried for 24 h and then in hot air oven maintained at $85 \pm 1^\circ\text{C}$ for 24 h. Then they

were cooled for 30 min in desiccators which contained calcium chloride and then weighed in an electronic balance. The drymatter production was expressed in g seedlings⁻¹⁰.

3.2.1.6. Vigour index (Abdul-Baki and Anderson, 1973)

Vigour index (VI) was computed using the following formula and expressed as whole number.

$$VI = \text{Germination per centage} \times \text{Seedling length (cm)}$$

3.2.2 Preliminary screening of seed priming treatments under sodicity and salinity stress conditions

The best performing treatments and soaking durations observed in the experiment 3.2.1. were tried with various priming agents as a combination treatments consisting of macro and micro nutrients, growth regulators and bio control agents as detailed below. Since Potassium chloride is recommended nutrient for seed priming it is included as one of the priming treatment.

3.2.2.1 Treatments

T₀ : Unprimed seed

T₁: Seed priming with 1% KCl

T₂: Seed priming with 1% mixture of CaSO₄+ZnSO₄+FeSO₄

T₃: Seed priming with 1% mixture of CaSO₄+ZnSO₄+FeSO₄ +GA₃ 20 ppm

T₄: Seed priming with 1% mixture of CaSO₄+ZnSO₄+FeSO₄ +GA₃20 ppm +Azophos 1.0%

T₅: Seed priming with 1% mixture of CaSO₄+ZnSO₄+FeSO₄+ GA₃20 ppm +Azophos1 % + *Pseudomonas fluorescens* 1.0 %

T₆: Seed priming with 1% mixture of KCl+ CaSO₄+ZnSO₄+FeSO₄ +GA₃20 ppm +Azophos 1.0 %

T₇: Seed priming with 1% mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃20ppm + Azophos 1.0 % + *Pseudomonas fluorescens* 1.0 %

The above combination treatments were tested under different sodicity and salinity levels as detailed in Table 1. The sodicity and salinity stress were created by dissolving sodium bicarbonate (NaHCO₃) and sodium chloride (NaCl), respectively in distilled water at the levels indicated in Table.1. The pH and EC maintained at each stress level are mentioned in Table 1.

The seeds of TNAU Rice TRY3 and I.W.Ponni were given priming treatment as detailed in 3.2.2.1 by soaking seeds for 18h and tried back to original moisture content. The primed seeds along with unprimed were germinated in paper media soaked in salt solutions for imposing three levels of sodicity and salinity stress each as indicated in Table 1. The control was maintained by using distilled water. The experiment was carried out with four replications in Factorial Completely Randomised Design (FCRD). The primed seeds were evaluated for the following germination and seedling characters.

3.2.2.1. Germination : as detailed in 3.2.1.1.

3.2.2.2. Speed of germination : as detailed in 3.2.1.2.

3.2.2.3. Root length : as detailed in 3.2.1.3.

3.2.2.4. Shoot length : as detailed in 3.2.1.4.

3.2.2.5. Drymatter Production : as detailed in 3.2.1.5.

3.2.2.6. Vigour Index : as detailed in 3.2.1.6.

Table 1: pH and EC of the salt solution used for screening experiment under sodicity (25 mM and 50 mM) and salinity (50 , 100 and 150 mM) stress levels

S.No	Sodicity stress level	pH	EC (dSm ⁻¹)
1.	0 mM	7.10	0.15
2.	25 mM	10.03	3.72
3.	50 mM	10.4	6.90
	Salinity stress level		
1.	50 mM	7.90	4.60
2.	100 mM	8.15	8.62
3.	150 mM	8.25	12.02

3.2.3. Final screening of seed priming treatments under further finetuned sodicity and salinity stress conditions

Since the sodicity levels imposed in previous experiment found to be high, the sodicity levels were reduced as detailed in Table.2. The best performing seed priming treatments of preliminary screening experiment (3.2.2) were selected and the seeds of TNAU Rice TRY3 and I.W.Ponni were given priming treatments by soaking the seeds in double the

volume of solution for 18 h duration and dried back to original moisture content. The experiment was carried out with four replications in Factorial Completely Randomised Design (FCRD). The primed seeds were evaluated for the following germination and seedling characters.

Table 2. pH and EC of the salt solution used for screening experiment under sodicity (14,16 and 18 mM) and salinity (125, 150 and 175 mM) stress levels

S.No	Sodicity stress level	pH	EC (dSm ⁻¹)
1.	0 mM	7.10	0.15
2.	14 mM	7.80	1.54
3.	16 mM	9.11	1.62
4.	18 mM	9.13	1.73
	Salinity stress level		
1.	125 mM	7.74	10.72
2.	150 mM	8.25	12.02
3.	175 mM	8.76	12.70

T₀ : Unprimed seed

T₁ : Seed priming with 1 % mixture of CaSO₄+ZnSO₄+FeSO₄

T₂ : Seed priming with 1 % mixture of CaSO₄+ZnSO₄+FeSO₄ +GA₃ 20 ppm +Azophos 1.0 %

T₃ : Seed priming with 1 % mixture of KCl+ CaSO₄+ZnSO₄+FeSO₄ +GA₃ 20 ppm +Azophos 1.0 %

T₄ : Seed priming with 1% mixture of KCl+ CaSO₄+ZnSO₄+FeSO₄ +GA₃ 20 ppm +Azophos 1.0% +
Pseudomonas fluorescens 1.0 %

3.2.3.1. Germination : as detailed in 3.2.1.1.

3.2.3.2. Speed of germination : as detailed in 3.2.1.2.

3.2.3.3. Root Length : as detailed in 3.2.1.3

3.2.3.4. Shoot Length : as detailed in 3.2.1.4

3.2.3.5. Drymatter production : as detailed in 3.2.1.5

3.2.3.6. Vigour index : as detailed in 3.2.1.6.

3.2.3.7. Stress tolerance index

Stress tolerance index was calculated using the following formula proposed by Dhopte and Livera (1989) and expressed as per cent

$$\text{Stress tolerance index} = \frac{\text{Vigour index of the treated seedling}}{\text{Vigour index of the control seedling}} \times 100$$

3.3. Effect of comprehensive seed priming treatments on alleviating sodicity and salinity stress at field level

Field experiments were carried out during July 2011 to January 2012 to study the effect of seed priming on alleviating the adverse effect of sodicity and salinity stress in rice in two locations as detailed below.

3.3.1. Location

For testing the seed priming treatments under sodic condition a field experiment was conducted during late July to December 2011 in ADAC& RI, TNAU, Trichy which is located at 10° N latitude and 78°E longitude at an altitude of 85 m above MSL. For testing the effect of seed priming under salinity condition a field experiment was laid out at Krishi Vigyan Kendra, Sikkal, Nagapattinam district. It is a coastal district of Tamil Nadu, lies between 10° 8' and 11°28' N latitude and 76°34' and 75°53' E longitude.

3.3.2. Soil characteristics

The soil of ADAC & RI, Trichy is naturally sodic clay loam in condition and Krishi Vigyan Kendra, Sikkal is saline sandy clay loam. The mechanical compositions and chemical properties of the soil from both the locations were analysed before the start of the experiment and data are presented in Table 3.

Table 3. Soil characteristics of the experimental fields at ADAC&RI, Trichy and KVK, Sikkal

Soil Characteristics	ADAC&RI	KVK, Sikkal
	Mechanical composition	
Coarse sand (%)	4.04	10.60
Fine sand (%)	5.03	35.40
Silt (%)	21.00	22.50

Clay (%)	68.50	31.30
Textural class	Clay loam	Sandy Clay loam
Chemical composition		
pH	9.5	7.5
EC (dSm ⁻¹)	0.45	4.5
ESP (%)	20.31	--
Exc.Ca+Mg (c mol kg ⁻¹)	14.12	--
Exc.Na(c mol kg ⁻¹)	10.14	--
Available nitrogen (kg ha ⁻¹)	189	126
Available phosphorus (kg ha ⁻¹)	15.33	9.3
Available potassium (kg ha ⁻¹)	364	112

Table 4. Weather parameters during the experimental period at ADAC&RI, Trichy and KVK, Sikkal

Month	Maximum temperature (°C)		Minimum temperature (°C)		Relative humidity (%)		Rainfall (mm)	
	ADAC&RI Trichy	KVK, Sikkal	ADAC&RI Trichy	KVK, Sikkal	ADAC&RI Trichy	KVK, Sikkal	ADAC&RI Trichy	KVK, Sikkal
July	35.8	--	26.3	--	81.2	--	8.2	--
August	35.4	33.6	25.7	25.4	77.6	76.2	3.6	58.0
September	35.8	34.1	23.8	25.4	84.2	76.3	4.7	37.5
October	35.6	34.1	25.2	25.4	86.2	76.3	11.1	267.5
November	35.3	29.2	22.3	23.7	86.2	88.3	8.8	349.5
December	33.6	28.5	22.5	22.2	93.1	86.7	6.9	100.5
January	--	28.7	--	20.8	--	84.1	--	5.0

3.3.3. Fertilizer application

Recommended dose of 150: 50: 50 kg ha⁻¹ of nitrogen, phosphorus and potassium in the form of urea (46 per cent N), Diammonium phosphate (18 per cent N, 46 per cent P₂O₅) and Muriate of potash (60 per cent K₂O) were applied. Full dose of phosphorus was applied

basally before transplanting. The nitrogen and potassium were applied in four equal splits at basal, active tillering, panicle initiation and heading stages of rice crop.

3.3.4. Experiment details:

The details of treatments and symbols used are presented below.

Main plot

M₁ : TNAU Rice TRY 3

M₂ : I. W. Ponni

Sub plot

S₁ : Control

S₂ : Seed priming with 1 % mixture of CaSO₄+ZnSO₄+FeSO₄

S₃ : Seed priming with 1% mixture of CaSO₄+ZnSO₄+FeSO₄ + GA₃ 20 ppm +Azophos 1.0 %

S₄ : Seed priming with 1% mixture of KCl + CaSO₄+ ZnSO₄+ FeSO₄ + GA₃ 20 ppm
+ Azophos 1.0 %

S₅ : Seed priming with 1% mixture of KCl + CaSO₄+ ZnSO₄+ FeSO₄ + GA₃ 20 ppm
+ Azophos 1.0% + *Pseudomonas fluorescens* 1.0 %

S₆ : Seed priming with 1% mixture of CaSO₄ + ZnSO₄ + FeSO₄ + foliar spray of 0.5% FeSO₄

S₇ : Seed priming with 1% mixture of CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1%
+ foliar spray of 0.5% ZnSO₄

S₈ : Seed priming with 1% mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 +Azophos
1% foliar spray of 2 % DAP

S₉ : Seed priming with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm
+Azophos 1% +*Pseudomonas fluorescens* 1% foliar spray of 2% cowpea pulse sprout
extract

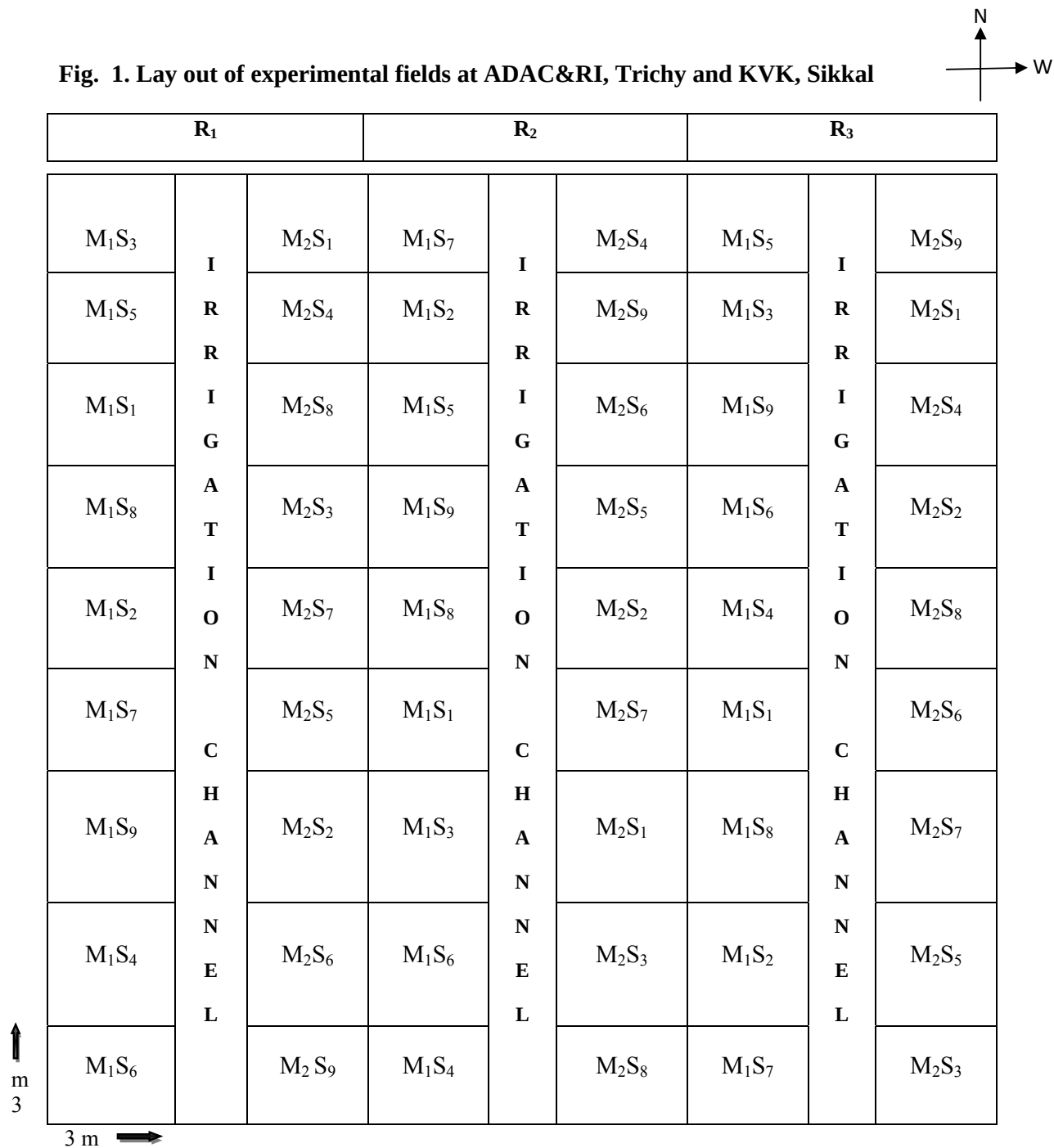
Design : Split plot

Replications : Three

Spacing : 20 x 10 cm

Plot size : 3 x 3 m

Fig. 1. Lay out of experimental fields at ADAC&RI, Trichy and KVK, Sikkal



The foliar spraying was given at active tillering and panicle initiation stages.

All the recommended package of practices were followed during crop growth period to raise a good healthy crop under sodic as well as in saline conditions.

3.3.5. Biometric observations

The biometric characters were recorded at maturity stage by selecting five representative samples at random from each replication under sodicity as well as in salinity. The methods followed in recording the observations are described below.

3.3.5.1. Days to first flowering

The number of days taken from the date of sowing to first flowering was counted and the mean values were expressed in days.

3.3.5.2. Days to 50 per cent flowering

The number of days taken for attaining 50 per cent flowering in a population was observed and recorded.

3.3.5.3. Number of total tillers

The total number of tillers in each hill was counted and the mean was expressed in number of tillers plant⁻¹.

3.3.5.4. Number of productive tillers

The number of ear bearing tillers in each hill at the time of maturity was counted and recorded.

3.3.5.5. Plant height

Plant height was measured from the ground level to the tip of the matured panicle was measured and expressed in cm.

3.3.5.6. Panicle length

The distance between the base to the tip of the randomly selected panicles measured with linear scale and the mean was expressed in cm.

3.3.5.7. Number of seeds panicle⁻¹

The numbers of fully developed and well filled seeds in each randomly selected panicle were counted and mean number of seeds panicle⁻¹ was recorded.

3.3.5.8. Seed set (%)

The matured seeds and unfilled –chaffy seeds from randomly selected panicles were separated and counted individually. The mean seed set per cent was calculated using the following formula.

$$\text{Seed setting (\%)} = \frac{\text{Total number of filled spikelets per panicle}}{\text{Total number of spikelets per panicle}} \times 100$$

3.3.5.9. Seed yield plant⁻¹

All the seeds extracted from selected single plants were cleaned, dried, processed, weighed at 13 per cent moisture content and expressed in grams.

3.3.5.10. Seed yield plot⁻¹

Seeds from net plot were cleaned sun dried and weighed at 13 per cent moisture content and seed yield was measured and expressed in kg plot⁻¹

3.3.5.11. Seed yield ha⁻¹

The seeds were harvested separately plot wise, weighed and computed for unit area and expressed in kg ha⁻¹

3.3.5.12. 100 seed weight

From each selected plant, one hundred well filled seeds selected at random were weighed and expressed in grams.

3.3.6. Physiological and biochemical observations

The leaf samples were collected during active tillering and panicle initiation stages from all the experimental plots and following physiological and biochemical observations were recorded.

3.3.6.1. Chlorophyll content (Chlorophyll 'a', Chlorophyll 'b', and Total Chlorophyll)

For estimation of chlorophyll 250 mg of leaf sample was taken and transferred to a pestle and mortar. The sample was macerated with 10 ml of 80% acetone, centrifuged the content at 3000 rpm for 10 minutes. The optical density measured at 645, 652 and 663 nm by an Optima UV-VIS spectrophotometer (Model SP-3000). The chlorophyll content of the sample was expressed as mg g⁻¹ of fresh weight (Yoshida *et al.*, 1971).

Formula for calculation of Chlorophyll 'a', 'b' and Total Chlorophyll

$$\text{Chlorophyll 'a'} = (12.7 \times \text{OD at 663}) - (2.69 \times \text{OD at 645}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll 'b'} = (22.9 \times \text{OD at 645}) - (4.68 \times \text{OD at 663}) \times \frac{V}{1000 \times W}$$

$$\text{Total Chlorophyll} = \frac{\text{OD at 652} \times 1000}{34.5} \times \frac{V}{1000 \times W}$$

Where,

OD	=	Optical Density
V	=	Final volume of supernatant (25 ml)
W	=	Weight of the leaf sample taken in gram

3.3.6.2. Chlorophyll stability index

Chlorophyll stability index (CSI) in leaf was estimated by spectrophotometric method as suggested by Kolyroas (1958).

Leaf sample (0.5gm) from middle portion of the third leaf was collected from the selected plants and put in a test tube containing 10 ml of water. This was placed in a water bath at a temperature of 65°C for an hour (treated). After one hour the leaf bits were macerated with 10 ml of 80 per cent acetone. It was then centrifuged at 3000 rpm for 10 minutes. The supernatant solution was taken and the volume was made upto 10 ml using 80 per cent acetone. The optical density read at 652 nm in spectrophotometer. For control (untreated) the leaf bits of same weight were put in a test tube containing 10 ml of distilled water and kept in ambient temperature for one hour and the above procedure was repeated. CSI was calculated as follows:

$$\text{CSI} = \frac{\text{OD value of heated sample}}{\text{OD value of unheated sample (control)}} \times 100$$

3.3.6.3. Sodium

Sodium content in leaf samples were analysed by flame photometrically using triple acid method (Jackson, 1973) and expressed as mg/gm on dry weight basis.

3.3.6.4. Potassium

Potassium content in leaf samples were analysed by flame photometrically using triple acid method (Jackson, 1973) and expressed as mg/gm on dry weight basis.

3.2.6.5. Sodium Potassium Ratio

Sodium Potassium ratio in leaf samples were worked out, based on the sodium and potassium content.

3.3.6.6. Soluble protein content

Soluble protein content of leaf was estimated as per the method of Lowry *et al.* (1951) and expressed as mg g⁻¹ fresh weight.

3.3.6.7. Proline content

Proline content of the leaf was estimated as per the method of Bates *et al.* (1973) and expressed as µg g⁻¹ fresh weight.

3.3.6.8. Nitrate reductase activity

Nitrate reductase activity was estimated in fully expanded functional leaves following the method of Nicholas *et al.* (1976) and the enzyme activity was expressed as µ moles NO₂⁻ g⁻¹ h⁻¹.

3.3.6.9. Catalase and peroxidase activity

For extraction of catalase and peroxidase enzymes 200 mg of leaf samples were homogenized in chilled 0.1 M phosphate buffer (pH 7). The homogenate was centrifuged at 15000 rpm for 15 min at 4°C and the supernatant was used for assaying catalase and peroxidase activity. Catalase activity was assayed by the method of Barber (1980). Enzyme extract (0.5ml) was added to 2.0 ml of hydrogen peroxide and 3.5 ml of phosphate buffer (pH 7.0). The reaction was stopped by adding 10ml of two per cent (v/v) concentrated sulphuric acid and the residual hydrogen peroxide was titrated against 0.01M KMnO₄ until a faint purple colour persisted for atleast 15 seconds. The titration was done for every min. and the activity of catalase was assayed and expressed in H₂O₂ oxidized Min⁻¹g⁻¹.

Peroxidase activity was assayed as per the method of Kar and Mishra (1976). To 0.5 ml of enzyme extract, 2.5 ml of 0.1 M phosphate buffer (pH 7.0), one ml of 0.01 M pyrogallol and one ml of 5mM H₂O₂ were added, After incubation, the reaction was stopped

by adding 1.0ml of 2.5 N H_2SO_4 . The amount of purpurogallin formed was estimated by measuring the change in peroxidase activity at 420nm in a spectrophotometer. The peroxidase activity was expressed in change in OD at 420nm $\text{Min}^{-1}\text{g}^{-1}$.

3.3.7. Nutrient analysis

The whole plants samples were collected carefully at the harvest stage. The roots of plants samples were then washed thoroughly with clean water, air dried in shade and finally oven dried at 70°C for two days. The dry weight of whole plant sample was recorded. These samples were finally powdered and used for chemical analysis. For calculating nutrient uptake, the nutrient content of plant samples was multiplied with the dry weight and expressed in kg ha^{-1} . The analysis was done as per the standard procedures furnished below.

3.3.7.1 Estimation of nitrogen

From the digested solution, nitrogen content was estimated following diacid semi automatic kjeldahl method described by Piper (1966) and expressed in kg ha^{-1} .

3.3.7.2. Estimation of phosphorus

From the digested solution, phosphorus content was estimated colorimetrically by van aomolybdate phosphoric yellow color method (Jackson, 1973) and expressed in kg ha^{-1} .

3.3.7.3. Estimation of potassium

Potassium content of the digested solution was estimated using Triacid extract – neutralized with ammonia and estimated using flame photometer (Jackson, 1973) and expressed in kg ha^{-1} .

Statistical Analysis

The data obtained from different experiments were analysed for the 'F' test of significance following the methods described by Panse and Sukhatme (1985). Wherever necessary, the per cent values were transformed to angular (Arc-sine) values before analysis. The critical differences (CD) were calculated at 5% probability level. The data were tested for statistical significance. If the F test is non-significant, it was indicated by the letters NS.

Results

CHAPTER IV

RESULTS

The results obtained from the laboratory experiments and field trials are presented in this chapter.

4.1. Standardization of seed priming treatment and soaking duration on rice

4.1.1. Germination (Table 5)

Significant differences were observed due to seed priming treatments and soaking durations in two varieties tested viz., TNAU Rice TRY 3 and I.W. Ponni. Between the soaking durations, 18h recorded higher germination of 90 per cent whereas 12h recorded 88 per cent.

Among seed treatments higher germination of 92 per cent was observed in seeds primed with Azophos 1.0 %, ZnSO₄ 1.0% and GA₃ 20ppm followed by *Pseudomonas fluorescens* (91 per cent) CaSO₄ 1.0% (90 per cent) ,ZnSO₄ 0.5% (90 per cent) and Azophos 0.5% which was on par with each other in above varieties respectively. While control recorded 84 per cent germination, irrespective of varieties and soaking durations.

4.1.2. Speed of germination (Table 6)

Significant differences were observed due to seed priming treatments and soaking durations. Between the durations, 18h recorded early germination of 8.1 and 12 h recorded 7.2. Among the priming treatments, irrespective of varieties and soaking durations Azophos 1.0% recorded early germination of 9.0 followed by ZnSO₄ 1.0% (8.6), GA₃ 20 ppm (8.5), *Pseudomonas fluorescens* 1.0% (8.0), CaSO₄ 1.0% (7.8) and FeSO₄ 1.0% (7.7). While control recorded (6.7).

4.1.3. Root length (Table 7)

Significant differences were observed due to seed priming treatments, soaking durations and their interactions with variety also.

Between the durations, 18h registered the longest root length (18.8 cm) than 12h (18.3 cm). The longest root length was registered in seed priming with Azophos 1.0% (19.3 cm) and ZnSO₄ 1.0% (19.1 cm) followed by seed priming with GA₃ 20 ppm (19.0 cm), *Pseudomonas fluorescens* 1.0 % (18.9 cm), CaSO₄ 1.0% (18.8 cm) and FeSO₄ 1.0% (18.7 cm). While control registered 18.0 cm.

Table 5. Effect of seed priming treatments and soaking durations on laboratory Germination (%) in rice varieties TNAU Rice TRY 3 and I. W. Ponni

Treatments	Germination (%)						Treatment mean
	TNAU Rice TRY 3 (V ₁)			I.W.Ponni (V ₂)			
	Soaking duration (D)						
	12h	18h	Mean	12h	18h	Mean	
T ₀	84 (66.52)	84 (66.52)	84 (66.52)	84 (66.52)	84 (66.52)	84 (66.52)	84 (66.52)
T ₁	86 (68.25)	88 (70.30)	87 (69.46)	85 (67.62)	87 (69.46)	86 (70.30)	87 (69.46)
T ₂	88 (69.36)	88 (69.43)	88 (69.44)	86 (68.11)	88 (69.76)	87 (69.46)	88 (69.76)
T ₃	89 (70.88)	90 (71.78)	90 (71.34)	89 (70.19)	90 (78.15)	89 (70.67)	90 (78.15)
T ₄	86 (68.15)	87 (68.93)	87 (68.55)	86 (67.88)	87 (68.48)	87 (68.18)	87 (68.48)
T ₅	90 (71.15)	92 (73.40)	91 (72.28)	88 (69.86)	89 (70.32)	88 (70.09)	90 (71.15)
T ₆	89 (70.32)	91 (72.77)	90 (71.55)	87 (68.98)	90 (71.15)	89 (70.32)	90 (71.15)
T ₇	92 (73.57)	93 (75.25)	93 (74.41)	89 (70.90)	91 (72.67)	90 (71.78)	92 (73.57)
T ₈	85 (67.62)	87 (69.46)	86 (70.30)	86 (68.25)	88 (70.30)	87 (69.46)	87 (69.46)
T ₉	89 (70.88)	90 (71.78)	90 (71.34)	86 (67.69)	89 (70.27)	87 (68.98)	89 (70.32)
T ₁₀	89 (70.88)	89 (70.32)	89 (70.32)	87 (68.98)	90 (71.15)	89 (70.32)	89 (70.32)
T ₁₁	90 (71.78)	95 (76.58)	93 (74.19)	91 (72.50)	90 (72.04)	90 (72.27)	92 (73.57)
T ₁₂	86 (68.15)	87 (68.93)	87 (68.55)	86 (67.88)	87 (68.48)	87 (68.18)	87 (69.46)
T ₁₃	85 (67.40)	90 (72.04)	88 (69.73)	86 (67.69)	89 (70.27)	87 (68.98)	88 (69.73)

T ₁₄	86 (68.15)	87 (68.93)	87 (68.55)	86 (67.88)	87 (68.48)	87 (68.18)	87 (69.46)
T ₁₅	90 (72.04)	94 (76.21)	92 (74.13)	89 (70.82)	90 (71.79)	89 (71.30)	91 (72.83)
T ₁₆	89 (70.72)	90 (71.78)	90 (71.26)	87 (68.93)	91 (72.83)	89 (70.88)	90 (71.15)
T ₁₇	90 (70.52)	95 (77.43)	93 (74.61)	90 (71.22)	92 (73.84)	91 (72.53)	92 (73.57)
T ₁₈	89 (70.32)	87 (68.93)	88 (69.63)	85 (67.45)	85 (67.27)	85 (67.36)	87 (69.46)
T ₁₉	89 (70.82)	89 (70.59)	89 (70.71)	88 (69.86)	89 (70.32)	88 (70.09)	89 (70.32)
Mean	88 (69.36)	90 (70.52)	89 (70.71)	88 (69.36)	89 (70.71)	88 (69.63)	89 (70.32)
Soaking duration	12 h			18 h			
Mean	88 (69.63)			90 (71.79)			

(Figures in parentheses indicate arcsine values)

	T	D	V	T x D	DxV	TxV	T x D x V
SEd	1.13	0.358	0.358	1.60	0.50	1.60	2.27
CD (P=0.05)	2.23	0.706	0.706	NS	NS NS NS	NS NS NS	NS

Table 6. Effect of seed priming treatments and soaking durations on speed of germination in rice varieties TNAU Rice TRY 3 and I. W. Ponni

Treatments	Speed of germination						Treatment mean
	TNAU Rice TRY 3 (V ₁)			I. W. Ponni (V ₂)			
	Soaking duration (D)						
	12h	18h	Mean	12h	18h	Mean	
T ₀	6.1	7.2	6.7	6.0	7.2	6.6	6.7
T ₁	6.6	7.6	7.1	6.4	7.2	6.8	7.0
T ₂	6.5	7.6	7.1	6.6	7.6	7.1	7.1
T ₃	7.2	8.0	7.6	7.2	8.0	7.6	7.6
T ₄	6.7	7.8	7.3	6.8	7.8	7.3	7.3
T ₅	7.6	8.4	8.0	7.2	8.0	7.6	7.8
T ₆	7.9	9.0	8.5	7.9	8.9	8.4	8.5
T ₇	8.4	9.2	8.8	7.8	9.0	8.4	8.6
T ₈	6.6	7.6	7.1	6.1	7.2	6.7	6.9
T ₉	7.6	8.4	8.0	7.0	7.8	7.4	7.7
T ₁₀	7.7	8.7	8.2	7.5	8.6	8.1	8.2
T ₁₁	8.1	8.9	8.5	7.6	9.2	8.4	8.5
T ₁₂	6.5	7.5	7.0	6.1	7.2	6.7	6.9
T ₁₃	7.2	8.1	7.7	6.7	7.6	7.1	7.4
T ₁₄	6.7	7.8	7.3	6.8	7.8	7.3	7.3
T ₁₅	7.8	8.3	8.1	7.4	8.3	7.8	8.0
T ₁₆	8.2	9.2	8.7	7.7	8.8	8.3	8.5
T ₁₇	8.6	9.4	9.0	8.6	9.4	9.0	9.0
T ₁₈	7.1	8.1	7.6	6.8	7.9	7.4	7.5
T ₁₉	7.4	8.3	7.8	7.4	8.3	7.8	7.8
Mean	7.2	8.2	7.8	7.1	8.0	8.0	7.7
Soaking duration	12 h			18 h			
Mean	7.2			8.1			

	T	D	V	T x D	D x V	T x V	T x D x V
SEd	0.13	0.04	0.04	0.19	0.06	0.19	0.27
CD (P=0.05)	0.27	0.08	0.08	NS	NS	0.38	NS

Table 7. Effect of seed priming treatments and soaking durations on root length (cm) in rice varieties TNAU Rice TRY 3 and I. W. Ponni

Treatments	Root length (cm)						Treatment mean
	TNAU Rice TRY 3 (V ₁)			I. W. Ponni (V ₂)			
	Soaking duration (D)						
	12h	18h	Mean	12h	18h	Mean	
T ₀	18.5	18.3	18.2	17.9	17.6	17.7	18.0
T ₁	18.0	18.8	18.4	18.0	17.9	17.9	18.2
T ₂	18.1	18.8	18.5	18.1	17.9	17.9	18.2
T ₃	18.2	19.7	18.9	18.4	18.1	18.2	18.6
T ₄	18.2	18.9	18.6	18.4	18.1	18.2	18.4
T ₅	18.6	19.8	19.2	18.3	18.5	18.4	18.8
T ₆	18.5	19.2	18.8	18.4	18.4	18.4	18.6
T ₇	18.6	20.4	19.5	18.6	18.6	18.6	19.1
T ₈	18.4	18.6	18.5	18.0	18.3	18.2	18.4
T ₉	18.5	19.7	19.1	18.1	18.4	18.2	18.7
T ₁₀	18.5	18.9	18.7	18.1	18.5	18.3	18.5
T ₁₁	18.7	20.1	19.4	18.5	18.5	18.5	19.0
T ₁₂	18.3	18.4	18.4	18.1	18.0	18.1	18.3
T ₁₃	18.5	19.6	19.0	18.1	18.4	18.2	18.6
T ₁₄	18.5	18.9	18.7	18.1	18.5	18.3	18.5
T ₁₅	18.5	20.3	19.3	18.1	18.8	18.4	18.9
T ₁₆	18.5	19.3	18.9	18.4	18.7	18.5	18.7
T ₁₇	18.7	20.4	19.5	18.7	19.2	19.0	19.3
T ₁₈	18.1	18.4	18.2	18.0	18.2	18.1	18.2
T ₁₉	18.4	18.5	18.4	18.1	18.0	18.0	18.2
Mean	18.4	19.2	18.8	18.2	18.4	18.3	18.5
Soaking duration	12 h			18 h			
Mean	18.3			18.8			

	T	D	V	T x D	D x V	T x V	T x D x V
SEd	0.15	0.04	0.05	0.21	0.06	0.21	0.30
CD (P=0.05)	0.29	0.09	0.09	0.42	0.13	0.41	0.59

The interaction showed that seed priming with *Azophos* 1.0% for 18h recorded the longest root length (20.4, 19.2 cm) followed by ZnSO₄ 1.0% (20.4, 18.6 cm), GA₃ 20 ppm (20.1, 18.5 cm), *Pseudomonas fluorescens* 1.0% (20.3, 18.8 cm), CaSO₄ 1.0% (19.8, 18.5 cm) and FeSO₄ (19.7, 18.4 cm) in both varieties.

4.1.4. Shoot length (Table 8)

Seed priming treatments and soaking durations showed a significant influence on shoot length. Interaction between seed priming and duration had significant impact on shoot length. Between the durations tried, 18h recorded longest shoot length (13.7 cm) than 12h (13.0 cm).

Among the treatments tried, irrespective of varieties and soaking durations *Azophos* 1.0 % registered more shoot length (14.1 cm), which was on par with ZnSO₄ 1.0% (14.0), GA₃ 20 ppm (13.8 cm), *Pseudomonas fluorescens* 1.0% (13.7 cm), CaSO₄ 1.0% (13.7 cm) and FeSO₄ 1.0% (13.6 cm). While the shortest shoot length was recorded in control (12.2 cm)

Among the interaction effects, seed priming with *Azophos* 1.0% for 18h registered the longest shoot length (14.8, 14.0 cm) followed by ZnSO₄ 1.0% (14.3, 14.1 cm), GA₃ 20 ppm (14.5, 13.8 cm), *Pseudomonas fluorescens* (14.2, 13.8 cm), CaSO₄ 1.0% (14.1, 13.7 cm) and FeSO₄ 1.0% (14.1, 13.6 cm) which were on par with each other whereas, control registered (12.5, 12.0 cm) in both varieties.

4.1.5. Seedling drymatter production (Table 9)

Significant differences in drymatter production were observed due to seed priming, soaking duration and varieties. Between the soaking durations, seed priming for 18h recorded higher seedling drymatter production (0.104 g seedlings⁻¹⁰) followed by 12h (0.103 g seedlings⁻¹⁰). Higher seedling drymatter production were recorded in the seeds treated with *Azophos* 1.0% (0.108 g seedlings⁻¹⁰) followed by ZnSO₄ 1.0% (0.106 seedlings⁻¹⁰), GA₃ 20 ppm (0.105 g seedlings⁻¹⁰) *Pseudomonas fluorescens* (0.104 g seedlings⁻¹⁰), CaSO₄ 1.0% (0.104 g seedlings⁻¹⁰) and FeSO₄ 1.0% (0.104 g seedlings⁻¹⁰) irrespective of varieties and soaking durations. While less drymatter production was registered in control with 0.098 g seedlings⁻¹⁰.

Table 8. Effect of seed priming treatments and soaking durations on shoot length (cm) in rice varieties TNAU Rice TRY 3 and I. W. Ponni

Treatments	Shoot length (cm)						Treatment mean
	TNAU Rice TRY 3 (V ₁)			I. W. Ponni (V ₂)			
	Soaking duration (D)						
	12h	18h	Mean	12h	18h	Mean	
T ₀	12.1	12.5	12.3	12.3	12.0	12.1	12.2
T ₁	12.5	13.3	12.9	12.1	12.8	12.5	12.7
T ₂	12.3	13.6	13.0	12.4	12.8	12.6	12.8
T ₃	13.0	14.2	13.6	12.7	13.4	13.1	13.4
T ₄	13.0	13.8	13.4	12.8	13.3	13.0	13.2
T ₅	13.4	14.1	13.8	13.4	13.7	13.5	13.7
T ₆	13.4	13.9	13.7	13.0	13.6	13.3	13.5
T ₇	14.0	14.3	14.2	13.2	14.1	13.7	14.0
T ₈	12.7	13.3	13.0	12.7	13.1	12.9	13.0
T ₉	13.4	14.1	13.7	13.2	13.6	13.4	13.6
T ₁₀	13.1	14.0	13.6	12.9	13.4	13.2	13.4
T ₁₁	13.5	14.5	14.0	13.4	13.8	13.6	13.8
T ₁₂	13.1	14.0	13.6	12.7	13.1	12.9	13.3
T ₁₃	13.0	14.4	13.7	13.0	13.8	13.4	13.6
T ₁₄	13.3	13.8	13.5	12.8	13.5	13.1	13.3
T ₁₅	13.6	14.2	13.9	13.3	13.8	13.5	13.7
T ₁₆	13.5	14.2	13.8	13.1	13.7	13.4	13.6
T ₁₇	14.0	14.8	14.4	13.5	14.0	13.8	14.1
T ₁₈	12.3	13.0	12.6	12.2	12.5	12.4	12.5
T ₁₉	12.9	13.5	13.2	12.4	13.3	12.9	13.1
Mean	13.1	13.9	13.5	12.9	13.4	13.1	13.3
Soaking duration	12 h			18 h			
Mean	13.0			13.7			

	T	D	V	T x D	D x V	T x V	T x D x V
SEd	0.20	0.06	0.06	0.30	0.09	0.28	0.41
CD (P=0.05)	0.40	0.13	0.13	0.57	NS	NS	NS

Table 9. Effect of seed priming treatments and soaking durations on drymatter production (g seedlings⁻¹⁰) in rice varieties TNAU Rice TRY 3 and I.W.Ponni

Treatments	Drymatter Production (g seedlings ⁻¹⁰)						Treatment mean
	TNAU Rice TRY 3 (V ₁)			I. W. Ponni (V ₂)			
	Soaking duration (D)						
	12h	18h	Mean	12h	18h	Mean	
T ₀	0.120	0.112	0.116	0.080	0.080	0.080	0.098
T ₁	0.118	0.118	0.118	0.080	0.084	0.082	0.100
T ₂	0.119	0.121	0.120	0.080	0.084	0.082	0.101
T ₃	0.122	0.120	0.121	0.084	0.083	0.084	0.103
T ₄	0.121	0.121	0.121	0.082	0.083	0.083	0.102
T ₅	0.122	0.123	0.123	0.084	0.085	0.085	0.104
T ₆	0.122	0.123	0.122	0.084	0.086	0.085	0.104
T ₇	0.122	0.126	0.124	0.086	0.090	0.088	0.106
T ₈	0.120	0.122	0.121	0.082	0.083	0.083	0.102
T ₉	0.121	0.122	0.122	0.084	0.085	0.085	0.104
T ₁₀	0.122	0.123	0.122	0.083	0.084	0.084	0.103
T ₁₁	0.122	0.123	0.123	0.088	0.084	0.086	0.105
T ₁₂	0.120	0.120	0.120	0.084	0.084	0.084	0.102
T ₁₃	0.120	0.121	0.121	0.084	0.084	0.084	0.103
T ₁₄	0.121	0.123	0.122	0.083	0.084	0.084	0.103
T ₁₅	0.123	0.124	0.123	0.083	0.087	0.085	0.104
T ₁₆	0.128	0.123	0.125	0.087	0.093	0.090	0.108
T ₁₇	0.124	0.125	0.125	0.095	0.084	0.090	0.108
T ₁₈	0.121	0.121	0.121	0.083	0.084	0.084	0.103
T ₁₉	0.120	0.120	0.120	0.084	0.085	0.085	0.103
Mean	0.121	0.122	0.122	0.084	0.085	0.085	0.103
Soaking duration	12 h			18 h			
Mean	0.103			0.104			

	T	D	V	T x D	D x V	T x V	T x D x V
SEd	0.001	0.0004	0.0004	0.02	0.0006	0.002	0.003
CD (P=0.05)	0.002	0.0009	0.0008	NS	NS	NS	NS

4.1.6. Vigour index (Table 10)

The vigour index was significantly influenced by seed priming treatments, soaking durations and varieties. Seed priming for 18h showed maximum vigour index (2905) followed by 12h (2765), irrespective of seed priming treatments and varieties tested.

Greater vigour index value of 3039 was registered by *Azophos* 1.0 % followed by ZnSO_4 1.0% (2987), GA_3 20ppm (2983), *Pseudomonas fluorescens* 1.0 %, (2942), CaSO_4 1.0% (2900) and FeSO_4 1.0% (2842). The lower vigour index value was recorded in control (2550) in both the varieties respectively.

Regarding the interaction effects between duration and varieties seed priming with *Azophos* 1.0 % for 18h registered the vigour index of 3259 and 3054 than 12h (2943 and 2898) followed by GA_3 20ppm for 18h (3221 and 2907) than 12h (2898 and 2903), which was on par with *Pseudomonas fluorescens* 1.0 % (3149 and 2934) for 18h than 12h (2889 and 2795) whereas, control registered the lowest vigour index of 2570, 2520 for 18h and 2587, 2520 for 12h respectively, in TNAU Rice TRY 3 and I.W.Ponni.

4.2. Preliminary screening of priming treatments under sodicity and salinity conditions

4.2.1 Germination (Table 11)

Significant treatment variations in germination were observed under different sodicity levels. Among the treatments, T_7 recorded higher germination of 83 per cent followed by T_6 (81 per cent) and T_4 (79 per cent), irrespective of varieties and sodicity levels. Whereas, control recorded the lowest germination of 68 per cent. Regarding sodicity levels, higher germination of 73 per cent was registered at 25mM stress level as compared to 50mM (62 per cent). Between the varieties, TNAU Rice TRY 3 recorded 77 per cent germination than I.W.Ponni (74 per cent).

A greater reduction was noticed in germination per cent at the sodicity level of 50 mM with 32 and 36 per cent and at 25mM with 21 and 22 per cent in TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.2.2. Speed of germination (Table 12)

Significant differences were observed due to sodicity stress levels, seed priming treatments, varieties and interaction between seed priming and sodicity level. Irrespective of treatments and stress level the speed of germination recorded at V_2 was 6.2 as compared to

Table 10. Effect of seed priming treatments and soaking durations on vigour index in rice varieties TNAU Rice TRY 3 and I.W.Ponni

Treatments	Vigour index						Treatment Mean
	TNAU Rice TRY 3 (V ₁)			I. W. Ponni (V ₂)			
	Soaking duration (D)						
	12h	18h	Mean	12h	18h	Mean	
T ₀	2587	2570	2579	2520	2520	2520	2550
T ₁	2601	2793	2697	2623	2702	2663	2680
T ₂	2710	2807	2759	2614	2702	2658	2709
T ₃	2777	3051	2914	2795	2835	2815	2865
T ₄	2683	2845	2764	2700	2732	2716	2740
T ₅	2880	3064	2972	2790	2866	2828	2900
T ₆	2839	3012	2926	2767	2880	2823	2875
T ₇	2999	3143	3071	2830	2976	2903	2987
T ₈	2643	2775	2709	2640	2763	2702	2706
T ₉	2839	2988	2914	2692	2848	2770	2842
T ₁₀	2812	2928	2870	2714	2871	2793	2832
T ₁₁	2898	3221	3060	2903	2907	2905	2983
T ₁₂	2700	2819	2760	2683	2706	2695	2728
T ₁₃	2678	3006	2842	2675	2866	2771	2807
T ₁₄	2735	2845	2790	2700	2784	2742	2766
T ₁₅	2889	3149	3019	2795	2934	2865	2942
T ₁₆	2848	3015	2932	2775	2948	2862	2897
T ₁₇	2943	3259	3101	2898	3054	2976	3039
T ₁₈	2706	2732	2719	2575	2610	2593	2656
T ₁₉	2786	2839	2813	2684	2786	2735	2774
Mean	2772	2979	2861	2754	2830	2767	2814
Soaking duration	12 h			18 h			
Mean	2765			2905			

	T	D	V	T x D	D x V	T x V	T x D x V
SEd	46.96	14.85	14.85	66.41	21.00	66.41	93.92
CD (P=0.05)	92.51	29.25	29.25	NS	41.40	NS	NS

Table 11. Effect of seed priming treatments on germination (%) of rice varieties TNAU Rice TRY 3 and I. W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)								Treatment Mean
	TNAU Rice TRY 3 (V ₁)				I.W.Ponni (V ₂)				
	0	25	50	Mean	0	25	50	Mean	
T ₀	87 (69.24)	65 (53.54)	57 (49.02)	70 (57.27)	85 (67.58)	63 (52.35)	52 (46.34)	66 (55.42)	68 (55.35)
T ₁	89 (71.05)	69 (55.97)	59 (50.19)	72 (59.07)	87 (69.28)	65 (53.74)	54 (47.49)	69 (56.83)	71 (58.36)
T ₂	95 (77.97)	75 (59.80)	65 (53.74)	78 (63.83)	93 (75.41)	72 (58.06)	60 (50.97)	75 (61.48)	77 (61.70)
T ₃	91 (73.04)	70 (57.00)	61 (51.36)	74 (60.46)	89 (71.10)	68 (55.35)	56 (48.64)	71 (58.36)	73 (59.76)
T ₄	97 (82.48)	79 (62.49)	67 (54.97)	81 (66.64)	95 (78.30)	74 (59.79)	62 (52.15)	77 (63.42)	79 (64.38)
T ₅	93 (75.28)	72 (58.27)	63 (52.54)	76 (62.03)	91 (73.12)	69 (56.38)	58 (49.80)	73 (59.76)	75 (59.80)
T ₆	98 (83.36)	81 (64.49)	69 (56.17)	83 (68.01)	96 (78.10)	77 (61.70)	64 (53.34)	79 (64.38)	81 (66.21)
T ₇	99 (84.50)	83 (65.65)	71 (57.42)	84 (69.19)	98 (81.53)	79 (62.55)	66 (54.54)	81 (66.21)	83 (68.01)
Mean	94 (77.11)	74 (59.66)	64 (53.17)	77 (61.70)	92 (74.30)	71 (57.49)	59 (50.41)	74 (60.46)	76 (62.03)
Sodicity	0mM				25mM			50mM	
Mean	93 (75.75)			73 (59.76)			62 (52.15)		

(Figures in parentheses indicate arcsine values)

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.91	0.55	0.45	1.58	0.79	1.29	2.23
CD (P=0.05)	1.81	1.10	0.91	NS	NS	NS	NS

**Table 12. Effect of seed priming treatments on speed of germination of rice varieties
TNAU Rice TRY3 and I. W.Ponni under sodicity stress condition**

Sodicity (S) Treatments (T)	Varieties (V)								Treatment Mean
	TNAU Rice TRY 3 (V ₁)				I.W.Ponni (V ₂)				
	0	25	50	Mean	0	25	50	Mean	
T ₀	6.0	5.0	4.0	5.0	5.7	4.7	3.7	4.7	4.9
T ₁	6.0	5.0	4.0	5.0	5.8	4.8	3.8	4.8	4.9
T ₂	7.8	6.8	5.8	6.8	7.6	6.6	5.6	6.6	6.7
T ₃	6.8	6.5	6.0	6.4	6.6	6.4	5.8	6.3	6.4
T ₄	8.0	7.0	6.0	7.0	7.7	6.7	5.7	6.7	6.9
T ₅	7.7	6.7	5.7	6.7	7.5	6.5	5.5	6.5	6.6
T ₆	8.1	7.1	6.1	7.1	8.0	7.0	6.0	7.0	7.0
T ₇	8.3	7.2	6.2	7.2	8.1	7.0	6.0	7.0	7.1
Mean	7.3	6.4	5.4	6.4	7.2	6.2	5.3	6.2	6.3
Sodicity	0mM			25mM			50mM		
Mean	7.3			6.3			5.4		

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.07	0.05	0.04	0.14	0.06	0.11	0.19
CD (P=0.05)	0.15	0.10	0.08	0.27	NS	NS	NS

V₁ 6.4. Among the priming treatments T₇ recorded early germination of 7.1 followed by T₆ with 7.0, T₄ registered 6.9. While the speed of germination for control was 4.9.

As the sodicity level increased, the speed of germination reduced with 5.4 in 50mM and 6.3 in 25 mM while no stress revealed 7.3. Among the interaction effects, T₇ improved the speed of germination at 25 mM (7.2 and 7.0) and 50 mM (6.2 and 6.0) followed by T₆ at 25 mM (7.1, 7.0) and 50 mM (6.1, 6.0) stress levels in both the varieties.

4.2.3. Root length (Table 13)

The adverse effect of sodicity stress at different levels also reflected on root growth in terms of root length. The sodicity stress at 25 mM concentration reduced the root growth by 34 per cent, whereas the higher concentration of 50 mM reduced the mean root length by 63 per cent over unstressed control.

Irrespective of priming treatments and sodicity levels V₁ registered root length of 13.9cm than V₂ (12.6 cm). Among the priming treatments, T₇ registered the longest root length of 14.1 cm followed by T₆ with 13.9 cm, T₄ with 13.7 cm and T₂ registered 13.4 cm. whereas, the control registered the shortest root length of 12.2 cm.

With respect to interaction between varieties and treatments, T₇ registered the longest root length of 14.8, 13.4 cm followed by T₆ (14.4, 13.3 cm), T₄ (14.3, 13.1 cm) and T₂ (14.0, 12.8 cm), whereas, the control registered the shortest root length of 12.8, 11.7 cm in TNAU Rice TRY 3 and I.W.Ponni, respectively.

Regarding the interaction effects between sodicity levels and treatments T₇ at 25 mM registered the longest root length of (14.6, 13.0 cm) than 50 mM (9.1, 7.4 cm) followed by T₆ at 25 mM (14.1, 12.8 cm) than 50 mM (8.5, 7.2 cm), T₄ (14.0, 12.7 cm) at 25 mM than 50 mM (8.5, 7.0 cm) and T₂ (13.7, 12.3 cm) at 25 mM than 50mM (8.2, 6.7 cm), whereas, control registered the lowest root length of 12.5, 11.3 cm at 25 mM and 7.0, 5.6 cm at 50mM, respectively in TNAU Rice TRY 3 and I.W.Ponni.

4.2.4. Shoot length (Table 14)

Various sodicity levels also exhibited their adverse effects in terms of reducing the shoot growth. The reduction was more pronounced at 50 mM concentration with 66 and 77 per cent as

Table 13. Effect of seed priming treatments on root length (cm) of rice varieties TNAU Rice TRY3 and I. W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)								Treatment Mean
	TNAU Rice TRY 3 (V ₁)				I.W.Ponni (V ₂)				
	0	25	50	Mean	0	25	50	Mean	
T ₀	19.0	12.5	7.0	12.8	18.2	11.3	5.6	11.7	12.2
T ₁	19.5	13.3	7.6	13.4	18.5	11.6	5.9	12.0	12.7
T ₂	20.1	13.7	8.2	14.0	19.3	12.3	6.7	12.8	13.4
T ₃	19.6	13.2	7.6	13.5	18.6	11.7	6.0	12.1	12.8
T ₄	20.4	14.0	8.5	14.3	19.6	12.7	7.0	13.1	13.7
T ₅	19.8	13.4	7.9	13.7	19.1	12.2	6.5	12.6	13.2
T ₆	20.5	14.1	8.5	14.4	19.8	12.8	7.2	13.3	13.9
T ₇	21.0	14.6	9.1	14.8	19.9	13.0	7.4	13.4	14.1
Mean	20.0	13.6	8.0	13.9	19.1	12.2	6.6	12.6	13.2
Sodicity	0mM			25mM			50mM		
Mean	19.6			12.9			7.3		

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.11	0.06	0.05	0.18	0.09	0.15	0.26
CD (P=0.05)	0.21	0.13	0.11	0.37	NS	0.30	0.52

Table 14. Effect of seed priming treatments on shoot length (cm) of rice varieties TNAU Rice TRY3 and I. W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)								Treatment Mean
	TNAU Rice TRY 3 (V ₁)				I.W.Ponni (V ₂)				
	0	25	50	Mean	0	25	50	Mean	
T ₀	12.9	8.7	3.5	8.3	12.5	7.2	1.8	7.2	7.8
T ₁	13.1	8.9	3.7	8.5	12.9	7.6	2.2	7.5	8.0
T ₂	14.5	10.3	5.1	10.0	14.4	9.1	3.7	9.1	9.6
T ₃	13.9	9.7	4.5	9.3	13.1	7.7	2.4	7.7	8.5
T ₄	14.8	10.6	5.4	10.3	14.6	9.3	3.9	9.3	9.8
T ₅	13.8	9.6	4.4	9.3	14.1	8.8	3.3	8.7	9.0
T ₆	15.4	11.2	6.0	10.9	15.0	9.8	4.4	9.7	10.3
T ₇	15.8	11.6	6.4	11.3	15.7	10.4	5.0	10.4	10.9
Mean	14.3	10.1	4.9	9.7	14.1	8.7	3.3	8.9	9.2
Sodicity	0mM			25mM			50mM		
Mean	14.2			9.4			4.1		

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.11	0.06	0.05	0.18	0.09	0.15	0.26
CD (P=0.05)	0.22	0.13	0.11	NS	0.19	0.30	NS

compared to 29 and 38 per cent at 25 mM concentration in both varieties. Irrespective of stress levels and treatments V_1 produced the longest root length of 9.7cm than V_2 (8.9 cm)

Irrespective of sodicity stress levels and varieties, T_7 registered the longest shoot length of 10.9 cm followed by T_6 with 10.3 cm, T_4 with 9.8cm whereas control registered 7.8 cm.

Interaction between varieties and treatments revealed that the treatment T_7 registered the longest root length of 11.3, 10.4 cm followed by T_6 (10.9, 9.7 cm), T_4 (10.3, 9.3 cm) and T_2 (10.0, 9.1 cm) whereas, control registered the shortest shoot length of 8.3, 7.2 cm, in TNAU Rice TRY 3 and I.W.Ponni, respectively.

The effect of T_7 at 25 mM sodicity registered the longest shoots length of 11.6, 10.4 cm as compared to 50mM (6.4 cm, 5.0 cm) in above varieties. The next best treatments with regard to improvement in shoot length were T_6 at 25 mM (11.2 and 9.8 cm) than 50 mM (6.0 and 4.4 cm). T_4 at 25 mM (10.6, 9.3 cm) than 50mM level (5.4, 3.9 cm). Whereas, the control registered the shortest shoot length of 8.7 and 7.2 cm at 25 mM and 3.5 and 1.8 cm at 50 mM level, in TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.2.5. Seedling drymatter production (Table 15)

Different levels of sodicity also caused adverse effects at various intensities on dry matter production of seedlings. Irrespective of treatments and stress level the variety V_1 registered the maximum drymatter production of ($0.095 \text{ g seedlings}^{-10}$) than V_2 ($0.068 \text{ g seedlings}^{-10}$). The overall varietal mean of dry matter production under unstressed condition was 0.129 and 0.098 g seedlings⁻¹⁰ and this was decreased to 0.097 and 0.065 at 25 mM and 0.062 and 0.041 at 50 mM sodicity stress levels in TNAU Rice TRY 3 and I.W.Ponni respectively. The per cent reduction due to these sodicity levels over control was 25 and 31 at 25mM and 52 and 58 at 50mM in the above said varieties.

Among the priming treatments, T_7 recorded higher drymatter production of $0.093 \text{ g seedlings}^{-10}$ followed by T_6 with $0.089 \text{ g seedlings}^{-10}$ which were on par with T_4 ($0.089 \text{ g seedlings}^{-10}$) whereas, the control recorded $0.070 \text{ g seedlings}^{-10}$.

Comparing the interaction between varieties and treatments, T_7 recorded higher drymatter production of 0.111 and $0.075 \text{ g seedlings}^{-10}$ followed by T_6 with 0.106 and $0.072 \text{ g seedlings}^{-10}$ which were on par with T_4 (0.105 and $0.074 \text{ g seedlings}^{-10}$) and T_2 (0.099

Table 15. Effect of seed priming treatments on drymatter production (g seedlings⁻¹⁰) of rice varieties TNAU Rice TRY3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)								Treatment Mean
	TNAU Rice TRY 3 (V ₁)				I.W.Ponni (V ₂)				
	0	25	50	Mean	0	25	50	Mean	
T ₀	0.122	0.070	0.051	0.081	0.090	0.051	0.035	0.059	0.070
T ₁	0.126	0.080	0.054	0.085	0.095	0.057	0.036	0.063	0.074
T ₂	0.127	0.107	0.065	0.099	0.098	0.067	0.041	0.069	0.084
T ₃	0.129	0.080	0.056	0.089	0.096	0.059	0.037	0.064	0.077
T ₄	0.133	0.114	0.069	0.105	0.106	0.069	0.045	0.074	0.089
T ₅	0.128	0.083	0.059	0.089	0.098	0.064	0.039	0.067	0.078
T ₆	0.131	0.116	0.070	0.106	0.097	0.073	0.046	0.072	0.089
T ₇	0.135	0.125	0.072	0.111	0.110	0.076	0.049	0.075	0.093
Mean	0.129	0.097	0.062	0.095	0.098	0.065	0.041	0.068	0.082
Sodicity	0mM			25mM			50mM		
Mean	0.114			0.081			0.052		

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.0008	0.0005	0.0004	0.0013	0.0007	0.0011	0.0019
CD (P=0.05)	0.0015	0.0009	0.0008	0.0026	0.0013	0.0022	0.0037

and 0.069 g seedlings⁻¹⁰) while control recorded 0.081 and 0.059 g seedlings⁻¹⁰ in TNAU Rice TRY 3 and I.W.Ponni, respectively.

Among the interaction effects, T₇ recorded higher dry matter production of 0.125 and 0.076 g seedlings⁻¹⁰ at 25 mM than at 50 mM with 0.072 and 0.049 of seedlings⁻¹⁰ followed by T₆ and T₄. While control recorded 0.070 and 0.051 g seedlings⁻¹⁰ at 25 mM and at 50 mM 0.051 and 0.035 g seedlings⁻¹⁰ in the above varieties.

4.2.6. Vigour index (Table 16)

The vigour index was significantly differed by the levels of sodicity. Sodicity at 50 mM concentration drastically reduced the mean vigour index by 74 and 81 per cent at 50 mM level and at 25 mM level the reduction was 46 and 56 per cent over control in TNAU Rice TRY 3 and I.W.Ponni varieties, respectively.

Among the priming treatments, irrespective of varieties and sodicity levels, T₇ recorded the maximum vigour index value of 2127 followed by T₆ with 2068, T₄ with 1932. Whereas, control recorded the minimum vigour index value of 1487.

In interaction effects between treatments and sodicity levels T₇ recorded higher vigour index of 2177 and 1847 at 25 mM than at 50 mM (1101 and 822) followed by T₆ and T₂ in both the varieties.

4.3. Salinity stress

4.3.1. Germination (Table 17)

Germination is an important index for salt tolerance and significant differences were observed due to priming treatments and varieties under stress conditions. While observing the effect of different salinity stresses imposed using sodium chloride at 50, 100 and 150 mM levels on germination, a greater reduction was noticed at the salinity level of 150 mM in both the varieties.

At this level of salinity the reduction in germination was (30 and 33 per cent) in TNAU Rice TRY 3 and I.W.Ponni. Germination 94 and 92 per cent was recorded under unstress condition in the above varieties respectively. At 50 mM and 100 mM concentration the reduction was 9 and 15 per cent in both varieties respectively. Comparing the performance of varieties

Table 16. Effect of seed priming treatments on vigour index of rice varieties TNAU Rice TRY3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments(T)	Varieties (V)								Treatment Mean
	TNAU Rice TRY 3 (V ₁)				I.W.Ponni (V ₂)				
	0	25	50	Mean	0	25	50	Mean	
T ₀	2777	1371	597	1582	2622	1161	391	1392	1487
T ₁	2912	1510	665	1696	2739	1246	441	1475	1586
T ₂	3206	1720	799	1908	2654	1402	507	1621	1765
T ₃	3056	1608	741	1801	2970	1425	556	1650	1726
T ₄	3260	1893	894	2015	3243	1630	670	1848	1932
T ₅	3288	1782	876	1982	3096	1505	620	1740	1861
T ₆	3518	2056	1005	2193	3332	1750	744	1942	2068
T ₇	3634	2177	1101	2304	3842	1847	822	2050	2127
Mean	3207	1765	834	1935	3055	1495	594	1715	1825
Sodicity	0mM			25mM			50mM		
Mean	3131			1630			714		

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	29.25	17.91	14.63	50.66	25.33	41.36	71.65
CD (P=0.05)	58.06	35.56	29.03	100.57	50.28	NS	NS

Table 17. Effect of seed priming treatments on germination (%) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Salinity (S) Treatments (T)	Varieties (V)											Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	50	100	150	Mean	0	50	100	150	Mean			
T ₀	90 (71.62)	81 (64.41)	75 (60.22)	55 (48.06)	75 (61.08)	86 (67.79)	81 (63.92)	73 (58.91)	51 (45.76)	73 (59.09)	74 (59.39)		
T ₁	92 (73.65)	82 (64.91)	79 (62.53)	60 (50.77)	78 (62.96)	90 (71.62)	81 (64.49)	77 (61.14)	56 (48.44)	76 (61.43)	77 (62.10)		
T ₂	95 (76.70)	84 (66.45)	80 (63.69)	68 (55.55)	82 (65.60)	94 (76.35)	85 (67.55)	78 (62.27)	64 (53.13)	80 (64.83)	81 (65.25)		
T ₃	94 (75.95)	85 (66.95)	79 (62.53)	62 (51.95)	80 (64.34)	90 (71.95)	82 (64.91)	77 (61.15)	59 (50.38)	77 (62.10)	79 (63.67)		
T ₄	96 (79.60)	88 (69.77)	82 (64.91)	70 (56.79)	84 (67.77)	92 (73.65)	87 (69.16)	80 (63.45)	67 (54.73)	81 (65.25)	83 (65.96)		
T ₅	92 (73.65)	83 (65.96)	79 (63.00)	66 (54.34)	80 (64.23)	93 (74.68)	84 (66.45)	77 (61.60)	62 (51.95)	79 (63.67)	80 (64.83)		
T ₆	96 (78.67)	90 (71.62)	84 (66.45)	72 (58.06)	85 (68.70)	94 (75.95)	85 (66.98)	82 (64.91)	68 (55.56)	82 (65.85)	84 (66.85)		
T ₇	97 (79.85)	93 (74.32)	84 (66.70)	76 (60.71)	85 (70.39)	95 (76.28)	90 (71.28)	82 (65.16)	72 (58.07)	85 (67.80)	85 (67.80)		
Mean	94 (76.21)	86 (68.05)	80 (63.75)	66 (54.53)	81 (65.25)	92 (73.59)	84 (66.85)	78 (62.33)	62 (52.25)	79 (63.67)	80 (64.83)		
Salinity	0mM					50mM					100mM		150mM
Mean	93 (74.68)					85 (66.95)					79 (63.67)		64 (53.85)

(Figures in parentheses indicate arcsine values)

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.53	0.38	0.27	1.07	0.53	0.75	1.51
CD (P=0.05)	1.05	0.75	0.53	2.11	NS	NS	NS

under salinity levels, higher salinity level of 150 mM recorded 66 and 62 per cent in TNAU Rice TRY 3 and I.W. Ponni, respectively.

Irrespective of varieties and stress conditions, the T₇ treatment found to be superior with 85 per cent germination which was on par with T₆ (84) and T₄ (83). This was followed by T₂ which registered 81 per cent while the control registered 74 per cent. The interactive effect of treatments with stress condition was significant with TNAU Rice TRY3 and I.W. Ponni. T₇ treatment (76 and 72 per cent) found to be superior over other treatments at 150 mM stress level.

4.3.2. Speed of Germination (Table 18)

Significant variations were observed due to seed priming, salinity levels and varieties. Irrespective of priming treatments and salinity levels the variety V₁ recorded early germination of 7.0 than V₂ (6.9). Among the priming treatments, T₇ recorded early germination of 7.7 followed by T₆ with 7.4. While, control registered 6.2.

Comparing the different salinity levels, 50 mM recorded early germination of (7.4, 7.3) followed by 100 mM level (6.9, 6.7) and 150 mM level (6.0, 6.0). Whereas, unstress recorded (7.6, 7.5) in TNAU Rice TRY 3 and I.W.Ponni.

Based on the treatment evaluation in varieties, T₇ found to be superior with early germination of 7.8, 7.6 followed by T₆ with 7.4, 7.4 which was on par with T₄ with 7.4 and 7.2. While control recorded 6.2 and 6.1 in TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.3.4. Root length (Table 19)

The reduction of root length was more pronounced at 150 mM concentration with 56, 61 per cent reduction followed by 34, 36 and 4 per cent at 100 mM and 50 mM concentration in TNAU Rice TRY 3 and I.W.Ponni, respectively over the unstress condition (20.0 and 19.1 cm).

Among the priming treatments, T₇ registered the longest root length of 16.0 cm followed by T₆ (15.6 cm), T₄ (15.3 cm). Whereas, control registered the shortest root length (13.7cm).

Among the interaction effects between treatments and salinity levels T₇ treatment registered the longest root length of (10.0, 8.3cm) at 150 mM level followed by T₆ (9.7, 8.1 cm), T₄ treatment recorded (9.5, 7.6 cm) whereas, control registered the shortest root length of (7.4, 6.4 cm) in TNAU Rice TRY 3 and I.W.Ponni.

Table 18. Effect of seed priming treatments on speed of germination in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Salinity (S) Treatments (T)	Varieties (V)											Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	50	100	150	Mean	0	50	100	150	Mean			
T ₀	6.6	6.4	6.8	5.0	6.2	6.8	6.5	5.9	5.1	6.1	6.2		
T ₁	7.1	6.9	6.4	5.6	6.5	7.0	6.8	6.2	5.4	6.4	6.5		
T ₂	7.8	7.6	7.0	6.2	7.1	7.7	7.5	6.9	6.1	7.0	7.1		
T ₃	7.4	7.2	6.6	5.8	6.7	7.3	7.1	6.5	5.7	6.6	6.7		
T ₄	8.0	7.8	7.2	6.4	7.4	7.9	7.6	7.0	6.2	7.2	7.3		
T ₅	7.6	7.4	6.8	6.0	7.0	7.4	7.2	6.6	5.8	6.7	6.9		
T ₆	8.1	7.9	7.3	6.5	7.4	8.0	7.8	7.4	6.6	7.4	7.4		
T ₇	8.4	8.2	7.6	6.8	7.8	8.3	8.0	7.4	6.8	7.6	7.7		
Mean	7.6	7.4	6.9	6.0	7.0	7.5	7.3	6.7	6.0	6.9	6.9		
Salinity	0mM					50mM					100mM		150mM
Mean	7.6					7.4					6.8		6.5

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.06	0.05	0.03	0.14	0.07	0.09	0.20
CD (P=0.05)	0.134	0.10	0.06	NS	NS	NS	NS

Table 19. Effect of seed priming treatments on root length (cm) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Salinity (S) Treatments (T)	Varieties (V)										Treatment Mean		
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	50	100	150	Mean	0	50	100	150	Mean			
T ₀	19.0	18.3	11.3	7.4	14.0	18.1	18.2	10.5	6.4	13.3	13.7		
T ₁	19.3	18.6	12.1	7.9	14.5	18.4	18.4	11.3	7.0	13.8	14.2		
T ₂	19.7	19.1	13.3	9.1	15.3	18.7	18.7	12.4	7.4	14.3	14.8		
T ₃	19.5	19.3	12.4	8.2	14.9	19.1	19.0	11.6	7.1	14.3	14.6		
T ₄	20.2	19.6	13.7	9.5	15.8	19.4	19.1	13.0	7.6	14.8	15.3		
T ₅	20.4	19.3	13.0	8.7	15.3	19.2	19.1	12.2	7.3	14.4	14.9		
T ₆	20.7	19.3	14.2	9.7	16.0	19.8	19.4	13.4	8.1	15.2	15.6		
T ₇	21.0	20.2	15.1	10.0	16.5	20.0	19.6	14.3	8.3	15.5	16.0		
Mean	20.0	19.2	13.1	8.8	15.3	19.1	18.9	12.3	7.4	14.5	14.9		
Salinity	0mM					50mM					100mM		150mM
Mean	19.6					19.1					12.7		8.1

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.08	0.05	0.04	0.15	0.08	0.11	0.22
CD (P=0.05)	0.15	0.11	0.08	0.30	0.15	NS	NS

4.3.3. Shoot length (Table 20)

Irrespective of salinity levels and priming treatments variety V_1 recorded the maximum shoot length of 11.2cm than V_2 (10.6cm) Among the priming treatments, T_7 recorded longer shoot length of 12.0cm followed by T_6 with 11.6cm and T_4 treatment (11.3cm). While, control recorded the shortest shoot length (9.8cm).

The adverse effect of salinity stress at different levels also reflected on shoot growth in terms of length. The salinity stress at 50 mM concentration had only minimum effect on shoot growth with less reduction of (12 and 15 per cent) whereas, the other higher concentrations of 100 mM and 150 mM reduced the mean shoot length by 28, 30 and 48, 53 per cent, respectively over unstressed control in TNAU Rice TRY 3 and I.W.Ponni.

The priming treatments showed its influence on shoot growth at different salinity stress level. T_7 and T_6 treatment registered (9.3 and 8.3 cm) and (8.5 and 7.3 cm), T_4 registered (8.0, and 7.6 cm) and T_2 registered (7.7 and 7.2 cm) at 150mM level. Whereas, control recorded shoot length of (5.6 and 4.8 cm) in TNAU Rice TRY 3 and I. W.Ponni, respectively.

4.3.5. Drymatter Production (Table 21)

Significant differences were observed due to salinity stress, seed priming varieties and interaction between treatments and salinity levels. Comparing the levels of salinity, at 150 mM concentrations drastically reduced the drymatter production by 50, 40 per cent over control. The other concentration of 50 mM and 100 mM recorded 14 and 13 and 27, 35 per cent reduction, respectively over control in TNAU Rice TRY 3 and I.W. Ponni.

Comparing priming treatments, T_7 registered higher dry matter production of 0.100 g seedlings⁻¹⁰ followed by T_6 with 0.096 g seedlings⁻¹⁰. While control registered 0.076 g seedlings⁻¹⁰. Between varieties TNAU Rice TRY 3 recorded 0.102 g seedlings⁻¹⁰ than I.W.Ponni which recorded 0.074 g seedlings⁻¹⁰.

In respect of interaction between treatment and varieties, T_7 treatment recorded higher dry matter production of 0.116 and 0.083 g seedlings⁻¹⁰, followed by T_6 treatment 0.111 and 0.080 g seedlings⁻¹⁰, T_4 treatment registered 0.108 and 0.079 g seedlings⁻¹⁰, whereas control registered 0.088 and 0.064 g seedlings⁻¹⁰ in TNAU Rice TRY 3 and I.W.Ponni, respectively.

The priming treatment under different salinity level influenced the dry matter production of seedlings. The interaction among seed priming treatments, varieties and stress conditions

Table 20. Effect of seed priming treatments on shoot length (cm) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Salinity (S) Treatments (T)	Varieties (V)											Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	50	100	150	Mean	0	50	100	150	Mean			
T ₀	12.9	12.1	9.3	5.6	10.0	12.9	11.5	8.7	4.8	9.5	9.8		
T ₁	13.1	12.5	9.8	6.9	10.6	12.9	11.6	9.4	5.2	9.8	10.2		
T ₂	13.6	12.8	10.5	7.7	11.2	13.1	11.8	9.9	7.2	10.5	10.9		
T ₃	13.8	12.6	10.1	6.3	10.7	14.1	12	9.5	5.7	10.3	10.5		
T ₄	14.6	12.8	10.7	8.0	11.5	14.4	12.3	10.1	7.6	11.1	11.3		
T ₅	14.8	12.5	10.3	7.3	11.2	14.7	12.3	9.7	6.8	10.8	11.0		
T ₆	15.5	12.9	10.9	8.5	12.0	15.1	12.2	10.2	7.3	11.2	11.6		
T ₇	15.9	12.9	11.1	9.3	12.3	15.8	12.2	10.4	8.3	11.7	12.0		
Mean	14.3	12.6	10.3	7.4	11.2	14.1	12.0	9.8	6.6	10.6	10.9		
Salinity	0mM					50mM					100mM		150mM
Mean	14.2					12.3					10.1		7.0

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.09	0.06	0.04	0.18	0.09	0.13	0.26
CD (P=0.05)	0.18	0.13	0.09	0.36	0.18	NS	NS

Table 21. Effect of seed priming treatments on drymatter production (g seedlings⁻¹⁰) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Salinity (S) Treatments (T)		Varieties (V)										Treatment Mean
		TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)					
		0	50	100	150	Mean	0	50	100	150	Mean	
T ₀	0.122	0.088	0.081	0.059	0.088	0.092	0.080	0.052	0.036	0.064	0.076	
T ₁	0.126	0.093	0.085	0.064	0.092	0.095	0.082	0.059	0.037	0.068	0.080	
T ₂	0.128	0.115	0.096	0.081	0.105	0.098	0.084	0.067	0.054	0.075	0.090	
T ₃	0.129	0.095	0.089	0.069	0.096	0.095	0.085	0.048	0.040	0.067	0.082	
T ₄	0.130	0.120	0.099	0.084	0.108	0.106	0.086	0.071	0.056	0.079	0.094	
T ₅	0.127	0.111	0.092	0.074	0.101	0.098	0.087	0.063	0.050	0.074	0.088	
T ₆	0.130	0.124	0.102	0.089	0.111	0.101	0.087	0.075	0.058	0.080	0.096	
T ₇	0.134	0.133	0.105	0.094	0.116	0.104	0.087	0.079	0.062	0.083	0.100	
Mean	0.128	0.110	0.094	0.077	0.102	0.098	0.085	0.064	0.049	0.074	0.088	
Salinity	0mM				50mM			100mM			150mM	
Mean	0.113				0.096			0.079			0.063	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.0007	0.0005	0.0004	0.0015	0.0007	0.0010	0.0021
CD (P=0.05)	0.0014	0.0010	0.0007	0.0029	0.0014	0.0020	0.0041

found to be significant with TNAU Rice TRY 3 at T₇ and T₆ which recorded 0.094 and 0.089 g seedling⁻¹⁰ and I.W. Ponni at T₇ and T₆ which registered 0.062 and 0.058 g seedlings⁻¹⁰, were found to be superior over rest of the treatments.

4.3.6. Vigour Index (Table 22)

The effect of salt stress on vigour indeed of priming treatments was assessed at different salinity levels. Among the treatments T₇ recorded the maximum vigour index of 2472 followed by T₆ with 2343 and the control recorded the minimum vigour index of 1827 irrespective of varieties and salinity levels.

The seedling vigour index was significantly altered by all the three levels of salinity, at 150 mM concentration drastically reduced the vigour index by 71, 66 per cent over control. The other concentrations of 50 mM and 100 mM recorded 15.0 and 14.0, 41.3 and 43 per cent reduction, respectively over control in TNAU Rice TRY 3 and I.W.Ponni.

TNAU Rice TRY 3 registered higher vigour index value of 2232 than I.W.Ponni 2071, irrespective of treatments and salinity levels.

Among the interaction effects, T₇ treatment at 150 mM stress level recorded vigour index value of (1458 and 1191) followed by T₆ (1286 and 1093), T₄ (1203 and 1013), T₂ (1128 and 933) whereas, control registered the vigour index value of 716 and 575 in TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.4. Final screening of seed priming treatments under further fine-tuned sodicity and Salinity stress condition

4.4.1. Germination (Table 23)

Based on the results of the previous experiment (0, 25 and 50 mM) on the germination and seedling growth parameters, the stress levels were further refined and fine tuned (0, 14, 16 and 18 mM) to further evaluate the performance of seed priming treatments on alleviating the effect of stress. Only the best performing priming treatments of previous experiments (4.2) were included in this experiment for further study.

Germination per cent is an important index for salt tolerance and significant variations in germination were observed due to stress treatments while observing the effect of different

Table 22. Effect of seed priming treatments on vigour index in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Salinity (S) Treatments (T)	Varieties (V)											Treatment Mean
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	50	100	150	Mean	0	50	100	150	Mean		
T ₀	2871	2480	1552	716	1905	2624	2396	1408	575	1750	1827	
T ₁	2981	2556	1727	884	2037	2814	2440	1591	683	1882	1959	
T ₂	3153	2678	1914	1128	2218	2989	2602	1751	933	2069	2143	
T ₃	3130	2697	1769	908	2126	2991	2547	1630	761	1982	2054	
T ₄	3358	2851	2007	1203	2355	3115	2745	1861	1013	2183	2269	
T ₅	3242	2655	1843	1043	2195	3155	2637	1681	868	2085	2140	
T ₆	3473	2898	2113	1286	2442	3269	2675	1945	1093	2245	2343	
T ₇	3570	3061	2209	1458	2574	3392	2854	2041	1191	2370	2472	
Mean	3222	2735	1891	1078	2232	3044	2612	1739	890	2071	2151	
Salinity	0mM					50mM			100mM			150mM
Mean	3133					2674			1815			984

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	19.34	13.71	9.70	38.79	19.39	27.43	54.87
CD (P=0.05)	38.40	27.14	19.19	76.77	NS	NS	NS

Table 23. Screening of seed priming treatments based on germination (%) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	14	16	18	Mean	0	14	16	18	Mean		
T ₀	91 (73.44)	82 (65.11)	76 (60.68)	70 (56.79)	80 (64.01)	90 (71.63)	79 (62.76)	73 (58.714)	69 (56.18)	78 (62.32)	79 (62.76)	
T ₁	96 (77.43)	84 (66.84)	81 (63.80)	78 (61.68)	84 (67.44)	94 (76.07)	82 (65.23)	80 (63.28)	76 (60.51)	83 (66.29)	84 (67.44)	
T ₂	97 (79.14)	85 (67.24)	82 (64.91)	80 (61.68)	85 (68.73)	95 (77.94)	83 (66.23)	81 (63.98)	76 (61.17)	84 (67.33)	85 (68.73)	
T ₃	98 (80.56)	86 (68.32)	83 (65.90)	82 (63.26)	86 (69.97)	96 (78.91)	84 (66.48)	81 (64.41)	77 (61.56)	84 (67.84)	85 (68.73)	
T ₄	97 (82.01)	88 (69.79)	86 (68.11)	82 (64.18)	88 (71.30)	97 (80.18)	86 (68.05)	83 (66.06)	79 (63.10)	86 (69.33)	87 (69.16)	
Mean	96 (78.58)	85 (67.46)	83 (64.68)	81 (62.43)	85 (68.73)	94 (76.93)	83 (65.76)	80 (63.29)	75 (60.51)	83 (66.29)	84 (67.44)	
Sodicity	0mM					14mM					16mM	18mM
Mean	95 (76.58)					84 (66.52)					82 (65.11)	78 (61.68)

(Figures in parentheses indicate arcsine values)

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.145	0.452	0.319	1.00	0.638	0.714	1.429
CD (P=0.05)	1.000	0.894	0.632	NS	NS	NS	NS

stresses imposed a reduction of germination was noticed at the sodicity level of 18 mM in both the varieties.

Irrespective of sodicity stress conditions, and varieties tested among the priming treatments, T₄ recorded the maximum germination of 87 per cent followed by T₃ and T₂ with 85 per cent each, while control recorded the minimum 79 per cent .

Among the different sodicity levels, at 14mM registered (85 and 83 per cent) followed by 16 mM (83 and 80 per cent) and 18 mM level (81 and 75 per cent) whereas control recorded higher germination of 96 and 94 per cent in both varieties, respectively.

The treatment T₄ registered higher germination of (88 and 86 per cent) followed by T₃ recorded (86 and 84 per cent), T₂ 84 and 83 whereas, control recorded lower germination of 80 and 78 per cent, respectively in both the varieties.

4.4.2. Speed of germination (Table 24)

Significant differences were noticed due to seed priming treatments, sodicity levels, varieties and also interaction between treatment and sodicity level and varieties.

The early germination of 7.2 was recorded in variety V₁ as compared to V₂ 7.0 irrespective of stress condition. The T₄ priming treatment recorded early germination of 7.7 followed by T₃ (7.5), whereas, control recorded 5.9.

Among the different sodicity levels at 14 mM recorded early germination of 7.3 and 7.1 followed by 7.1 and 6.9 at 16 mM sodicity level whereas, at 18 mM level the early germination was recorded 6.4 and 6.2. While control recorded 7.8 and 7.7 in TNAU Rice TRY 3 and I. W. Ponni, respectively.

Interaction between treatments and varieties showed that T₄ recorded early germination of 7.8 and 7.6 followed by T₃ 7.5 and 7.4 which was on par with T₂ 7.4 and 7.3, while control recorded 6.1 and 5.7 in above said varieties, respectively.

Among the interaction effects between treatments and sodicity levels, T₄ at 14 mM level concentration recorded (7.9 and 7.6), (7.7 and 7.4), (7.1 and 6.9) at 16 mM and 18 mM concentrations respectively followed by T₃ recorded (7.7 and 7.5) at 14 mM concentration, (7.5 and 7.3) (6.7 and 6.5) at 16 mM and 18 mM concentrations, respectively. Whereas, control recorded (6.1 and 5.7), (5.8 and 5.5) and (5.6 and 5.1) at 14, 16 and 18 mM concentrations, respectively in TNAU Rice TRY 3 and I.W.Ponni.

Table 24. Screening of seed priming treatments based on speed of germination in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	14	16	18	Mean	0	14	16	18	Mean		
T ₀	6.6	6.1	5.8	5.6	6.1	6.9	5.7	5.5	5.1	5.7	5.9	
T ₁	7.6	7.3	7.1	6.2	7.0	7.4	7.0	6.8	6.1	6.9	7.0	
T ₂	8.1	7.6	7.4	6.6	7.4	7.9	7.5	7.3	6.5	7.3	7.4	
T ₃	8.1	7.7	7.5	6.7	7.5	8.0	7.5	7.3	6.5	7.4	7.5	
T ₄	8.4	7.9	7.7	7.1	7.8	8.3	7.6	7.4	6.9	7.6	7.7	
Mean	7.8	7.3	7.1	6.4	7.2	7.7	7.1	6.9	6.2	7.0	6.6	
Sodicity	0mM					14mM					18mM	
Mean	7.8					7.2					7.0 6.3	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.052	0.05	0.03	0.10	0.06	0.07	0.146
CD (P=0.05)	0.102	0.091	0.06	0.20	0.13	NS	NS

4.4.3. Root length (Table 25)

Irrespective of priming treatments and sodic stress levels among the priming treatments T₄, T₃ and T₂ recorded the maximum root length of 20.2, 20.1 and 20.2cm each and the control recorded the minimum root length of 18.4 cm. The variety TNAU Rice TRY 3 recorded the maximum root length of 20.1 cm than I.W.Ponni 18.9 cm.

Among the different sodicity levels at 14 mM registered the longest root length of (20.3 and 19.0 cm) followed by 16 mM (19.8 and 18.6 cm) and 18 mM recorded (19.4 and 18.2 cm) whereas control registered the shortest root length (20.6 and 19.3 cm).

With the respect to interaction between treatments and varieties, treatments T₄ and T₃ registered the highest root length of 20.9 and 19.5 cm and 20.9 and 19.2 cm which was on par with T₂ (20.7, 19.7 cm). Whereas, control registered the lowest root length (18.9 and 17.9 cm) in TNAU Rice TRY 3 and I.W.Ponni.

4.4.4. Shoot length (Table 26)

Significant differences for shoot length were observed in seed priming treatments, sodicity levels, varieties and interaction between treatments and varieties. Irrespective of treatments and different level of sodic stress conditions, the treatments, T₄ recorded the highest shoot length of 14.7 cm followed by T₃ 14.4 cm. The variety TNAU Rice TRY 3 recorded the shoot length of 14.1 cm, whereas I.W.Ponni recorded 13.5 cm.

Under the different sodicity levels, shoot length of 14.4 and 13.8 cm was recorded at 14 mM than control (14.8 and 14.0 cm).

In respect of interaction between treatments and varieties, T₄ recorded the longest shoot length of 14.8 and 14.6 cm followed by T₃ (14.6 and 14.2 cm) and T₂ (14.2 and 13.6 cm) whereas, control recorded the shortest shoot length of 13.3 and 12.4 cm respectively in TNAU Rice TRY 3 and I.W.Ponni.

4.4.5. Drymatter production (Table 27)

Irrespective of priming treatments and different level of sodic stress conditions, the variety TNAU Rice TRY 3 recorded 0.119 g seedlings⁻¹⁰ than I.W.Ponni 0.095 g seedlings⁻¹⁰. Among the treatments, T₄ recorded the maximum dry matter production of 0.143 g seedlings⁻¹⁰

Table 25. Screening of seed priming treatments based on root length (cm) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	14	16	18	Mean	0	14	16	18	Mean		
T ₀	19.5	19.2	18.7	18.3	18.9	18.5	18.2	17.7	17.3	17.9	18.4	
T ₁	20.2	19.5	19.0	18.6	19.3	18.8	18.5	18.1	17.7	18.3	18.8	
T ₂	21.2	20.0	19.5	19.2	20.7	19.5	19.2	18.8	18.4	19.7	20.2	
T ₃	21.7	21.5	20.6	20.1	20.9	19.7	19.5	19.1	18.7	19.2	20.1	
T ₄	20.7	21.5	21.0	20.6	20.9	20.0	19.7	19.3	19.0	19.5	20.2	
Mean	20.6	20.3	19.8	19.4	20.1	19.3	19.0	18.6	18.2	18.9	19.5	
Sodicity	0mM					14mM					16mM	18mM
Mean	20.0					19.8					19.0	18.8

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.08	0.07	0.05	0.15	0.10	0.11	0.21
CD (P=0.05)	0.15	0.14	0.10	NS	NS	0.22	NS

Table 26. Screening of seed priming treatments based on shoot length (cm) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean		
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	14	16	18	Mean	0	14	16	18	Mean			
T ₀	14.0	13.6	13.0	12.5	13.3	13.0	12.6	12.3	11.8	12.4	12.9		
T ₁	14.6	13.6	13.3	12.7	13.5	13.2	13.0	12.5	12.1	12.7	13.1		
T ₂	15.1	14.4	14.0	13.5	14.2	14.1	13.9	13.4	13.0	13.6	13.9		
T ₃	15.6	14.9	14.2	13.7	14.6	14.7	14.5	14.1	13.6	14.2	14.4		
T ₄	14.8	15.4	14.9	14.3	14.8	15.2	15.0	14.4	14.0	14.6	14.7		
Mean	14.8	14.4	13.9	13.3	14.1	14.0	13.8	13.3	12.9	13.5	13.7		
Sodicity	0mM					14mM					16mM		18mM
Mean	14.4					14.1					13.6		13.1

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.07	0.06	0.04	0.13	0.08	0.09	0.19
CD (P=0.05)	0.133	0.121	0.08	NS	NS	0.18	NS

Table 27. Screening of seed priming treatments based on drymatter production (g seedlings⁻¹⁰) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	14	16	18	Mean	0	14	16	18	Mean		
T ₀	0.108	0.106	0.102	0.16	0.104	0.091	0.090	0.089	0.088	0.089	0.097	
T ₁	0.123	0.121	0.118	0.116	0.112	0.096	0.094	0.091	0.089	0.093	0.103	
T ₂	0.127	0.125	0.123	0.121	0.124	0.102	0.100	0.098	0.096	0.099	0.112	
T ₃	0.130	0.129	0.127	0.124	0.128	0.101	0.099	0.097	0.095	0.098	0.113	
T ₄	0.128	0.126	0.124	0.123	0.125	0.104	0.101	0.099	0.097	0.100	0.143	
Mean	0.127	0.125	0.123	0.121	0.119	0.099	0.097	0.095	0.093	0.095	0.113	
Sodicity	0mM					14mM					16mM	18mM
Mean	0.113					0.111					0.109	0.107

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.0006	0.0006	0.0005	0.0013	0.0009	0.0009	0.0018
CD (P=0.05)	0.0013	0.0013	0.0009	NS	NS	0.0018	NS

followed by T₃ (0.113 g seedlings⁻¹⁰), while control recorded the minimum drymatter production of (0.097 g seedlings⁻¹⁰)

Among the different sodicity levels, 14 mM recorded 0.125 and 0.097 g seedlings⁻¹⁰ followed by 16 mM (0.123 and 0.095 g seedlings⁻¹⁰) and 18 mM (0.121 and 0.093 g seedlings⁻¹⁰) whereas control registered (0.127 and 0.099 g seedlings⁻¹⁰) in both the varieties, respectively.

Interaction between treatments and varieties showed that the treatment T₄ recorded higher drymatter production (0.125 and 0.100 g seedlings⁻¹⁰) followed by T₃ (0.128 and 0.098 g seedlings⁻¹⁰), T₂ recorded (0.124 and 0.099 g seedlings⁻¹⁰) and T₁ (0.112 and 0.093 g seedlings⁻¹⁰) whereas, control recorded the minimum drymatter production (0.104 and 0.089 g seedlings⁻¹⁰) in TNAU Rice TRY 3 and I.W.Ponni respectively.

4.4.6. Vigour index (Table 28)

Different levels of sodicity also caused adverse effects on vigour index of rice seedlings. Irrespective of varieties and different level of sodicity stress conditions, the treatments, T₄ recorded the maximum vigour index of 3079 followed by T₃ with 2949 and the control recorded the minimum (2474). The variety TNAU Rice TRY 3 registered 2888 and I.W.Ponni registered 2701.

Among the different priming treatments, T₄ recorded higher vigour index value of 3198 and 2960 followed by T₃ (3052 and 2845), T₂ (2898 and 2753) and T₁ (2714 and 2579) whereas, control recorded the lowest vigour index value of 2579 and 2369 in TNAU Rice TRY 3 and I.W.Ponni respectively.

The interaction effect between seed priming treatments and varieties was found to be significant. At 18 mM sodicity stress level T₄ recorded the vigour index of 2885 and 2627 followed by T₃ 2777 and 2144, while control recorded 2159 and 2015 in TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.4.7. Stress tolerance index (Table 29)

The stress tolerance index revealed that with the increase in sodicity level, there was a decreasing trend in both the varieties, indicating that higher the stress, lesser the tolerance.

Table 28. Screening of seed priming treatments based on vigour index in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	14	16	18	Mean	0	14	16	18	Mean		
T ₀	3043	2695	2419	2159	2579	2826	2441	2195	2015	2369	2474	
T ₁	3198	2798	2605	2431	2714	3010	2598	2448	2260	2579	2647	
T ₂	3361	2926	2755	2606	2898	3209	2778	2606	2417	2753	2826	
T ₃	3533	3098	2905	2777	3052	3316	2857	2706	2144	2845	2949	
T ₄	3657	3248	3089	2885	3198	3407	2988	2817	2627	2960	3079	
Mean	3358	2953	2755	2572	2888	3154	2732	2555	2365	2701	2795	
Sodicity	0mM					14mM					18mM	
Mean	3256					2843					2469	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	19.10	17.08	12.08	38.21	24.17	27.02	54.04
CD (P=0.05)	37.83	33.83	23.92	NS	NS	0.19	NS

Table 29. Screening of seed priming treatments based on stress tolerance index (%) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean		
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	14	16	18	Mean	0	14	16	18	Mean			
T ₀	100.0 (89.75)	88.5 (65.11)	79.5 (60.67)	71.0 (59.79)	85.0 (68.08)	100.0 (89.75)	80.2 (62.76)	77.6 (58.71)	71.0 (56.18)	82.2 (66.85)	84.0 (69.71)		
T ₁	100.0 (89.75)	87.5 (66.84)	81.5 (63.80)	76.0 (59.83)	86.0 (70.35)	100.0 (89.75)	81.2 (65.30)	81.3 (63.27)	75.0 (60.51)	84.4 (69.71)	85.0 (70.63)		
T ₂	100.0 (89.75)	87.0 (68.69)	81.7 (64.75)	78.0 (62.39)	87.0 (70.93)	100.0 (89.75)	83.0 (68.25)	81.2 (64.35)	75.2 (60.18)	85.0 (70.63)	86.0 (89.75)		
T ₃	100.0 (89.75)	87.7 (69.63)	82.2 (65.16)	79.0 (63.16)	87.2 (71.28)	100.0 (89.75)	81.0 (68.11)	81.6 (64.62)	75.5 (60.26)	84.0 (70.68)	86.0 (89.75)		
T ₄	100.0 (89.75)	89.0 (70.46)	84.5 (68.08)	79.0 (63.16)	88.1 (71.99)	100.0 (89.75)	82.0 (69.11)	82.6 (65.13)	77.1 (61.20)	85.4 (71.29)	87.0 (70.93)		
Mean	100.0 (89.75)	88.0 (68.15)	82.0 (64.06)	77.0 (60.15)	87.0 (69.63)	100.0 (89.75)	86.0 (89.75)	81.0 (66.70)	75.0 (63.21)	86.0 (89.75)	86.0 (89.75)		
Sodicity	0mM					14mM					16mM		18mM
Mean	100 (89.75))					87 (68.69)					82 (64.06)		76 (59.83)

(Figures in parentheses indicate arcsine values)

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.404	0.361	0.255	0.807	0.510	0.571	1.142
CD (P=0.05)	0.799	0.715	0.505	1.599	NS	NS	NS

Among the treatments, T₄ registered 87 per cent followed by T₃ (86 per cent) whereas, control recorded 84 per cent. Between varieties TNAU Rice TRY 3 recorded stress tolerance index of 87 per cent and I.W.Ponni recorded 86 per cent.

The overall mean stress tolerance index of seeds at 18 mM sodicity level was reduced from 100 to 77 and 75 per cent and at other sodicity levels of 14 and 16 mM, stress tolerance index was recorded as 88 and 86 per cent, 82 and 81 per cent, respectively over control in TNAU Rice TRY 3 and I.W.Ponni, respectively.

The interaction effect between seed priming treatments, and stress found to be significant. T₄ treatment recorded the stress tolerance index of 79 and 77.1 in TNAU Rice TRY 3 and I.W.Ponni while control recorded 71.0 in both the varieties, respectively at 18 mM stress level.

4.5 Salinity Stress (125-175 mM)

4.5.1. Germination (Table 30)

Since the results of the above experiments revealed the severe impact of salinity stress levels tried (0, 50, 100 and 150 mM) on the germination and seedling growth parameters, the stress levels were further refined and fine tuned (0, 125, 150 and 175 mM) to further evaluate the performance of seed priming treatments on alleviating the effect of stress. Only the best performing priming treatments of previous experiment (4.3) were included in this experiment for further study.

Irrespective of priming treatments and stress levels, variety V₁ recorded 73 per cent than V₂ (68 per cent). Among the treatments, T₄ recorded 76 per cent followed by T₃ (74 per cent), whereas, the control recorded 64 per cent. At 125 mM concentration higher germination of 75 and 73 per cent was recorded followed by 65 and 59 per cent at 150 mM concentration 56 and 49 per cent at 175 mM concentration. Whereas, control registered 97 and 95 per cent germination in TNAU Rice TRY 3 and I.W.Ponni, respectively. Between varieties TNAU Rice TRY 3 (73 per cent) performed better than I.W.Ponni (68 per cent) in all stress conditions.

In interaction between seed priming treatments and salinity stress levels, T₄ treatment at 175 mM level registered (61 and 55 per cent) followed by T₃ (58 and 50 per cent) and T₂ (54 and 46 per cent) whereas control registered (47 and 40 per cent) in TNAU Rice TRY 3 and I.W.Ponni, respectively.

Table 30. Screening of seed priming treatments based on germination (%) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean		
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)							
	0	125	150	175	Mean	0	125	150	175	Mean			
T ₀	91 (73.44)	65 (53.74)	59 (50.18)	47 (43.28)	66 (55.16)	90 (71.63)	63 (52.24)	54 (47.30)	40 (39.07)	62 (52.56)	64 (53.85)		
T ₁	95 (77.43)	72 (57.75)	63 (52.39)	51 (45.72)	70 (58.32)	93 (76.08)	68 (55.56)	58 (49.61)	43 (41.26)	66 (55.63)	68 (55.56)		
T ₂	96 (79.50)	78 (62.06)	65 (53.73)	54 (47.29)	73 (60.65)	94 (77.94)	74 (59.39)	59 (50.19)	46 (42.70)	68 (57.56)	71 (59.66)		
T ₃	98 (80.55)	81 (63.84)	69 (56.18)	58 (49.89)	76 (62.62)	95 (78.90)	79 (63.12)	61 (51.36)	50 (45.29)	71 (59.66)	74 (61.18)		
T ₄	98 (82.00)	83 (65.69)	71 (57.43)	61 (51.65)	78 (64.19)	96 (80.09)	81 (64.19)	63 (52.54)	55 (47.87)	74 (61.18)	76 (62.62)		
Mean	97 (78.58)	75 (60.62)	65 (53.98)	56 (47.57)	73 (60.65)	95 (76.93)	73 (58.90)	59 (50.20)	49 (43.24)	68 (55.56)	70 (58.32)		
Salinity	0mM					125mM					150mM		175mM
Mean	96 (79.50)					74 (61.18)					62 (52.56)		53 (46.12)

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.51	0.46	0.32	1.02	0.64	0.73	1.44
CD (P=0.05)	1.01	0.91	0.64	2.02	1.28	NS	NS

4.5.1. Speed of germination (Table 31)

Significant differences were observed due to seed priming and salinity stresses. The priming treatment T₄ was best in recording early germination of 7.5 followed by T₃ (7.2) while control recorded 5.7. The variety TNAU Rice TRY 3 registered the early germination of 6.9 and I.W.Ponni registered 6.8. Among the salinity levels, at 125 mM concentration recorded 7.1 and 6.9 followed by 150 mM 6.9 and 6.7 and 175 mM 6.1 and 6.0, whereas control registered 7.8 and 7.7 speed of germination in TNAU Rice TRY 3 and I.W.Ponni, respectively.

The interaction action between seed priming treatments and salinity stress levels was significant in T₄ treatment which recorded early germination of 6.5 and 6.6 at 175 Mm in TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.5.2. Root length (Table 32)

The priming treatment, T₄ recorded the maximum root length of 12.8 cm followed by T₃ with 12.1 cm. The variety TNAU Rice TRY 3 recorded 11.8 cm and I.W.Ponni recorded 11.2 cm. whereas the minimum root length of 10.3 cm was recorded in control irrespective of varieties and stress levels. The reduction was more pronounced at 175 mM concentration (5.7 cm) followed by 150 mM concentration (8.1cm) and 125 mM concentration registered (12.4cm) whereas control recorded (19.7 cm).

The interaction action between seed priming treatments and salinity stress levels was found to be significant. T₄ registered 7.7 and 6.2 cm followed by T₃ (6.5 and 5.6 cm) at 175 mM in TRY 3 and I.W.Ponni respectively. While, control recorded the minimum root length of 5.0 and 4.4 cm.

4.5.3. Shoot length (Table 33)

Among the treatments, T₄ recorded the maximum shoot length of 9.7 cm followed by T₃ with 9.2 cm whereas control recorded 7.4 cm. Irrespective of varieties and stress level, TNAU Rice TRY 3 recorded 9.0 cm and the variety I.W.Ponni recorded 8.1 cm.

The reduction was more pronounced at 175 mM concentration 64 per cent. The other concentrations 125 mM (44 per cent) and 150 mM registered 53 per cent respectively over unstressed control (14.3cm). Regardless of seed priming treatments and stress levels, variety, TNAU Rice TRY 3 performed better than I.W.Ponni.

Table 31. Screening of seed priming treatments based on speed of germination in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	125	150	175	Mean	0	125	150	175	Mean		
T ₀	6.6	5.9	5.6	5.2	5.8	6.6	5.5	5.3	4.7	5.5	5.7	
T ₁	7.6	7.1	6.9	6.7	7.1	7.4	6.8	6.6	5.9	6.7	6.9	
T ₂	8.1	7.4	7.2	6.1	7.2	7.9	7.3	7.1	6.2	7.1	7.2	
T ₃	8.1	7.5	7.3	6.1	7.2	8.0	7.4	7.1	6.3	7.2	7.2	
T ₄	8.4	7.7	7.5	6.5	7.5	8.3	7.4	7.2	6.6	7.4	7.5	
Mean	7.8	7.1	6.9	6.1	6.9	7.7	6.9	6.7	6.0	6.8	6.9	
Salinity	0mM					125mM					175mM	
Mean	7.4					7.0					6.8	
											6.1	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.51	0.46	0.32	1.02	0.64	0.73	1.44
CD (P=0.05)	1.01	0.91	0.64	2.02	1.28	NS	NS

Table 32. Screening of seed priming treatments based on root length (cm) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	125	150	175	Mean	0	125	150	175	Mean		
T ₀	19.2	11.3	7.0	5.0	10.6	18.2	10.7	6.3	4.4	9.9	10.3	
T ₁	19.5	12.1	7.40	5.6	11.1	18.7	11.7	7.2	4.8	10.6	10.9	
T ₂	20.2	12.6	8.1	6.0	11.6	19.5	12.3	7.8	5.2	11.2	11.4	
T ₃	21.2	13.2	9.0	6.5	12.4	19.7	12.8	8.8	5.6	11.8	12.1	
T ₄	21.5	13.9	9.7	7.7	13.2	20.0	13.5	9.5	6.2	12.3	12.8	
Mean	20.2	12.6	8.2	6.2	11.8	19.2	12.2	7.9	5.2	11.2	11.5	
Salinity	0mM					125mM					150mM	
Mean	19.7					12.4					8.1	
											5.7	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.10	0.09	0.06	0.20	0.13	0.14	0.28
CD (P=0.05)	0.20	0.18	0.13	0.40	0.25	NS	NS

Table 33. Screening of seed priming treatments based on shoot length (cm) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	125	150	175	Mean	0	125	150	175	Mean		
T ₀	13.6	7.3	6.1	4.1	7.8	12.8	6.5	5.1	3.6	7.0	7.4	
T ₁	13.9	7.8	6.6	5.4	8.4	13.2	6.8	6.0	4.0	7.51	8.0	
T ₂	14.6	8.3	7.2	6.0	9.0	14.1	7.2	6.4	4.5	8.1	8.6	
T ₃	15.1	9.3	7.7	6.5	9.7	14.7	7.9	6.7	5.1	8.6	9.2	
T ₄	15.6	9.8	8.3	7.2	10.2	15.2	8.5	7.2	5.4	9.1	9.7	
Mean	14.6	8.5	7.1	5.8	9.0	14.0	7.4	6.3	4.5	8.1	8.5	
Salinity	0mM					125mM					175mM	
Mean	14.3					8.0					5.2	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.09	0.08	0.06	0.18	0.11	0.13	0.26
CD (P=0.05)	0.18	0.16	0.13	NS	0.22	NS	NS

The interaction action between salinity stress levels and varieties was found to be significant. T₄ registered 7.2 and 5.4 cm followed by T₃ (6.5 and 5.1 cm) at 175 mM in TRY 3 and I.W.Ponni respectively. While, control recorded the minimum root length of 4.1 and 3.6 cm.

4.5.4. Drymatter production (Table 34)

Irrespective of varieties and different stress levels, the treatments, T₄ registered 0.079 g seedlings⁻¹⁰ followed by T₃ with 0.077 g seedlings⁻¹⁰. While the control recorded 0.065 g seedlings⁻¹⁰. TNAU Rice TRY 3 registered 0.086 g seedlings⁻¹⁰ and I.W.Ponni recorded 0.060 g seedlings⁻¹⁰. A pronounced effect of salinity stress was noticed in drymatter production. At 125 mM concentration level the maximum drymatter production was recorded (0.086 and 0.058 g seedlings⁻¹⁰) followed at 150 mM and 175 mM registered 0.071, 0.046 and 0.066, 0.038 g seedlings⁻¹⁰ respectively in TNAU Rice TRY 3 and I.W.Ponni. Whereas, control registered more drymatter production of 0.123 and 0.099 g seedlings⁻¹⁰. The interaction between varieties and treatments had significant effect on drymatter production of seedlings. T₄ recorded 0.094, 0.065 g seedlings⁻¹⁰ followed by T₃ with (0.091 and 0.062 g seedlings⁻¹⁰) and T₂ (0.088 and 0.062 g seedlings⁻¹⁰) whereas control registered 0.076 and 0.054 g seedlings⁻¹⁰.

At 175 mM salinity level, T₄ treatment registered 0.074 and 0.042 g seedlings⁻¹⁰ followed by T₃ (0.071 and 0.040 g seedlings⁻¹⁰) and T₂ (0.068 and 0.039 g seedlings⁻¹⁰) whereas, control registered 0.055 and 0.033 g seedlings⁻¹⁰ in both varieties, respectively.

4.5.5. Vigour Index (Table 35)

The effect of salt stress on vigour index of priming treatments was assessed at different salinity levels. The T₄ priming treatment registered 1794 followed by T₃ with 1748, while the control recorded the vigour index of 1275. TNAU Rice TRY 3 recorded 1638 and I.W.Ponni recorded 1487.

The seedling vigour index was significantly altered by the levels of salinity at 175 mM concentration reduced the mean vigour index by 85 and 77 per cent were recorded in TNAU Rice TRY 3 and I.W.Ponni respectively.

The interaction effect showed that T₄ treatment at 175 mM level registered 917 and 634 followed by T₃ (759 and 538), T₂ (646 and 448). While control registered 428 and 321 in TNAU Rice TRY 3 and I.W.Ponni respectively.

Table 34. Screening of seed priming treatments based on drymatter production (g seedlings⁻¹⁰) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	125	150	175	Mean	0	125	150	175	Mean		
T ₀	0.108	0.075	0.067	0.055	0.076	0.091	0.051	0.042	0.033	0.054	0.065	
T ₁	0.123	0.081	0.069	0.062	0.083	0.096	0.054	0.045	0.036	0.058	0.071	
T ₂	0.127	0.087	0.071	0.068	0.088	0.102	0.057	0.051	0.039	0.062	0.075	
T ₃	0.130	0.091	0.072	0.071	0.091	0.101	0.062	0.044	0.040	0.062	0.077	
T ₄	0.128	0.096	0.077	0.074	0.094	0.104	0.064	0.049	0.042	0.065	0.079	
Mean	0.123	0.086	0.071	0.066	0.086	0.099	0.058	0.046	0.038	0.060	0.073	
Salinity	0mM					125mM					175mM	
Mean	0.111					0.072					0.052	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.0007	0.0007	0.0005	0.0015	0.0009	0.0011	0.0017
CD (P=0.05)	0.0015	0.0013	0.0009	0.0029	0.0018	0.0021	NS

Table 35. Screening of seed priming treatments based on vigour index in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	125	150	175	Mean	0	125	150	175	Mean		
T ₀	2995	1212	771	428	1352	2780	1074	611	321	1197	1275	
T ₁	3180	1419	877	564	1510	2991	1259	763	384	1349	1430	
T ₂	3336	1631	991	646	1652	3209	1444	839	448	1482	1567	
T ₃	3499	1817	1151	759	1807	3311	1959	943	538	1688	1748	
T ₄	3636	1643	1277	917	1868	3414	1784	1049	634	1720	1794	
Mean	3329	1545	1013	663	1638	3139	1504	841	465	1487	1563	
Salinity	0mM					125mM					150mM	
Mean	3234					1525					927	
											564	

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	14.56	13.03	9.21	29.13	18.42	20.59	41.19
CD (P=0.05)	28.84	25.79	18.24	57.68	36.48	NS	81.57

4.5.6. Stress tolerance index (Table 36)

The results revealed that with increase in salinity level, there was a decreasing trend in STI in both the varieties indicating that higher the stress, lesser the tolerance. Among the treatments, T₄ recorded the stress tolerance index of 54 per cent followed by T₃ with 52 per cent while the control recorded 45 per cent. The variety TNAU Rice TRY 3 performing better with the stress tolerance index of 52 per cent than the I.W.Ponni with 48 per cent, irrespective of treatments and stress levels.

The overall mean stress tolerance index of seeds at 175 mM salinity level was reduced from (27.2 and 14.6 per cent). And at 125 mM and 150 mM, stress tolerance index was reduced to 48 and 45.6 per cent; (30.2 per cent each) respectively over control in TNAU Rice TRY 3 and I.W.Ponni respectively.

The interaction effect between treatments and salinity levels had significant effect on stress tolerance index. At 175 mM the stress tolerance index was drastically reduced invariably in all the treatments. T₄ registered the maximum (33.1 and 18.5 per cent) followed by T₃ (30.4 and 16.2 per cent), T₂ (27.2 and 14.0 per cent) whereas, control registered the minimum stress tolerance index of 21.2 and 11.5 per cent TNAU Rice TRY 3 and I.W.Ponni, respectively.

4.6. Effect of comprehensive seed priming treatments on alleviating sodicity and salinity stresses at field level

To assess the influence of different seed priming treatments followed by foliar spray on alleviating the adverse effects of sodicity stress and salinity stress, field trials were conducted under sodic and saline soil conditions. The rice varieties TNAU Rice TRY 3 as tolerant variety and I.W.Ponni as moderately tolerant variety were employed in this study. The results of the study are presented below.

4.6.1. Biometrical observations

4.6.1.1. Days to first flowering (Table 37)

Under sodicity condition, among two main plot treatments, in M₁ the first flowering was advanced by 3.4 days (100.2 days) as compared to M₂ (103.6 days). Among the sub plot treatments, the days to first flowering initiated at 99.8 days by S₇ followed by S₉ (100.0 days) as

Table 36. Screening of seed priming treatments based on stress tolerance index (%) in rice varieties TNAU Rice TRY 3 and I.W.Ponni under salinity stress condition

Sodicity (S) Treatments (T)	Varieties (V)										Treatment Mean	
	TNAU Rice TRY 3 (V ₁)					I.W.Ponni (V ₂)						
	0	125	150	175	Mean	0	125	150	175	Mean		
T ₀	100.0 (89.77)	40.5 (39.52)	26.0 (30.54)	21.2 (22.25)	47.0 (45.52)	100.0 (89.77)	39.0 (38.56)	22.0 (28.33)	11.5 (20.07)	43.1 (44.18)	45 (45.40)	
T ₁	100.0 (89.77)	45.1 (42.13)	27.5 (31.69)	24.1 (25.22)	50 (47.20)	100.0 (89.77)	42.1 (40.570)	25.5 (30.35)	12.8 (20.93)	45.1 (45.40)	48 (47.05)	
T ₂	100.0 (89.77)	49.0 (44.57)	29.2 (33.08)	27.2 (26.10)	51.3 (48.38)	100.0 (89.77)	45.2 (42.23)	31.0 (34.21)	14.0 (21.99)	48.0 (47.05)	50 (47.20)	
T ₃	100.0 (89.77)	52.0 (45.80)	33.0 (34.99)	30.4 (27.76)	54.0 (49.58)	100.0 (89.77)	49.6 (44.80)	35.0 (36.13)	16.2 (23.76)	50.2 (48.61)	52 (45.80)	
T ₄	100.0 (89.77)	54.0 (47.38)	35.1 (36.51)	33.1 (30.13)	56.0 (50.94)	100.0 (89.77)	52.2 (46.39)	37.4 (37.76)	18.5 (25.54)	52.0 (49.86)	54 (49.58)	
Mean	100.0 (89.77)	48.0 (43.88)	30.2 (33.36)	27.2 (26.29)	52.0 (45.80)	100.0 (89.77)	45.6 (42.51)	30.2 (33.35)	14.6 (22.46)	48.0 (47.05)	50 (47.20)	
Salinity	0mM					125mM					150mM	175mM
Mean	100 (89.77)					46.8 (45.52)					30.2 (33.36)	20.9 (22.08)

	T	S	V	T x S	S x V	T x V	T x V x S
SEd	0.216	0.193	0.137	0.432	0.273	0.305	0.611
CD (P=0.05)	0.428	0.382	0.270	0.855	0.540	NS	1.209

Table 37. Effect of seed priming and foliar spray on days to first flowering in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁	M ₂	Mean		M ₁	M ₂	Mean	
S ₁	102.0	105.0	103.5		101.7	105.0	103.3	
S ₂	102.0	104.7	102.7		101.0	104.7	102.8	
S ₃	100.3	104.3	102.3		102.0	103.3	102.7	
S ₄	103.3	104.3	103.8		103.0	104.0	103.5	
S ₅	98.7	103.0	100.8		99.0	103.7	101.3	
S ₆	101.7	103.7	102.7		100.3	104.0	102.2	
S ₇	97.3	102.3	99.8		98.0	102.3	100.2	
S ₈	98.3	103.0	100.7		98.7	103.3	101.0	
S ₉	98.0	102.0	100.0		19.3	102.7	100.0	
Mean	100.2	103.6			100.1	103.7		
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.45	0.80	1.79	0.97	1.47	0.89	1.89	1.09
CD (P=0.05)	6.22	1.62	NS	NS	6.32	1.82	NS	NS

compared to control (103.5). There was no significant interactive effect on days to first flowering in TNAU Rice TRY 3 and I.W.Ponni.

Under salinity condition comparing two main plots, M_1 advanced by 3.6 days to first flowering (100.1 days) than M_2 (103.7 days). Among sub plot treatments, S_9 advanced by 3.3 days to first flowering (100.0 days), followed by S_7 (100.2 days), S_8 (101.0 days) and S_5 (101.3 days). There was no significant interactive effect influenced on the days to first flowering.

4.6.1.2. Days to 50 per cent flowering (Table 38)

Under both soil conditions, the day to 50 percent flowering was advanced by 3.9 days in M_1 (106.6 days) as compared to M_2 (110.5 days). Under sodicity condition among the sub plot treatments, S_7 advanced the days to 50 percent flowering by 3.6 days (106.7 days) followed by S_9 (107.5 days), S_8 (107.7 days) and S_5 (108.0 days). Whereas, control registered the days to 50 per cent flowering by 110.3 days.

The interaction effects, S at M were significant. Among the treatments combinations, M_1 S_7 advanced the days to 50 per cent flowering by 5.5 days (103.3 days) followed by M_1S_8 (105.0 days) and M_1S_9 (105.7 days). Whereas, M_1S_1 recorded the days to 50 per cent flowering by 109.3 days.

Under saline condition among the main plot treatments, M_1 advanced the days to 50 per cent flowering by 3.8 days (106.6 days) over M_2 (110.2 days). In sub plot treatments, S_9 advanced the days to 50 per cent flowering by 5.3 days (105.5 days) followed by S_7 (106.8 days), S_8 (107.2 days) and S_5 (108.5 days). There was no significant interactive effect on the days to 50 percent flowering.

4.6.1.3. Number of total tillers (Table 39)

Numbers of tillers per hill differs significantly due to main plot and sub plot treatments. Comparing two main plots under both soil conditions, TNAU Rice TRY 3 (M_1) recorded the highest number of total tillers (18.0 and 16.6) as compared to I.W.Ponni (16.3 and 15.3). Under sodicity condition, the sub plot treatments S_7 registered more number of total tillers (19.2) followed by S_9 (18.6) and S_8 (18.2). The control (S_1) produced 14.6 number of tillers irrespective of varieties, the interaction effect did not set an impact on total tillers.

Table 38. Effect of seed priming and foliar spray on days to 50 per cent flowering in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	109.3		111.3	110.3	109.0		112.7	110.8
S ₂	108.7		111.7	110.2	107.7		111.7	109.7
S ₃	107.7		108.7	108.2	108.0		110.0	109.0
S ₄	107.3		111.3	109.3	107.3		111.3	109.3
S ₅	105.3		110.7	108.0	107.7		109.3	108.5
S ₆	107.0		111.0	109.0	107.0		111.0	109.0
S ₇	103.3		110.0	106.7	105.0		108.7	106.8
S ₈	105.0		110.3	107.7	105.0		109.3	107.2
S ₉	105.7		109.3	107.5	103.0		108.0	105.5
Mean	106.6		110.5		106.6		110.2	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.67	0.54	1.82	0.66	0.19	0.64	0.88	0.79
CD (P=0.05)	7.20	1.11	7.40	1.56	0.79	1.31	NS	NS

**Table 39. Effect of seed priming and foliar spray on total tillers in rice varieties TNAU
Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions**

Treatments	Sodicity			Salinity			
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	
S ₁	15.3	13.8	14.6	14.2	12.6	13.4	
S ₂	16.7	14.8	15.7	14.7	13.6	14.1	
S ₃	18.1	16.4	17.2	16.8	15.5	16.1	
S ₄	17.4	15.6	16.5	15.6	14.3	14.9	
S ₅	18.3	16.8	17.5	17.4	16.1	16.7	
S ₆	17.6	16.0	16.8	16.1	14.9	15.5	
S ₇	20.1	18.3	19.2	18.2	17.0	17.6	
S ₈	19.1	17.2	18.2	17.8	16.6	17.2	
S ₉	19.3	17.8	18.6	18.9	17.5	18.2	
Mean	18.0	16.3		16.6	15.3		
	M	S	M x S	S x M	M	S	M x S
SEd	0.28	0.32	0.51	0.39	0.22	0.31	0.47
CD (P=0.05)	1.21	0.65	NS	NS	0.94	0.63	NS

Under salinity condition, S₉ resulted in higher number of tillers (18.2) followed by S₇ (17.6), S₈ (17.2) and S₅ (16.7). S₁ produced remarkably lower number of total tillers (13.4). The interaction effect did not set an impact on total tillers.

4.6.1.4. Number of productive tillers (Table 40)

The main plot treatments differed significantly with respect to number of productive tillers. M₁ produced more number of productive tillers with 16.1 and 14.6 in sodic and saline soil conditions when compared to M₂ (14.3 and 13.0). All the sub plot treatments showed their significant effect on number of productive tillers over control. Under sodicity condition, S₇ was the most effective treatment with 17.2 productive tillers followed by S₉ with 16.5 whereas control recorded only 12.6.

The interaction effects, S x M were significant. Among the treatments combinations, M₁ S₇ recorded the increased number of productive tillers (18.2) followed by M₁S₉ treatment (17.6). Whereas, M₂S₁ registered with 11.8 productive tillers. The effect of priming with varieties had influences significantly the number of tillers productive under saline condition. The profound increase in number of productive tillers was registered due to seed priming in TNAU Rice TRY 3 with 14.6 and 13.0 in I.W.Ponni. Superior effect of S₉ was evident as more number of tillers were productive both in TNAU Rice TRY 3 (16.6) and I.W.Ponni (15.2). The next best treatment S₇ recorded 16.1 in TNAU Rice TRY 3 and 14.8 in I.W.Ponni followed by S₈ with 15.8 in M₁ and 14.3 in M₂.

The interaction effects S x M were significant. Among the treatments combinations, M₁ S₉ recorded more number of productive tillers (16.6) followed by M₁ S₇ treatment (16.1). Whereas, M₂S₁ recorded the lowest number of productive tillers (10.5).

4.6.1.5. Plant height (Table 41)

The plant height was significantly influenced by seed priming treatments. Irrespective of treatments, I.W.Ponni (M₂) recorded 150.4 and 152.2 cm respectively under sodic and saline soil conditions. Which was significantly higher than TNAU Rice TRY 3 (M₁) with 138.2 and 143.1 cm.

Application of stress alleviating priming treatments at sub plot level distinctly influenced the plant height in these varieties under both soil conditions. Under sodicity condition, the sub

**Table 40. Effect of seed priming and foliar spray on productive tillers in rice varieties
TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions**

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	13.4		11.8	12.6	12.1		10.5	11.3
S ₂	14.5		12.7	13.6	13.0		11.6	12.3
S ₃	16.3		14.9	15.6	14.5		12.9	13.7
S ₄	15.4		13.9	14.6	13.5		12.0	12.8
S ₅	16.5		14.5	15.5	15.3		13.4	14.4
S ₆	15.5		14.1	14.8	14.2		12.4	13.3
S ₇	18.2		16.2	17.2	16.1		14.8	15.4
S ₈	17.1		15.1	16.1	15.8		14.3	15.0
S ₉	17.6		15.4	16.5	16.6		15.2	15.9
Mean	16.1		14.3		14.6		13.0	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.22	0.23	0.38	0.37	0.19	0.50	0.69	0.61
CD (P=0.05)	0.93	0.47	1.25	0.86	0.83	1.02	2.30	1.43

**Table 41. Effect of seed priming and foliar spray on plant height (cm) in rice varieties
TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions**

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	132.2		136.9	134.5	128.2		136.5	132.3
S ₂	132.9		144.2	138.6	136.7		146.2	141.4
S ₃	138.5		151.7	145.1	137.0		149.6	143.3
S ₄	134.4		143.3	138.9	138.7		148.5	143.6
S ₅	139.3		154.0	146.6	146.0		152.2	149.1
S ₆	134.5		150.4	142.4	141.9		153.0	147.4
S ₇	146.6		157.4	152.0	147.0		155.2	151.1
S ₈	141.6		154.6	148.1	145.3		155.9	150.5
S ₉	143.1		155.3	149.2	141.9		157.7	154.4
Mean	138.2		150.4		143.1		152.2	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	3.03	1.54	3.66	1.88	3.81	1.64	4.4	2.00
CD (P=0.05)	13.0	3.13	13.9	4.42	16.37	3.33	14.7	6.70

plot treatments, S₇ recorded the maximum plant height of 152.0 cm followed by S₉ (149.2 cm) whereas, S₁ recorded the minimum (134.5 cm). The increase in plant height due to S₇ and S₉ was 13.0 and 10.9 per cent, respectively over control (S₁).

Among the interaction effect, M₂S₇ recorded the maximum plant height of 157.4 cm followed by M₂S₉ with 155.3 cm. Whereas, M₁S₁ registered the minimum with 132.2 cm.

Under salinity condition, the sub plot treatments, S₉ recorded the maximum plant height of 154.4 cm followed by S₇ (151.1cm) which was on par with S₈ (150.5cm). The increase in plant height due to S₉ and S₇ was 16.7 and 14.2 per cent, irrespectively over control (S₁). The minimum plant height of 132.3 cm was recorded in S₁.

Among the interaction treatments, M₂ S₉ recorded the maximum plant height of 157.7 cm followed by M₂ S₈ (155.9cm). The minimum plant height of 128.2 cm was recorded in control in M₁S₁.

4.6.1.6. Panicle length (Table 42)

Panicle length found to sway over the varieties. Variations due to seed priming and seed priming cum foliar spray treatments were significant in both the varieties. Under sodic condition M₁ produced the longest panicles of 28.7 cm whereas, M₂ produced the shortest panicles (23.8 cm).

Among the seed priming cum foliar spray treatments, S₇ found to be dominating by producing the longest panicles (27.7 cm) followed by S₉ (27.0 cm) , S₈ (26.6 cm) and S₅ (25.9 cm), irrespective of varieties. The control S₁ put forth panicles of 24.0 cm.

Similar to sodicity condition in salinity also appreciable changes in panicle length was notable due to seed priming cum foliar spray treatments. The longest panicles were recorded in M₁ (28.3 cm) than M₂ (22.6 cm). The treatments exerted profound effect in both varieties. The effect of cowpea pulse extract (S₉) was predominated with the longest panicles of 26.6 cm followed by ZnSO₄ foliar spray (S₇) with 26.4 cm. While Control S₁ recorded 23.9 cm.

4.6.1.7. Total number seeds panicle⁻¹ (Table 43)

Between varieties more number of seeds were recorded in M₁ (147.6) over M₂ (135.7) under sodicity condition. Appreciable variation due to seed priming cum foliar spray treatments predominated in both the varieties with maximum number of seeds panicle⁻¹ of 148.8 in S₇ and

**Table 42. Effect of seed priming and foliar spray panicle length (cm) in rice varieties TNAU
Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions**

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	26.2		21.8	24.0	26.3		21.6	23.9
S ₂	27.8		21.4	24.6	27.6		21.8	24.2
S ₃	28.3		23.4	25.8	28.1		22.5	25.3
S ₄	27.8		22.9	25.3	27.4		22.6	25.0
S ₅	29.0		23.0	25.9	28.6		23.5	26.1
S ₆	28.4		22.5	25.5	28.0		22.2	25.1
S ₇	31.0		24.4	27.7	30.2		22.5	26.4
S ₈	29.5		23.8	26.6	28.4		23.4	25.9
S ₉	30.3		23.7	27.0	29.7		23.5	26.6
Mean	28.7		23.8		28.3		22.6	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.74	0.58	1.06	0.706	0.56	0.53	0.90	0.65
CD (P=0.05)	3.20	1.17	NS	NS	2.43	1.08	NS	NS

Table 43. Effect of seed priming and foliar spray on Total number of seeds panicle⁻¹ in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	141.5		131.1	136.3	136.3		127.3	131.8
S ₂	143.2		132.0	137.6	139.0		129.3	134.1
S ₃	146.3		135.6	141.0	146.1		133.5	139.8
S ₄	143.8		133.8	138.8	140.9		127.0	133.9
S ₅	148.7		136.3	142.5	148.2		134.7	141.5
S ₆	144.8		134.5	139.6	144.2		131.5	137.9
S ₇	156.5		141.1	148.8	150.1		138.5	144.3
S ₈	149.7		137.3	143.5	148.9		136.3	142.6
S ₉	153.8		139.6	146.7	151.6		140.3	145.9
Mean	147.6		135.7		145.0		133.2	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.93	2.25	3.56	2.75	1.93	1.62	2.89	1.98
CD (P=0.05)	8.29	4.60	NS	NS	8.32	3.30	NS	NS

The control S_1 recorded the least (136.3) number of seeds panicle⁻¹. The interaction effect of varieties with seed priming cum foliar spray treatment failed to impart significant variations.

Under salinity conditions, M_1 recorded maximum number of seed panicle⁻¹ than (145.0) M_2 (133.2). Seed priming with foliar spray treatments had astounding effect on total number of seeds panicle⁻¹, the varieties and its possible interaction with priming cum foliar spray treatments failed to impart differences in both the varieties. Seed priming cum foliar spray of 2 % cowpea pulse sprout extract (S_9) promoted a phenomenal rise in number of total seeds panicle⁻¹ (145.9) and seed priming cum foliar spray of $ZnSO_4$ (S_7) found to be comparable with above treatment by recording 144.3 followed by seed priming cum foliar spray of 2% DAP (S_8) by recording 142.6 number of seeds panicle⁻¹. While the control recorded 131.8 number of seeds panicle⁻¹. The interaction effect of varieties with seed priming cum foliar spray treatment failed to impart significant variations.

4.6.1.8. Seed set per cent (Table 44)

Under sodicity condition, between two varieties M_1 resulted in higher seed set of 89.1 per cent over M_2 with 86.6 per cent. Among the seed priming cum foliar spray treatments, S_7 established its superiority over the other treatments by recording higher seed set of 91.5 per cent. S_9 and S_8 were as the next best treatments recorded higher seed set of 91.4 and 90.0 per cent, respectively. While, control (S_1) resulted with 84.0 per cent. However, the interaction of varieties and seed priming cum foliar spray treatments found to be non-significant.

Under salinity condition, between the two varieties, M_1 resulted in higher seed set of 87.6 per cent over M_2 with 85.0 per cent. Among the seed priming cum foliar spray treatments S_9 established its superiority over the other treatments by recording remarkably higher seed set of 90.3 per cent. S_7 was the next best treatment recorded higher seed set of 89.6 per cent. While the control S_1 recorded 82.2 per cent seed set. However, the varieties with seed priming cum foliar spray treatment found to be non-significant.

4.6.1.9. Seed yield plant⁻¹ (Table 45)

Variation in seed yield plant⁻¹ was remarkable between varieties and seed priming cum foliar spray treatments. Under sodicity condition, irrespective of treatments, M_1 registered higher seed yield plant⁻¹ of 29.6 g over M_2 with 28.0 g. Among the seed priming treatments S_7 recorded

**Table 44. Effect of seed priming and foliar spray on seed set per cent in rice varieties
TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions**

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	84.9		82.5	84.0	84.0		80.5	82.2
S ₂	85.4		84.8	85.1	83.9		82.7	83.3
S ₃	88.9		86.4	87.7	84.7		84.6	84.7
S ₄	87.0		85.6	86.3	86.4		85.0	85.7
S ₅	90.7		85.4	88.0	86.9		84.4	85.6
S ₆	88.9		86.2	87.2	88.5		84.7	86.6
S ₇	92.4		90.5	91.5	91.0		88.2	89.6
S ₈	91.6		88.2	90.0	89.9		86.3	88.1
S ₉	93.2		89.5	91.4	92.8		87.7	90.3
Mean	89.1		86.6		87.6		85.0	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.23	0.77	1.60	0.94	1.23	0.85	1.67	1.04
CD (P=0.05)	5.30	1.57	NS	NS	5.29	1.73	NS	NS

Table 45. Effect of seed priming and foliar spray on Seed yield plant⁻¹ (g) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	26.8		24.6	25.7	23.5		19.4	21.4
S ₂	27.1		25.1	26.1	25.3		20.8	23.1
S ₃	29.0		28.1	28.5	28.1		22.8	25.4
S ₄	28.4		26.7	27.5	26.2		22.0	24.1
S ₅	29.7		28.7	29.2	28.9		23.5	26.2
S ₆	28.7		27.5	28.1	27.5		22.3	24.9
S ₇	35.0		30.8	33.0	30.2		24.9	27.5
S ₈	30.5		29.4	30.0	29.7		24.5	27.1
S ₉	31.7		30.3	31.0	30.7		25.2	27.9
Mean	29.6		28.0		27.8		22.8	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.61	0.94	1.39	1.15	0.36	0.60	0.87	0.73
CD (P=0.05)	2.63	1.91	4.58	2.70	1.54	1.23	2.90	1.71

33.0 g followed by S₉ and S₈ 31.0 and 30.0 g, respectively. The control S₁ recorded the lowest seed yield of 25.7 g. The interaction had significant effect on seed yield⁻¹. Among the interaction treatments M₁S₇ recorded 35.0 g followed by M₁S₉ and M₁S₈ with 31.7g, 30.5 g, respectively. Whereas, control recorded the lowest yield of 26.8g.

Under saline condition, among the main plot treatments, M₁ registered higher seed yield plant⁻¹ of 27.8 g over M₂ (22.8 g). Regarding sub plot treatments, seed priming cum foliar spray of 2 % cowpea pulse sprout extract S₉ found to increase the seed yield plant⁻¹ with 27.9 g followed by seed priming with foliar spray of 0.5 % ZnSO₄ (S₇) registered 27.5 g and the seed priming with foliar spray of 2% DAP (S₈) registered 27.1 g which was on par with S₅ treatment with 26.2 g. While the control registered 21.4 g. The combined effect of priming followed along with foliar spray treatment with varieties appeared to be significant. Among the interaction treatments M₁S₉ recorded 30.7g followed by M₁S₇ and M₁S₈ with 30.2g, 29.7g respectively. While the control recorded 23.5g.

4.6.1.10. Seed yield plot⁻¹ (Table 46)

Under sodicity condition between two main plots M₁ resulted in higher seed yield plot⁻¹ (5.20 kg) over M₂ recorded (4.43 kg). Seed priming with foliar spray of 0.5% ZnSO₄ (S₇) excelled other treatments by recording 5.18 kg seed yield. Considerably higher seed yield of 5.06 kg plot⁻¹ and 4.96 kg plot⁻¹ recorded by S₉ and S₈, respectively followed by S₅ (4.88 kg plot⁻¹). The control (S₁) recorded the lowest seed yield plot⁻¹ of 4.48 kg. The combined effect of varieties with seed priming cum foliar spray treatment appeared to be non-significant.

Under saline condition between the two main plot treatments M₁ registered higher seed yield plot⁻¹ (5.10 kg) over M₂ (4.31 kg). The seed priming cum foliar spray of cowpea pulse sprout extract S₉ found to increase the seed yield with 5.0 kg followed by S₇ recorded (4.91 kg) which was on par with S₈ (4.85 kg). The control (S₁) yielded relatively lower seed yield of 4.37 kg plot⁻¹. The interaction had no significant effect on seed yield.

4.6.1.11. Seed yield ha⁻¹ (Table 47)

Under sodicity condition, the seed yield of M₁ was remarkably higher with 5743 kg ha⁻¹ as compared to M₂ which recorded 4928 kg ha⁻¹. Among the seed priming treatments (S₇) out yielded other treatments by recording 5758 kg ha⁻¹. Seed yield was also influenced by seed

Table 46. Effect of seed priming and foliar spray on Seed yield plot⁻¹ (kg) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	4.84		4.12	4.48	4.76		3.98	4.37
S ₂	4.90		4.18	4.54	4.81		4.12	4.46
S ₃	5.11		4.40	4.75	5.01		4.36	4.72
S ₄	4.95		4.28	4.62	4.90		4.23	4.57
S ₅	5.20		4.56	4.88	5.19		4.39	4.79
S ₆	5.03		4.40	4.72	5.01		4.28	4.64
S ₇	5.63		4.74	5.18	5.33		4.48	4.91
S ₈	5.34		4.58	4.96	5.29		4.42	4.85
S ₉	5.49		4.63	5.06	5.50		4.50	5.00
Mean	5.20		4.43		5.10		4.31	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.09	0.06	0.121	0.073	0.064	0.054	0.096	0.066
CD (P=0.05)	0.39	0.12	NS	NS	0.277	0.109	NS	NS

**Table 47. Effect of seed priming and foliar spray on Seed yield (kg ha⁻¹) in rice varieties
TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions**

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	5396		4580	4988	5290		4424	4857
S ₂	5447		4650	5048	5341		4576	4959
S ₃	5667		4899	5283	5642		4843	5243
S ₄	5513		4779	5146	5446		4702	5074
S ₅	5783		5054	5419	5766		4880	5323
S ₆	5586		4905	5245	5563		4755	5159
S ₇	6253		5263	5758	5918		4987	5453
S ₈	5930		5083	5506	5883		4908	5395
S ₉	6102		5136	5619	6088		5027	5557
Mean	5743		4928		5660		4789	
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	95.9	68.80	132.7	84.2	71.13	57.60	104.7	70.61
CD (P=0.05)	413.1	140.10	443.2	197.8	306.0	117.4	350.5	166.1

priming cum foliar spray of 2 % cowpea pulse sprout extract S₉ with 5619 kg ha⁻¹ followed by seed priming cum foliar spray of 2% DAP (S₈) recorded 5506 kg ha⁻¹ and seed priming alone (S₅) registered 5419 kg ha⁻¹. The control (S₁) yielded relatively lower seed yield of 4988 kg ha⁻¹.

The combined effect of seed priming cum foliar spray treatment with varieties appeared to be significant. The highest seed yield of 6253 kg ha⁻¹ was recorded by M₁S₇, closely followed by M₁S₉ (6102 kg ha⁻¹) and M₁S₈ (5930 kg ha⁻¹). In the other combinations, M₂S₇ performed better with seed yield of 5263 kg ha⁻¹, followed by M₂S₉ with 5136 kg ha⁻¹, M₂S₁ recorded the lowest seed yield of 4580 kg ha⁻¹.

Under saline condition between two varieties M₁ established its superiority by recording the highest seed yield of 5660 kg ha⁻¹ over M₂ 4789 kg ha⁻¹. Among the seed priming treatments, S₉ established its supremacy by recording higher seed yield of 5557 kg ha⁻¹ followed by (S₇) with 5453 kg ha⁻¹ and (S₈) 5395 kg ha⁻¹. Seed priming alone (S₅) registered seed yield of 5323 kg ha⁻¹. The control (S₁) yielded relatively lower seed yield of 4857 kg ha⁻¹. The combined effect of varieties with seed priming cum foliar spray treatments appeared to be significant. The highest seed yield of 6088 kg ha⁻¹ was recorded by M₁S₉, closely followed by M₁S₇ (5918 kg ha⁻¹) and M₁S₈ (5883 kg ha⁻¹). M₂S₉ performed better with seed yield of 5027 kg ha⁻¹, followed by M₂S₇ with 4987 kg ha⁻¹. M₂S₁ recorded the lowest seed yield of 4424 kg ha⁻¹.

4.6.1.12. 100 seed weight (Table 48)

Under sodicity condition, there was a considerable influence on the weight of 100 seeds due to varieties and seed priming cum foliar spray treatments. The weight of 100 seeds ranged between 2.40 and 2.60 g in M₁ and 1.6 and 1.8 g in M₂. Seed priming cum foliar spray of 0.5 % ZnSO₄ (S₇) produced heavier seeds with 2.24 g followed by S₉ with 2.22 g which was on par with S₈ treatment. While the control (S₁) recorded (2.04g), the lowest seed weight.

Under salinity condition between two varieties, M₁ produced heavier seeds of 2.50 g whereas, M₂ produced 1.70 g. Among the seed priming cum foliar spray treatments S₉ produced 2.17 g followed by S₇ and S₈ with 2.11 g each. Whereas, the control (S₁) recorded the 100 seed weight 2.0g. The combined effect of varieties with seed priming cum foliar spray treatments had impact on seed weight. Among the treatments combinations, M₁ S₉ recorded 2.62g followed by M₁S₇ (2.51g) and M₁S₈ (2.51g). Whereas, M₂S₁ recorded the minimum (1.61 g).

**Table 48. Effect of seed priming and foliar spray on 100 seed weight (g) in rice varieties
TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions**

Treatments	Sodicity				Salinity			
	M ₁	M ₂	Mean		M ₁	M ₂	Mean	
S ₁	2.4	1.6	2.04		2.38	1.61	2.00	
S ₂	2.5	1.7	2.06		2.40	1.62	2.01	
S ₃	2.5	1.8	2.14		2.48	1.68	2.08	
S ₄	2.5	1.7	2.09		2.42	1.64	2.03	
S ₅	2.6	1.8	2.18		2.50	1.69	2.09	
S ₆	2.5	1.7	2.12		2.46	1.66	2.06	
S ₇	2.6	1.8	2.24		2.51	1.72	2.11	
S ₈	2.6	1.8	2.20		2.51	1.72	2.11	
S ₉	2.6	1.8	2.22		2.62	1.73	2.17	
Mean	2.54	1.74			2.50	1.70		
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.03	0.01	0.03	0.01	0.03	0.02	0.04	0.03
CD (P=0.05)	0.13	0.02	NS	NS	0.13	0.05	0.15	0.07

4.6.2. Physiological and Biochemical components

4.6.2.1. Chlorophyll 'a' content (Table 49 and 50)

The results of chlorophyll 'a' content exhibited an increasing trend from active tillering and panicle initiation stages. Both the varieties differed significantly at growth stages. Under sodicity condition, at active tillering stage, M_1 recorded higher chlorophyll 'a' content of 1.004 mg g^{-1} than M_2 with 0.932 mg g^{-1} . Among the subplot treatments, S_7 recorded higher chlorophyll 'a' content with 1.203 mg g^{-1} followed by S_9 (1.112 mg g^{-1}). While, control S_1 recorded the lowest chlorophyll 'a' content of 0.801 mg g^{-1} .

Interaction of main plot with sub plot treatments found to be significant. M_1S_7 recorded the highest chlorophyll 'a' content of 1.305 mg g^{-1} followed by M_1S_9 (1.135 mg g^{-1}). While, M_2S_1 recorded the lowest chlorophyll 'a' content (0.780 mg g^{-1}).

Similar to sodicity condition in saline condition also, chlorophyll 'a' content exhibited an increasing trend from active tillering to panicle initiation stages. Main plot and sub plot treatments differed significantly. At active tillering stage, M_1 recorded higher chlorophyll 'a' content of 0.765 mg g^{-1} than M_2 (0.737 mg g^{-1}). Among the subplot treatments, S_9 recorded higher chlorophyll 'a' content with 0.913 mg g^{-1} followed by S_7 (0.907 mg g^{-1}). While the control S_1 recorded the lowest chlorophyll 'a' content of 0.603 mg g^{-1} .

Under sodicity condition, at panicle initiation stage, M_1 recorded higher chlorophyll 'a' content (1.278 mg g^{-1}) than M_2 (1.230 mg g^{-1}). Among the sub plot treatments S_7 registered significantly higher chlorophyll 'a' content (1.433 mg g^{-1}), followed by S_9 (1.412 mg g^{-1}) and S_8 (1.343 mg g^{-1}) than control (1.100 mg g^{-1}). The interaction effects of S at M found to be significant. $M_1 S_7$ recorded the highest value of (1.505 mg g^{-1}) followed by M_1S_9 (1.445 mg g^{-1}) and M_1S_8 (1.355 mg g^{-1}) whereas, M_2S_1 registered the lowest chlorophyll 'a' content of 1.070 mg g^{-1} .

Under salinity condition at panicle initiation stage, M_1 recorded higher chlorophyll 'a' content (1.076 mg g^{-1}) than M_2 (1.020 mg g^{-1}). The sub plot treatments also differed significantly. S_9 registered significantly higher chlorophyll 'a' content (1.240 mg g^{-1}) followed by S_7 (1.209 mg g^{-1}) and S_8 (1.144 mg g^{-1}) than control (0.900 mg g^{-1}). The interaction effects S at M

Table 49. Effect of seed priming and foliar spray on chlorophyll a (mg g^{-1}) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	0.823		0.780	0.801	0.635		0.572	0.603
S ₂	0.850		0.824	0.837	0.653		0.623	0.638
S ₃	0.913		0.903	0.908	0.735		0.700	0.720
S ₄	0.862		0.822	0.842	0.670		0.636	0.653
S ₅	1.045		0.995	1.020	0.845		0.795	0.820
S ₆	0.880		0.835	0.857	0.680		0.641	0.660
S ₇	1.305		1.101	1.203	0.910		0.905	0.907
S ₈	1.046		1.037	1.042	0.840		0.846	0.843
S ₉	1.135		1.090	1.112	0.938		0.888	0.913
Mean	1.004		0.932		0.767		0.734	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.01	0.02	0.03	0.03	0.012	0.020	0.027	0.022
CD (P=0.05)	0.06	0.05	0.09	0.06	0.053	0.036	NS	NS

Table 50. Effect of seed priming and foliar spray on chlorophyll a (mg g⁻¹) in leaf at panicle initiation stages in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	1.130		1.070	1.100	0.935		0.870	0.900
S ₂	1.150		1.120	1.135	0.950		0.920	0.935
S ₃	1.235		1.200	1.217	1.020		1.005	1.012
S ₄	1.160		1.130	1.145	0.946		0.937	0.942
S ₅	1.345		1.290	1.317	1.150		1.020	1.085
S ₆	1.180		1.140	1.160	0.980		0.945	0.962
S ₇	1.505		1.360	1.433	1.245		1.173	1.209
S ₈	1.355		1.330	1.343	1.158		1.130	1.144
S ₉	1.445		1.380	1.412	1.300		1.180	1.240
Mean	1.278		1.230		1.076		1.020	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.02	0.02	0.03	0.02	0.014	0.015	0.024	0.020
CD (P=0.05)	0.06	0.03	0.08	0.04	0.062	0.030	0.075	0.042

were significant. M_1S_9 recorded the highest value of 1.300 mg g^{-1} followed by M_1S_7 (1.245 mg g^{-1}), M_1S_8 (1.158 mg g^{-1}) and M_2S_1 (0.870 mg g^{-1}).

4.6.2.2. Chlorophyll 'b' content (Table 51 and 52)

Similar to chlorophyll 'a', chlorophyll 'b' content also exhibited an increasing trend from active tillering to panicle initiation stages. Main plot and sub plot treatments differed significantly. Under sodicity condition, at active tillering stage, M_1 recorded higher chlorophyll 'b' content of 0.553 mg g^{-1} than M_2 with 0.470 mg g^{-1} . Among the sub plot treatments, S_7 recorded higher chlorophyll 'b' content with 0.590 mg g^{-1} . While the control (S_1) recorded the lowest chlorophyll 'b' content of 0.423 mg g^{-1} . Interaction of main plot with sub plot treatments was significant. M_1S_7 recorded higher chlorophyll content of 0.635 mg g^{-1} . While control M_2S_1 recorded the lowest chlorophyll 'b' content of 0.393 mg g^{-1} .

Under saline condition at active tillering stage M_1 recorded with a value of 0.356 mg g^{-1} where M_2 recorded chlorophyll 'b' content of 0.270 mg g^{-1} . Among the sub plots, S_9 was effective in increasing chlorophyll 'b' content (0.400 mg g^{-1}) than control (0.235 mg g^{-1}). The interaction effects of $S \times M$ was significant. M_1S_9 recorded (0.450 mg g^{-1}) followed by M_1S_7 (0.438 mg g^{-1}), and M_2S_1 (0.190 mg g^{-1}).

Under sodicity condition, the difference between M_1 and M_2 at panicle initiation stage was wide with higher value recorded by M_1 (0.885 mg g^{-1}) over M_2 (0.745 mg g^{-1}). Among the sub plots, S_7 was effective in increasing chlorophyll 'b' content (0.948 mg g^{-1}) than control (0.710 mg g^{-1}).

The interaction effects of S at M were significant. M_1S_7 ranked first (1.078 mg g^{-1}) followed by M_1S_9 and M_1S_8 which recorded 1.060 mg g^{-1} each, than control M_2S_1 (0.670 mg g^{-1}).

Under saline condition, at panicle initiation stage M_1 recorded chlorophyll 'b' content of 0.742 mg g^{-1} and M_2 recorded 0.552 mg g^{-1} . Among the sub plots, S_9 was effective in increasing chlorophyll 'b' content (0.837 mg g^{-1}) than S_7 (0.833 mg g^{-1}), S_8 (0.813 mg g^{-1}) and control (0.515 mg g^{-1}).

The interaction effects of $M \times S$ and $S \times M$ were significant. M_1S_9 recorded 1.040 mg g^{-1} of chlorophyll 'b'. M_1S_7 and M_1S_8 which were on par with each other the minimum chlorophyll 'b' content was recorded in M_2S_1 (0.480 mg g^{-1}).

Table 51. Effect of seed priming and foliar spray on chlorophyll b (mg g⁻¹) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	0.454		0.393	0.423	0.281		0.190	0.235
S ₂	0.501		0.405	0.453	0.301		0.215	0.260
S ₃	0.541		0.453	0.497	0.336		0.267	0.302
S ₄	0.510		0.440	0.475	0.310		0.230	0.270
S ₅	0.547		0.484	0.515	0.350		0.290	0.320
S ₆	0.525		0.473	0.499	0.325		0.275	0.300
S ₇	0.635		0.545	0.590	0.438		0.300	0.369
S ₈	0.631		0.500	0.565	0.414		0.325	0.370
S ₉	0.635		0.545	0.590	0.450		0.340	0.400
Mean	0.553		0.470		0.356		0.270	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.007	0.006	0.011	0.007	0.006	0.008	0.012	0.009
CD (P=0.05)	0.031	0.012	0.036	0.016	0.030	0.015	0.034	0.022

Table 52. Effect of seed priming and foliar spray on chlorophyll b (mg g⁻¹) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	0.750		0.670	0.710	0.550		0.480	0.515
S ₂	0.765		0.724	0.745	0.575		0.509	0.542
S ₃	0.770		0.731	0.750	0.570		0.545	0.557
S ₄	0.805		0.720	0.763	0.60		0.530	0.565
S ₅	0.874		0.755	0.815	0.670		0.536	0.603
S ₆	0.806		0.720	0.763	0.600		0.526	0.563
S ₇	1.078		0.818	0.948	1.040		0.626	0.833
S ₈	1.060		0.775	0.918	1.040		0.586	0.813
S ₉	1.060		0.796	0.928	1.040		0.634	0.837
Mean	0.885		0.745		0.742		0.552	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.011	0.010	0.017	0.012	0.009	0.009	0.015	0.011
CD (P=0.05)	0.048	0.021	0.060	0.030	0.038	0.019	0.046	0.026

4.6.2.3. Total chlorophyll content (Table 53 and 54)

The data on total chlorophyll content reflected the trend of chlorophyll 'a' and b. Main plots differed significantly at both active tillering and panicle initiation stages. Under sodic condition, at active tillering stage, M_1 recorded higher chlorophyll content of 1.535 mg g^{-1} over M_2 (1.405 mg g^{-1}). Among the sub plot treatments, S_7 recorded higher chlorophyll content of 1.800 mg g^{-1} followed by S_9 (1.681 mg g^{-1}) while control (S_1) recorded the lowest total chlorophyll content (1.241 mg g^{-1}).

Interaction of main plot with sub plot treatments was significant. M_1S_7 and M_1S_9 recorded higher total chlorophyll content of 1.940 mg g^{-1} and 1.745 mg g^{-1} while M_2S_1 recorded (1.173 mg g^{-1}).

Under saline condition, main plot treatments differed significantly at growth stages. At active tillering stage, M_1 recorded higher chlorophyll content of 1.122 mg g^{-1} than M_2 with 1.003 mg g^{-1} . In sub plot treatments, S_9 recorded higher total chlorophyll content of 1.300 mg g^{-1} followed by S_7 with 1.283 mg g^{-1} . Whereas, control (S_1) recorded the lowest total chlorophyll content of 0.762 mg g^{-1} .

Interaction of main plot with sub plot treatment was significant. M_1S_9 and M_1S_7 recorded higher chlorophyll content of 1.360 mg g^{-1} and 1.352 mg g^{-1} , respectively. While M_2S_1 recorded the lowest chlorophyll 'b' content of 0.765 mg g^{-1} .

Under sodicity condition, at panicle initiation stage, M_1 out performed with higher total chlorophyll content of 2.168 mg g^{-1} than M_2 (1.970 mg g^{-1}). Significant differences were observed in total chlorophyll content among sub plot treatments. Seed priming cum foliar spray treatments S_7 recorded the highest chlorophyll content of 2.380 mg g^{-1} followed by S_9 (2.340 mg g^{-1}) and S_8 (2.260 mg g^{-1}). However, S_1 recorded the lowest content of 1.822 mg g^{-1} , among the treatments.

Interaction of main plot with sub plot treatments was significant. Among them, M_1S_7 registered the highest total chlorophyll content (2.583 mg g^{-1}). M_1S_9 (2.505 mg g^{-1}) and M_1S_8 (2.415 mg g^{-1}) also performed better than other treatment, whereas M_2S_1 registered the lowest chlorophyll content of 1.740 mg g^{-1} .

Under saline condition at panicle initiation stage, M_1 recorded higher total chlorophyll content of 1.818 mg g^{-1} over M_2 (1.572 mg g^{-1}). In sub plot treatments, S_9 recorded the highest

Table 53. Effect of seed priming and foliar spray on Total chlorophyll (mg g⁻¹) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	1.277		1.173	1.225	0.916		0.762	0.839
S ₂	1.351		1.230	1.300	0.954		0.835	0.894
S ₃	1.454		1.360	1.407	1.071		0.967	1.019
S ₄	1.372		1.262	1.320	0.980		0.870	0.925
S ₅	1.592		1.479	1.535	1.195		1.085	1.140
S ₆	1.401		1.308	1.354	1.005		0.920	0.962
S ₇	1.940		1.650	1.800	1.348		1.205	1.276
S ₈	1.680		1.540	1.610	1.254		1.171	1.212
S ₉	1.770		1.635	1.703	1.388		1.228	1.308
Mean	1.537		1.404		1.123		1.004	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.020	0.021	0.034	0.026	0.020	0.018	0.030	0.022
CD (P=0.05)	0.084	0.043	0.103	0.061	0.078	0.036	0.093	0.051

Table 54. Effect of seed priming and foliar spray on Total chlorophyll (mg g⁻¹) in leaf at Panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	1.900		1.740	1.822	1.485		1.350	1.417
S ₂	1.920		1.844	1.882	1.525		1.429	1.477
S ₃	2.010		1.931	1.970	1.590		1.550	1.570
S ₄	1.965		1.850	1.907	1.546		1.467	1.506
S ₅	2.220		2.050	2.135	1.820		1.556	1.688
S ₆	1.986		1.860	1.923	1.580		1.471	1.525
S ₇	2.583		2.178	2.380	2.285		1.799	2.042
S ₈	2.415		2.105	2.260	2.198		1.716	1.957
S ₉	2.505		2.176	2.340	2.340		1.814	2.077
Mean	2.164		1.969		1.818		1.572	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.023	0.020	0.033	0.022	0.018	0.018	0.030	0.022
CD (P=0.05)	0.099	0.040	0.112	0.052	0.078	0.036	0.093	0.051

chlorophyll content of 2.077 mg g⁻¹ followed by S₇ (2.042 mg g⁻¹) and S₈ (1.952 mg g⁻¹). However, S₂ recorded the lowest content of 1.477 mg g⁻¹.

Interaction of main plot x sub plot treatment was significant. Among them, M₁S₉ registered the highest total chlorophyll content (2.340 mg g⁻¹) followed by M₁S₇ (2.285 mg g⁻¹) and M₄S₈ (2.198 mg g⁻¹) whereas, control registered the lowest chlorophyll content of 1.49 mg g⁻¹.

4.6.2.3. Chlorophyll stability index (Table 55 and 56)

The results of chlorophyll stability index exhibited an increasing trend from active tillering stage to panicle initiation stage. Both the varieties differed significantly at growth stages. Under sodicity condition, at active tillering stage, M₁ recorded higher chlorophyll stability index of 63.5 over M₂ with 47.3. Among the sub plot treatments, S₇ recorded higher chlorophyll stability index of 60.3, followed by S₉ recorded 58.8 whereas, control recorded 49.3.

Under saline condition, at active tillering stage, M₁ recorded higher chlorophyll stability index of 62.1 over M₂ with 45.7. Among the sub plot treatments, S₉ recorded higher chlorophyll index of 59.2 followed by S₇ recorded 56.8 while control recorded chlorophyll stability index of 49.4.

Under sodicity condition, at panicle initiation stage M₁ recorded higher Chlorophyll stability index (68.0) than M₂ (52.0). The sub plot treatments also differed significantly at all stages of growth period. S₇ registered the highest (65.3) followed by S₈ (63.0) and control (55.0) recorded the lowest.

Under saline condition, at panicle initiation stage, among the main plot treatments M₁ recorded the highest Chlorophyll stability index of 66.0 than M₂ (50.1). Among the sub plot treatments S₉ registered higher Chlorophyll stability index of 63.6 followed by S₇ (60.8), S₈ (60.4) and control (53.5).

4.6.2.3. Leaf sodium content (Table 57 and 58)

The sodium content revealed a gradual increase from active tillering to panicle initiation stages. Main plot treatments and sub plot treatments varied significantly at the growth stages.

M₂ recorded significantly higher leaf sodium content during the growth stages under sodicity condition at active tillering stage, M₂ recorded significantly higher leaf sodium content

Table 55. Effect of seed priming and foliar spray on chlorophyll stability index (%) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	55.6		42.3	49.3	57.8		40.9	49.4
S ₂	62.0		44.6	53.3	58.7		43.2	51.6
S ₃	63.5		46.5	55.0	61.9		45.8	53.8
S ₄	61.5		44.8	53.1	60.4		42.3	51.33
S ₅	65.3		48.3	56.8	63.1		46.4	54.7
S ₆	62.5		45.6	54.0	61.0		44.0	52.5
S ₇	68.3		52.3	60.3	64.4		49.3	56.8
S ₈	66.7		50.3	58.5	65.1		48.3	56.6
S ₉	66.5		51.1	58.8	66.8		51.6	59.2
Mean	63.53		47.30		62.1		45.7	53.9
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.800	1.080	1.645	1.321	0.81	1.50	2.15	1.83
CD (P=0.05)	3.442	2.197	NS	NS	3.50	3.04	NS	NS

Table 56. Effect of seed priming and foliar spray on chlorophyll stability index (%) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	63.7		46.0	55.0	61.6		45.5	53.5
S ₂	66.6		47.5	57.2	62.5		46.3	54.4
S ₃	68.0		51.1	59.5	65.2		49.8	57.5
S ₄	66.3		48.1	57.2	63.2		47.4	55.3
S ₅	70.6		52.6	61.6	67.4		51.6	59.5
S ₆	66.2		51.0	58.5	64.4		47.6	55.9
S ₇	72.4		58.2	65.3	69.0		52.7	60.8
S ₈	70.7		55.1	63.0	68.2		52.7	60.4
S ₉	71.4		55.0	63.0	70.5		56.7	63.6
Mean	68.0		52.0		66.0		50.1	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.860	0.884	1.460	1.020	1.10	1.41	2.20	1.73
CD (P=0.05)	3.700	1.801	NS	NS	4.72	2.87	NS	NS

of 2.51 mg g⁻¹ over M₁ with 1.56 mg g⁻¹. Among the sub plot treatments, S₁ recorded higher sodium content of 2.25 mg g⁻¹ whereas S₇ showed the lowest sodium content of 1.80 mg g⁻¹ followed by S₉ with a value of 1.83 mg g⁻¹.

The interaction effects of main plot with sub plot treatments were found to be significant. M₂S₁ recorded higher sodium content of 2.73 mg g⁻¹. The lowest values of 1.25 mg g⁻¹ and 1.33 mg g⁻¹ were recorded by M₁S₇ and M₁S₉, respectively.

Under saline condition the sodium content showed gradual increase from active tillering to panicle initiation stages. Main plot and sub plot treatments varied significantly at the growth stages. At active tillering stage, M₂ recorded higher leaf sodium content of 2.75 mg g⁻¹ over M₁ with 1.76 mg g⁻¹. Among the sub plot treatments, S₁ recorded higher leaf sodium content of 2.46 mg g⁻¹. S₉ showed the lowest leaf sodium content of 1.95 mg g⁻¹ followed by S₇ which recorded the lowest sodium content of 2.10 mg g⁻¹.

The interaction effect of main plot with sub plot treatments was significant. M₂S₁ recorded higher leaf sodium content of 2.95 mg g⁻¹. Whereas the lowest value of 1.45 mg g⁻¹ recorded by M₁S₉ followed by M₁S₇ with a value of 1.53 mg g⁻¹.

Under sodicity condition, at panicle initiation stage, among the sub plot treatments, S₁ recorded the highest sodium content of 3.30 mg g⁻¹. While, S₇ showed the lowest content of 2.74 mg g⁻¹.

The interaction effects of S x M were significant. Among the interaction treatments, M₂S₁ recorded the highest sodium content of 3.78 mg g⁻¹. The lowest value of 2.26 mg g⁻¹ was recorded by M₁ S₇ which was closely followed by M₁ S₉ with the value of 2.33 mg g⁻¹. The same effect was also observed in M₂ S₇ and M₂S₉ with the value of 3.21 mg g⁻¹ and 3.37 mg g⁻¹, respectively.

Under saline condition, at panicle initiation stage, M₂ recorded significantly higher sodium content during the growth stage. Among the sub plot treatments, S₁ recorded the highest sodium content of 3.41 mg g⁻¹ and S₉ showed the lowest content of 2.82 mg g⁻¹.

The interaction effects, S x M was significant. M₂S₁ recorded the highest sodium content of 3.76 mg g⁻¹ which was closely followed by M₁ S₇ with the value of 2.53 mg g⁻¹. The lowest value of 2.46 mg g⁻¹ was recorded by M₁S₉. The same effect was also observed in M₂S₉ and M₂S₇ with the value of 3.19 mg g⁻¹ and 3.43 mg g⁻¹, respectively.

Table 57. Effect of seed priming and foliar spray on sodium content (mg g^{-1}) at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W.Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	1.77		2.73	2.25	1.97		2.95	2.46
S ₂	1.71		2.70	2.22	1.91		2.85	2.43
S ₃	1.58		2.46	2.02	1.78		2.87	2.33
S ₄	1.73		2.69	2.21	1.93		2.89	2.41
S ₅	1.52		2.30	1.91	1.72		2.58	2.15
S ₆	1.68		2.64	2.16	1.88		2.93	2.40
S ₇	1.25		2.35	1.80	1.53		2.66	2.10
S ₈	1.42		2.38	1.89	1.62		2.57	2.09
S ₉	1.33		2.32	1.83	1.45		2.45	1.95
Mean	1.56		2.51		1.756		2.75	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.03	0.03	0.05	0.04	0.03	0.05	0.07	0.06
CD (P=0.05)	0.12	0.07	0.16	0.10	0.14	0.01	0.20	0.14

Table 58. Effect of seed priming and foliar spray on sodium content (mg g^{-1}) at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I. W.Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	2.82		3.78	3.30	3.02		3.76	3.41
S ₂	2.71		3.74	3.23	2.91		3.87	3.39
S ₃	2.58		3.56	3.07	2.78		3.60	3.20
S ₄	2.72		3.74	3.23	2.92		3.74	3.32
S ₅	2.52		3.38	2.95	2.72		3.42	3.10
S ₆	2.68		3.60	3.14	2.88		3.56	3.22
S ₇	2.26		3.21	2.74	2.53		3.43	3.01
S ₈	2.42		3.39	2.91	2.62		3.40	3.02
S ₉	2.33		3.37	2.85	2.46		3.19	2.82
Mean	2.56		3.50		2.761		3.56	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.04	0.03	0.06	0.04	0.05	0.04	0.06	0.04
CD (P=0.05)	0.20	0.06	0.21	0.08	0.20	0.06	0.22	0.09

4.6.2.4. Potassium content (Table 59 and 60)

The data on leaf potassium content indicated an increase from active tillering to panicle initiation stages. The two main plot treatments exhibited significant variations at above growth stages. Under sodicity condition, at active tillering stage, M_2 recorded higher leaf potassium content of 4.35 mg g^{-1} over M_1 with 3.30 mg g^{-1} . Among the sub plot treatments S_7 and S_9 recorded higher potassium content of 4.10 mg g^{-1} and 4.08 mg g^{-1} , respectively. Whereas, control recorded the lowest potassium content 3.50 mg g^{-1} .

The interaction effect of main plot with sub plot treatments was significant. M_1S_7 recorded higher potassium content of 4.60 mg g^{-1} followed by M_1S_9 with a value of 4.48 mg g^{-1} , while control M_2S_1 recorded the lowest potassium content of 2.84 mg g^{-1} .

Under saline condition the potassium content of leaf increased from active tillering to panicle initiation stages. The main plots M_1 and M_2 varied significantly at two stages of growth. Under sodicity condition at active tillering stage, M_1 recorded higher leaf potassium content of 4.44 mg g^{-1} over M_2 (3.19 mg g^{-1}). Among the sub plot treatments, S_9 recorded higher potassium content of 4.10 mg g^{-1} followed by S_7 and S_8 with a value of 3.98 and 3.94 mg g^{-1} . Whereas, control recorded potassium content of 3.60 mg g^{-1} .

Under sodicity condition, at panicle initiation stage, M_1 recorded a higher value of 5.33 mg g^{-1} . The sub plot treatments also differed significantly at both the growth stages. Among the treatments, S_7 registered higher leaf potassium content of 5.24 mg g^{-1} followed by S_9 (5.10 mg g^{-1}) and S_8 (4.94 mg g^{-1}). Control recorded the lowest leaf potassium content of 4.66 mg g^{-1} .

The interaction effects of $S \times M$ were significant. $M_1 S_7$ registered the highest value of 5.49 mg g^{-1} followed by M_1S_9 (5.46 mg g^{-1}) and M_1S_8 (5.27 mg g^{-1}). Among the other varietal interactions, $M_2 S_7$ recorded the highest leaf potassium content of 4.99 mg g^{-1} followed by M_2S_9 (4.66 mg g^{-1}) and M_2S_8 (4.61 mg g^{-1}), whereas M_2S_1 recorded the potassium content of 4.13 mg g^{-1} .

Under saline condition, M_1 registered higher potassium content of 5.47 mg g^{-1} at panicle initiation stage. The sub plot treatments also exhibited significant differences at two stages of growth. S_9 registered the highest value of 5.10 mg g^{-1} followed by S_7 (4.99 mg g^{-1}) and S_8 (4.92 mg g^{-1}). All the other treatments also recorded significantly higher value than control.

Table 59. Effect of seed priming and foliar spray on potassium content (mg g⁻¹) at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	4.16		2.84	3.50	4.25		2.95	3.60
S ₂	4.22		3.16	3.80	4.32		3.15	3.74
S ₃	4.36		3.26	3.81	4.46		3.13	3.79
S ₄	4.27		3.14	3.70	4.37		3.05	3.71
S ₅	4.35		3.33	3.84	4.46		3.14	3.80
S ₆	4.25		3.19	3.72	4.35		3.04	3.71
S ₇	4.60		3.61	4.10	4.57		3.39	3.98
S ₈	4.42		3.50	3.96	4.52		3.37	3.94
S ₉	4.48		3.68	4.08	4.70		3.51	4.10
Mean	4.35		3.30		4.44		3.19	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.06	0.09	0.13	0.12	0.05	0.04	0.08	0.08
CD (P=0.05)	0.30	0.18	0.40	0.25	0.23	0.09	NS	NS

Table 60. Effect of seed priming and foliar spray on potassium content (mg g⁻¹) at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I. W.Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	5.19		4.13	4.66	5.28		4.02	4.54
S ₂	5.19		4.25	4.68	5.34		3.98	4.66
S ₃	5.37		4.24	4.81	5.47		4.01	4.78
S ₄	5.30		4.32	4.81	5.40		3.98	4.70
S ₅	5.30		4.27	4.78	5.51		4.14	4.82
S ₆	5.40		4.34	4.87	5.37		4.10	4.73
S ₇	5.49		4.99	5.24	5.60		4.38	4.99
S ₈	5.27		4.61	4.94	5.56		4.28	4.92
S ₉	5.46		4.66	5.10	5.72		4.47	5.10
Mean	5.33		4.42		5.47		4.17	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.09	0.07	0.13	0.09	0.07	0.05	0.09	0.06
CD (P=0.05)	0.40	0.15	0.45	0.21	0.42	0.09	0.35	0.13

The interaction effect of S x M was significant. Among the interaction treatments M₁S₉ followed by M₁S₇ and M₁S₈ recorded significantly higher values of 5.72 mg g⁻¹, 5.60 mg g⁻¹ and 5.56 mg g⁻¹ respectively over control M₁S₁ with (5.28 mg g⁻¹). Similarly, M₂S₉, M₂S₇ and M₂S₈ recorded higher values of 4.47 mg g⁻¹, 4.38 mg g⁻¹ and 4.28 mg g⁻¹ respectively than control (4.02 mg g⁻¹).

4.6.2.5. Sodium potassium Ratio (Table 61 and 62)

The sodium potassium ratio recorded a gradual increase from active tillering to panicle initiation stages with main plot and sub plot treatments varied significantly at two growth stages. M₂ recorded higher sodium- potassium ratio during the growth stages. Under sodicity condition, at active tillering stage, M₂ recorded higher sodium potassium ratio of 0.77 over M₁ 0.36. Among the sub plot treatments, S₇ and S₉ recorded sodium potassium ratio of 0.46 each. Whereas, control recorded higher sodium potassium ratio of 0.69.

The interaction of main plot with sub plot treatments found to be significant. M₂S₁ recorded higher sodium potassium ratio of 0.96 whereas, lower sodium potassium ratio was recorded in M₁S₇ with a value of 0.27.

The data on Na /K ratio of leaf exhibited an increasing trend from active tillering to panicle initiation stages. The two main plot treatments differed significantly at two stages of growth. M₂ performed higher Na / K ratio during the growth stages. All the sub plot treatments differed significantly at growth stages. Under saline condition, at active tillering stage, M₂ recorded higher sodium potassium ratio of 0.62. Among the sub plot treatments, S₉ recorded lower sodium potassium ratio of 0.50 followed by S₇ (0.56) whereas, control recorded higher sodium potassium ratio of 0.73.

The interaction of main plot with sub plot treatments was significant. M₂S₁ recorded higher sodium potassium ratio of 1.00 whereas, the lowest sodium potassium ratio was recorded by M₁S₉ with 0.31.

Under sodicity condition, at panicle initiation stage, S₁ recorded the highest Na /K ratio of 0.73. S₇ showed the lowest Na / K ratio of 0.52 followed by S₉ with 0.57. The interaction effect of S x M was found to be significant. Among the interaction treatments, M₂S₁ recorded the highest Na/K ratio of 0.92 and the lowest value of 0.41 was recorded by M₁ S₇ followed by M₁S₉

Table 61. Effect of seed priming and foliar spray on sodium potassium ratio at active tillering stage in rice varieties of TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions.

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	0.43		0.96	0.69	0.46		1.00	0.73
S ₂	0.40		0.85	0.63	0.44		0.94	0.70
S ₃	0.36		0.75	0.55	0.40		0.92	0.66
S ₄	0.43		0.86	0.64	0.44		0.95	0.69
S ₅	0.35		0.69	0.52	0.39		0.82	0.60
S ₆	0.39		0.83	0.61	0.43		0.96	0.69
S ₇	0.27		0.65	0.46	0.34		0.79	0.56
S ₈	0.32		0.68	0.50	0.36		0.76	0.56
S ₉	0.30		0.63	0.47	0.31		0.70	0.50
Mean	0.36		0.77		0.40		0.62	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.02	0.036	0.051	0.044	0.02	0.02	0.03	0.02
CD (P=0.05)	0.07	0.080	0.122	0.104	0.10	0.03	0.11	0.05

Table 62. Effect of seed priming and foliar spray on sodium potassium ratio at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I. W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	0.54		0.92	0.73	0.57		0.94	0.75
S ₂	0.52		0.88	0.70	0.54		0.97	0.76
S ₃	0.48		0.84	0.66	0.51		0.90	0.70
S ₄	0.51		0.86	0.68	0.54		0.94	0.74
S ₅	0.48		0.79	0.64	0.49		0.83	0.66
S ₆	0.50		0.83	0.66	0.54		0.87	0.70
S ₇	0.41		0.64	0.52	0.45		0.78	0.62
S ₈	0.46		0.73	0.60	0.47		0.79	0.63
S ₉	0.43		0.72	0.57	0.43		0.71	0.57
Mean	0.48		0.80		0.50		0.86	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.02	0.015	0.03	0.02	0.07	0.05	0.01	0.05
CD (P=0.05)	0.10	0.03	0.11	0.04	0.32	0.09	0.35	0.13

with the value of 0.43, the same effect was also observed in M_2S_7 and M_2S_9 with value of 0.64 and 0.72, respectively.

Under saline condition, at panicle initiation stage S_1 recorded the highest Na/ K ratio of 0.75. S_9 showed the lowest Na/K ratio of 0.57. The interaction effects of $S \times M$ found to be significant. Among the interaction treatments, $M_2 S_1$ recorded the highest Na/K ratio of 0.94. The lowest value of 0.43 was recorded by M_1S_9 followed by M_1S_7 with the value of 0.45. The same effect was also observed in M_2S_9 and M_2S_7 with the value of 0.71 and 0.78, respectively.

4.6.2.6. Soluble protein content (Table 63 and 64)

Progressive increasing trend in soluble protein content was observed from active tillering to panicle initiation stages. Under sodicity condition, at active tillering stage, M_1 recorded higher soluble protein content of 9.57 mg g^{-1} over M_2 with 6.13 mg g^{-1} . Among the sub plot treatments, S_7 recorded higher soluble protein content of 8.63 mg g^{-1} followed by S_9 with a value of 8.50 mg g^{-1} while control recorded the lowest soluble protein of 7.15 mg g^{-1} .

The interaction of main plot with sub plot treatments was found to be significant. M_1S_7 recorded higher soluble protein content of 10.40 mg g^{-1} followed by M_1S_8 and M_1S_9 with 10.10 mg g^{-1} each whereas control M_2S_1 recorded the lowest soluble protein content of 5.40 mg g^{-1} .

Under saline condition, at active tillering stage, M_1 recorded higher soluble protein content of 9.24 mg g^{-1} over M_1 with 6.11 mg g^{-1} . Among the sub plot treatments, S_9 and S_7 recorded soluble protein content of 8.55 and 8.30 mg g^{-1} respectively, while control recorded the lowest soluble protein content of 6.60 mg g^{-1} . Among the interaction effects M_1S_9 recorded higher soluble protein content of 10.20 mg g^{-1} followed by M_1S_7 recorded 10.00 mg g^{-1} whereas, M_2S_1 recorded the lowest soluble protein content of 4.92 mg g^{-1} .

Under sodicity condition, the two main plot treatments, differed significantly with the higher value of 10.64 mg g^{-1} being recorded by M_1 at panicle initiation stage than M_2 (7.14 mg g^{-1}). Among the sub plot treatments, S_7 (9.72 mg g^{-1}), S_9 (9.43 mg g^{-1}) and S_8 (9.33 mg g^{-1}) were on par with each other and their performance values was significantly greater than control (8.25 mg g^{-1}).

Under saline condition, the two main plot treatments, differed significantly with higher value of 10.67 mg g^{-1} being recorded by M_1 at panicle initiation stage than M_2 (6.69 mg g^{-1}).

Table 63. Effect of seed priming and foliar spray on soluble protein activity (mg g⁻¹) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	8.90		5.40	7.15	8.25		4.92	6.60
S ₂	8.70		5.70	7.22	8.40		5.40	6.90
S ₃	9.60		6.10	7.83	9.30		6.10	7.70
S ₄	8.80		6.20	7.52	8.80		6.03	7.80
S ₅	10.0		6.20	8.12	9.50		6.05	7.77
S ₆	9.40		5.60	7.50	8.95		6.62	7.80
S ₇	10.40		6.90	8.63	10.00		6.50	8.30
S ₈	10.10		6.40	8.25	9.80		6.50	8.20
S ₉	10.10		6.70	8.50	10.20		6.90	8.55
Mean	9.57		6.13		9.24		6.11	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.12	0.15	0.24	0.19	0.11	0.13	0.21	0.16
CD (P=0.05)	0.51	0.31	0.67	0.44	0.46	0.26	0.60	0.40

Table 64. Effect of seed priming and foliar spray on soluble protein activity (mg g⁻¹) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	10.0		6.50	8.25	9.50		6.00	7.75
S ₂	10.15		6.62	8.38	9.85		6.25	8.10
S ₃	10.60		7.23	8.92	10.35		6.80	8.60
S ₄	10.20		6.70	8.45	9.95		6.65	8.22
S ₅	10.80		7.01	8.93	10.60		7.00	8.80
S ₆	10.40		6.93	8.67	10.20		6.50	8.40
S ₇	11.35		8.10	9.72	10.95		7.52	9.23
S ₈	11.05		7.61	9.33	10.85		7.21	9.03
S ₉	11.25		7.61	9.43	11.05		7.70	9.37
Mean	10.64		7.14		10.67		6.69	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.13	0.12	0.21	0.15	0.12	0.18	0.27	0.22
CD (P=0.05)	0.56	0.25	NS	NS	0.53	0.36	NS	NS

Among the sub plot treatments, S₉ (9.37 mg g⁻¹), S₇ (9.23 mg g⁻¹) and S₈ (9.03 mg g⁻¹) were on par with each other and their performance was significantly greater than control (7.75 mg g⁻¹).

4.6.2.7. Proline content (Table 65 and 66)

The proline content showed an increasing trend from active tillering to panicle initiation stage. Under sodicity condition, at active tillering stage M₁ recorded higher proline content of 791.6 µg g⁻¹. Among the sub plot treatments, S₇ recorded higher proline content of 744.5 µg g⁻¹ which was on par with S₉ and S₈ treatment, while control recorded 685.7 µg g⁻¹.

The interaction of main plot with sub plot treatments, was significant. M₁S₇ recorded higher proline content of 826.7 µg g⁻¹ followed by M₁S₉ (819.7 µg g⁻¹) while M₂S₁ recorded lower proline content of 623.0 µg g⁻¹.

Under saline condition, the proline content increased from active tillering to panicle initiation stages. Main plot treatment, differed significantly at two stages of growth period with higher proline content in M₁ than M₂. At active tillering stage, M₁ recorded higher proline content of 776.1 µg g⁻¹. Among the sub plot treatments, S₉ recorded higher proline content of 739.5 µg g⁻¹ followed by S₇ (729.1 µg g⁻¹), while control recorded lower proline content of 669.3 µg g⁻¹.

The interaction of main plot with sub plot treatments, was found to be significant. M₁S₉ recorded higher proline content of 813.3 µg g⁻¹, while control M₂S₁ recorded lower proline content of 623.0 µg g⁻¹.

Under sodicity condition, at panicle initiation stage, M₁ had a maximum proline content of 943.0 µg g⁻¹ followed by M₂ (851.5 µg g⁻¹). Among the effect of sub plot treatments, S₇ recorded the maximum proline accumulation of 912.5 µg g⁻¹ and this was followed by S₉ (910.0 µg g⁻¹) and S₈ (906.2 µg g⁻¹) whereas, control recorded 880.2 µg g⁻¹.

The interaction effects of S at M were found to be significant. Among the interaction treatments, M₁S₇ recorded the maximum proline content of 958.0 µg g⁻¹. This treatment was closely followed by M₁ S₉ (955.0 µg g⁻¹) and M₁ S₈ (950.7 µg g⁻¹).

Under saline condition also, all the sub plot treatments exhibited their significant differences. At panicle initiation stage, higher proline content was registered by S₉ 916.2 µg g⁻¹ followed by S₇ 913.7 µg g⁻¹, S₈ 909.0 µg g⁻¹ and S₅ 903.5 µg g⁻¹ whereas, control recorded 862.3 µg g⁻¹.

Table 65. Effect of seed priming and foliar spray on proline activity ($\mu\text{g g}^{-1}$) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	748.3		623.0	685.7	716.0		623.0	669.3
S ₂	762.0		634.3	698.2	758.0		632.3	695.0
S ₃	787.7		645.0	716.3	769.3		649.0	709.0
S ₄	784.3		629.7	707.0	764.3		633.3	699.3
S ₅	796.3		653.7	725.0	792.0		645.3	718.5
S ₆	788.3		653.7	721.0	778.0		636.3	707.0
S ₇	826.7		662.3	744.5	802.3		656.0	729.1
S ₈	810.3		655.7	733.0	792.3		663.0	727.5
S ₉	819.7		662.3	741.0	813.3		666.0	739.5
Mean	791.6		646.6		776.1		644.9	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	9.91	5.81	12.6	7.11	10.5	6.26	13.40	7.73
CD (P=0.05)	42.6	11.83	46.2	16.73	45.03	12.80	49.00	18.05

Table 66. Effect of seed priming and foliar spray on proline activity ($\mu\text{g g}^{-1}$) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	922.0		838.3	880.2	911.0		814.0	862.3
S ₂	938.3		839.0	888.7	923.0		832.0	879.7
S ₃	939.0		853.0	896.0	942.0		845.0	893.3
S ₄	934.7		844.3	889.5	941.0		838.0	889.2
S ₅	948.3		852.3	900.3	957.3		850.0	903.5
S ₆	940.7		842.7	891.7	949.0		847.0	898.0
S ₇	958.0		867.1	912.5	962.0		865.3	913.7
S ₈	950.7		861.7	906.2	957.3		861.0	909.0
S ₉	955.0		865.0	910.0	964.3		868.0	916.2
Mean	943.0		851.5		945.63		846.56	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	12.2	3.21	13.62	3.94	12.70	5.66	14.80	7.30
CD (P=0.05)	55.6	6.55	56.65	9.30	51.70	11.52	NS	NS

4.6.2.8. Nitrate reductase activity (Table 67 and 68)

The data on nitrate reductase activity revealed an increasing trend from active tillering to panicle initiation stages. M_1 performed better with significantly higher values than M_2 at both the growth stages. Under sodicity condition, at active tillering stage, M_1 recorded higher nitrate reductase activity of $22.5 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ over M_2 with $11.6 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$. Among the sub plot treatments, S_7 recorded $21.3 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ followed by S_9 with $19.5 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ whereas control recorded $14.2 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$. Among the interaction treatments, M_1S_7 and M_1S_9 recorded 28.4 and $25.2 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ while M_2S_1 recorded $8.8 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$.

Under saline condition, nitrate reductase activity increased remarkably from active tillering to panicle initiation stages. Comparing the main plot treatments, M_1 performed better with significantly higher values than M_2 at both the growth stages. At active tillering stage M_1 recorded the nitrate reductase activity of $20.5 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ over M_2 with $9.81 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$. Among the sub plot treatments, S_9 recorded $19.4 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ followed by S_7 with $17.7 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$, whereas control recorded lower nitrate reductase activity of $11.6 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$. The interaction of main plot with sub plot treatments, was significant. M_1S_9 and M_1S_7 recorded 26.3 and $23.3 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$, while control M_2S_1 recorded the lowest value of $7.5 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$.

Under sodicity condition, at panicle initiation stage S_7 recorded the highest value of $25.1 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ followed by S_9 ($24.1 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$) and S_8 ($23.2 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$). Whereas, control recorded ($17.5 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$).

Under saline condition, at panicle initiation stage, S_9 recorded the highest value of $23.4 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ followed by S_7 ($22.6 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$) and S_8 ($21.0 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$). The significantly the lowest value of $16.5 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ was recorded by S_2 and the effect was significantly higher than control ($15.2 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$). Interaction treatments, exhibited their significant differences among the growth stages. The combination of M_1S_9 registered its highest rate of $30.3 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$. Similarly, M_1S_7 and M_1S_8 showed their better enzymatic activity with $29.4 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$ and $26.7 \mu \text{ moles } \text{No}_2 \text{ g}^{-1} \text{ h}^{-1}$, respectively

Table 67. Effect of seed priming and foliar spray on nitrate reductase activity (μ moles $\text{NO}_2^- \text{g}^{-1} \text{h}^{-1}$) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	19.6		8.8	14.2	16.0		7.5	11.6
S ₂	20.5		9.8	15.2	17.5		7.8	12.7
S ₃	21.1		11.6	16.4	19.4		9.7	14.5
S ₄	19.8		9.6	14.7	18.6		7.8	13.2
S ₅	23.3		12.7	18.1	21.5		11.5	16.5
S ₆	20.7		11.0	15.9	19.8		10.4	15.1
S ₇	28.4		14.2	21.3	23.3		12.0	17.7
S ₈	24.0		13.4	18.7	22.6		11.8	17.2
S ₉	25.2		13.7	19.5	26.3		12.5	19.4
Mean	22.5		11.6		20.5		9.81	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.25	0.53	0.74	0.64	0.22	0.45	0.64	0.55
CD (P=0.05)	1.08	1.07	1.80	1.51	0.95	0.92	1.57	1.31

Table 68. Effect of seed priming and foliar spray on nitrate reductase activity (μ moles $\text{NO}_2^- \text{g}^{-1} \text{h}^{-1}$) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	22.5		12.5	17.5	19.0		11.4	15.2
S ₂	23.0		13.5	18.3	21.5		11.6	16.5
S ₃	25.4		14.9	20.2	23.0		12.7	17.9
S ₄	24.5		13.6	19.1	22.8		11.7	17.2
S ₅	27.4		16.6	22.0	25.5		13.4	19.5
S ₆	25.0		14.4	19.7	22.7		12.4	17.6
S ₇	31.3		18.9	25.1	29.4		15.9	22.6
S ₈	28.7		17.7	23.2	26.7		15.2	21.0
S ₉	30.0		18.1	24.1	30.3		16.5	23.4
Mean	26.4		15.6		24.5		13.2	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.29	0.48	0.70	0.58	0.30	0.52	0.75	0.64
CD (P=0.05)	1.26	0.97	NS	NS	1.20	1.06	1.87	1.50

over the control. The other varietal combination M₂ S₉ also performed equally with M₁S₉ (16.5 μ moles NO₂ g⁻¹h⁻¹).

4.6.2.9. Peroxidase activity (Table 69 and 70)

Peroxidase activity exhibited similar pattern of reductase activity. Under sodicity condition, at active tillering stage, M₁ recorded higher peroxidase activity of 3.54 Min⁻¹ g⁻¹ over M₂ with 1.94 Min⁻¹ g⁻¹. Among the sub plot treatments, S₇ recorded higher peroxidase activity of 3.05 Min⁻¹ g⁻¹ followed by S₉ with 2.97 Min⁻¹ g⁻¹ whereas control recorded the peroxidase activity of 2.35 Min⁻¹ g⁻¹. Among the interaction treatments, M₁S₇ recorded 3.85 Min⁻¹ g⁻¹ whereas control M₂S₁ recorded 1.43 Min⁻¹ g⁻¹.

The time trend of peroxidase activity also revealed a gradual increase from active tillering to panicle initiation stage. The main plot treatments and sub plot treatments varied significantly at the growth stages. Under saline condition, at active tillering stage, M₁ recorded higher peroxidase activity of 3.08 Min⁻¹ g⁻¹ over M₂ 1.61 Min⁻¹ g⁻¹. Among the sub plot S₉ recorded higher peroxidase activity of 2.72 Min⁻¹ g⁻¹ followed by S₇ with 2.62 Min⁻¹ g⁻¹ while control recorded 2.02 Min⁻¹ g⁻¹. Among the interaction treatments, M₁S₇ recorded 3.28 Min⁻¹ g⁻¹ followed by M₁S₉ with 3.25 Min⁻¹ g⁻¹, while control M₂S₁ recorded the lowest value of 1.22 Min⁻¹ g⁻¹.

Under sodicity condition, at the time of panicle initiation, enzyme activity was maximum in, M₁ which showed its superiority (4.02 Min⁻¹ g⁻¹) compared to M₂ (1.95 Min⁻¹ g⁻¹). All the sub plot treatments also varied significantly. S₇ registered significantly higher activity (3.35 Min⁻¹ g⁻¹) followed by S₉ and S₈ with the activity of 3.31 Min⁻¹ g⁻¹ and 3.15 Min⁻¹ g⁻¹ respectively. In the interaction effect, the varietal and seed priming cum foliar spray treatment showed significant variations with respect to the enzyme activity. M₁S₇ (4.40 Min⁻¹ g⁻¹) which was on par with M₁S₉ and M₁ S₈ recorded the value of 4.20 Min⁻¹ g⁻¹ respectively.

Under saline condition, M₁ recorded comparatively higher activity (4.03 Min⁻¹ g⁻¹) at panicle initiation stage than M₂ (1.89 Min⁻¹ g⁻¹). The influence of S₉ (3.30 Min⁻¹ g⁻¹) was comparable with S₇ (3.29 Min⁻¹ g⁻¹) and S₈ (3.14 Min⁻¹ g⁻¹). The interaction effect of the varietal and seed priming cum foliar spraying treatments, showed significant variations with respect to peroxidase enzyme activity with M₁S₉ (4.45 Min⁻¹ g⁻¹) followed by M₁ S₇ (4.38 Min⁻¹ g⁻¹) and M₁S₈ (4.18 Min⁻¹ g⁻¹).

Table 69. Effect of seed priming and foliar spray on catalase activity ($\text{Min}^{-1}\text{g}^{-1}$) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	2.20		1.39	1.79	2.19		1.00	1.59
S ₂	2.49		1.74	2.11	2.32		1.40	1.86
S ₃	2.63		1.47	2.06	2.45		1.77	2.11
S ₄	2.43		1.80	2.11	2.20		1.55	1.87
S ₅	2.70		1.73	2.22	2.45		1.56	2.01
S ₆	2.60		1.43	2.02	2.30		1.37	1.83
S ₇	3.60		2.17	2.88	3.10		2.01	2.60
S ₈	3.10		1.96	2.53	2.95		2.12	2.53
S ₉	3.20		2.16	2.68	3.50		2.53	3.02
Mean	2.82		1.71		2.71		1.70	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.13	0.14	0.226	0.173	0.08	0.12	0.18	0.143
CD (P=0.05)	0.54	0.29	NS	NS	0.36	0.24	0.49	0.34

Table 70. Effect of seed priming and foliar spray on catalase activity ($\text{Min}^{-1}\text{g}^{-1}$) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	3.40		1.98	2.69	2.60		1.99	2.31
S ₂	3.50		2.13	2.82	2.85		2.08	2.47
S ₃	3.70		2.51	3.11	3.25		2.35	2.80
S ₄	3.55		2.21	2.88	3.03		2.34	2.69
S ₅	3.95		2.49	3.22	3.40		2.61	3.01
S ₆	3.65		2.40	3.03	3.15		2.17	2.66
S ₇	4.45		3.13	3.79	3.75		2.56	3.16
S ₈	4.10		2.65	3.40	3.60		2.34	2.34
S ₉	4.25		2.85	3.55	3.95		2.82	3.40
Mean	3.81		2.52		3.29		2.36	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.08	0.81	0.136	0.01	0.09	0.07	0.130	0.082
CD (P=0.05)	0.35	0.16	NS	NS	0.40	0.14	0.431	0.194

4.6.2.10. Catalase activity (Table 71 and 72)

The catalase activity also revealed a gradual increase from active tillering to panicle initiation stages. The main plot and sub plot treatments, varied significantly at growth stages. Under sodicity condition, at active tillering stage, M_1 recorded higher catalase activity of $2.82 \text{ Min}^{-1} \text{ g}^{-1}$ over M_2 $1.71 \text{ Min}^{-1} \text{ g}^{-1}$. Among the sub plot treatments, S_7 recorded higher catalase activity of $2.88 \text{ Min}^{-1} \text{ g}^{-1}$ followed by S_9 with $2.68 \text{ Min}^{-1} \text{ g}^{-1}$, whereas control recorded the lowest catalase activity of $1.79 \text{ Min}^{-1} \text{ g}^{-1}$.

Under saline condition, the main plot and sub plot treatments, varied significantly at growth stages. At active tillering stage, M_2 recorded higher catalase activity of $2.71 \text{ Min}^{-1} \text{ g}^{-1}$ over M_1 with $1.70 \text{ Min}^{-1} \text{ g}^{-1}$. Among the sub plot treatments, S_9 recorded higher catalase activity of $3.02 \text{ Min}^{-1} \text{ g}^{-1}$ followed by S_7 with $2.60 \text{ Min}^{-1} \text{ g}^{-1}$ while control recorded $1.59 \text{ Min}^{-1} \text{ g}^{-1}$. Among the interaction treatments, M_1S_9 and M_1S_7 recorded $3.50 \text{ Min}^{-1} \text{ g}^{-1}$ and $3.10 \text{ Min}^{-1} \text{ g}^{-1}$ respectively whereas, M_2S_1 recorded the lowest value of $1.00 \text{ Min}^{-1} \text{ g}^{-1}$.

Under sodicity condition, at panicle initiation stages, M_1 showed its superiority with $3.81 \text{ Min}^{-1} \text{ g}^{-1}$ compared to M_2 ($2.52 \text{ Min}^{-1} \text{ g}^{-1}$). All the sub plot treatments, also varied significantly with S_7 as an effective treatment which registered significantly higher activity ($3.79 \text{ Min}^{-1} \text{ g}^{-1}$) than S_9 ($3.55 \text{ Min}^{-1} \text{ g}^{-1}$) and S_8 ($3.40 \text{ Min}^{-1} \text{ g}^{-1}$). Whereas, control recorded $2.69 \text{ Min}^{-1} \text{ g}^{-1}$.

Under saline condition, M_1 recorded its superiority with $3.29 \text{ Min}^{-1} \text{ g}^{-1}$ over M_2 ($2.36 \text{ Min}^{-1} \text{ g}^{-1}$). All the sub plot treatments, also varied significantly with S_9 registered significantly higher activity ($3.40 \text{ Min}^{-1} \text{ g}^{-1}$) followed by S_7 and S_8 with the activity of $3.16 \text{ Min}^{-1} \text{ g}^{-1}$ and $2.34 \text{ Min}^{-1} \text{ g}^{-1}$ respectively. The interaction between varieties and treatments also varied significantly. The higher enzyme activity of $3.95 \text{ Min}^{-1} \text{ g}^{-1}$ was registered by M_1S_9 at panicle initiation stage which was significantly higher over the other treatments.

4.6.3. Nutrient analysis

4.6.3.1. Nitrogen uptake in plant (Table 73)

The nitrogen uptake in plants differed significantly among the varieties and treatments. Under sodicity condition, the uptake nitrogen was the highest in M_1 (101.2 kg ha^{-1}) than M_2 (87.0 kg ha^{-1}). Plants received seed priming treatment with nutrients followed by foliar

Table 71. Effect of seed priming and foliar spray on peroxidase activity ($\text{Min}^{-1}\text{g}^{-1}$) in leaf at active tillering stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	3.26		1.43	2.35	2.82		1.22	2.02
S ₂	3.39		1.75	2.57	2.91		1.31	2.12
S ₃	3.52		2.02	2.77	3.10		1.42	2.26
S ₄	3.28		1.87	2.58	2.93		1.41	2.17
S ₅	3.60		1.98	2.80	3.24		1.75	2.50
S ₆	3.36		1.95	2.65	3.01		1.36	2.19
S ₇	3.85		2.25	3.05	3.28		1.95	2.62
S ₈	3.77		2.14	2.96	3.18		1.91	2.54
S ₉	3.79		2.14	2.97	3.25		2.18	2.72
Mean	3.54		1.94		3.08		1.61	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.04	0.07	0.098	0.081	0.09	0.08	0.14	0.10
CD (P=0.05)	0.19	0.13	0.26	0.19	0.40	0.17	0.45	0.24

Table 72. Effect of seed priming and foliar spray on peroxidase activity ($\text{Min}^{-1}\text{g}^{-1}$) in leaf at panicle initiation stage in rice varieties of TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	3.40		1.59	2.45	3.60		1.45	2.53
S ₂	3.60		1.72	2.67	3.71		1.54	2.62
S ₃	4.00		2.01	3.01	3.92		1.92	2.92
S ₄	3.80		1.70	2.80	3.81		1.69	2.75
S ₅	4.20		2.10	3.14	4.17		2.07	3.12
S ₆	4.10		1.88	3.00	4.09		1.91	3.00
S ₇	4.40		2.31	3.35	4.38		2.19	3.29
S ₈	4.20		2.09	3.15	4.18		2.10	3.14
S ₉	4.40		2.22	3.31	4.45		2.12	3.30
Mean	4.02		1.95		4.03		1.89	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.05	0.07	0.11	0.09	0.06	0.09	0.13	0.11
CD (P=0.05)	0.21	0.15	0.29	0.21	0.27	0.18	0.40	0.25

spraying of 0.5 % ZnSO₄ (S₇) accumulated higher nitrogen in plants (101.6 kg ha⁻¹) followed by S₉ (99.1 kg ha⁻¹) and S₈ (97.1 kg ha⁻¹) whereas, control recorded the least uptake of nitrogen was (88.0 kg ha⁻¹). The interaction had sustained effect on nitrogen uptake. M₁S₇ registered the highest nitrogen uptake of 110 Kg ha⁻¹ which was followed by M₁S₇ which registered 108 Kg ha⁻¹ whereas, M₂S₁ registered the lowest nitrogen uptake of 81.0 Kg ha⁻¹.

The nitrogen uptake in plants differed significantly among the varieties and treatments. Under saline condition, the nitrogen uptake was more in the plants harvested from M₁ (98.5 kg ha⁻¹) than M₂ (84.4 kg ha⁻¹). Seed priming followed by foliar spray of 2% cowpea pulse sprout extract recorded the highest N uptake in plants (98.0 kg ha⁻¹) followed by S₇ (96.0 kg ha⁻¹), S₈ (95.0 kg ha⁻¹) and S₅ (94.0 kg ha⁻¹), whereas, control recorded the lowest nitrogen uptake of 85.5 kg ha⁻¹. There is a significant interaction between varieties and seed priming cum foliar spray treatments. M₁S₉ registered the highest nitrogen uptake of 107.1 Kg ha⁻¹ and it was followed by M₁S₇ registered 104.2 Kg ha⁻¹. Whereas, M₁S₁ registered the lowest nitrogen uptake of 77.9 Kg ha⁻¹.

4.6.3.2. Phosphorous uptake in plant (Table 74)

There was a significant difference in phosphorous uptake due to varieties and seed priming cum foliar spray of nutrients. Under sodicity condition, phosphorous uptake in plants was more in M₁ with 37.3 kg ha⁻¹ followed by M₂ (32.0 kg ha⁻¹). Among the sub plot treatments, seed priming with nutrients followed by foliar spray of 0.5 % ZnSO₄ (S₇) increased the phosphorous uptake at 37.4 kg ha⁻¹ followed by S₉ (36.5 kg ha⁻¹) and S₈ (35.8 kg ha⁻¹) whereas, control recorded the lowest phosphorous uptake in plants at 32.4 kg ha⁻¹. Interaction of main plot with subplot treatments was significant M₁S₇ and M₂S₁ registered the highest and lowest phosphorous uptake of 40.6 Kg ha⁻¹ and 29.8 Kg ha⁻¹, respectively.

The phosphorous uptake in plants differed significantly among the varieties and treatments. Under saline condition, highest accumulation of phosphorous was recorded in M₁ (36.8 kg ha⁻¹) than M₂ (31.1 kg ha⁻¹). Among the sub plot treatments, S₉ recorded the highest uptake of phosphorous in plants with a value of 36.2 kg ha⁻¹ followed by S₇ (35.4 kg ha⁻¹) and S₈ (35.1 kg ha⁻¹). S₂ recorded the lowest P uptake of 32.2 kg ha⁻¹. Whereas, control registered 31.6 kg ha⁻¹. There was a significant interaction between varieties and seed priming cum foliar spray treatments. M₁S₉ and M₁S₇ registered the highest phosphorous uptake of 39.7 kg ha⁻¹ and 38.5 kg ha⁻¹, respectively. While M₂S₁ registered the lowest uptake of 28.8 kg ha⁻¹.

Table 73. Effect of seed priming and foliar spray on total nitrogen uptake (kg ha⁻¹) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	95		81	88.0	93.1		77.9	85.5
S ₂	96		82	89.1	84.0		80.6	82.3
S ₃	100		86	93.2	99.3		85.3	92.3
S ₄	97		84	90.8	95.9		82.8	89.3
S ₅	102		89	95.6	101.5		86.0	94.0
S ₆	98		87	92.5	97.9		83.8	90.8
S ₇	110		93	101.6	104.2		87.9	96.0
S ₈	105		90	97.1	103.5		86.5	95.0
S ₉	108		91	99.1	107.1		88.6	98.0
Mean	101.2		87.0		98.5		84.4	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	1.63	1.21	2.30	1.49	2.23	2.40	3.89	2.94
CD (P=0.05)	7.04	2.47	7.68	3.50	9.59	4.88	13.00	6.90

Table 74. Effect of seed priming and foliar spray on total phosphorous uptake (kg ha^{-1}) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	35.1		29.8	32.4	34.4		28.8	31.6
S ₂	35.4		30.2	32.8	34.7		29.7	32.2
S ₃	36.8		31.8	34.3	36.7		31.5	34.1
S ₄	35.8		31.1	33.5	35.4		30.6	33.0
S ₅	37.6		32.9	35.2	37.5		31.7	34.5
S ₆	36.3		31.9	34.1	36.2		30.9	33.5
S ₇	40.6		34.2	37.4	38.5		32.4	35.4
S ₈	38.5		33.0	35.8	38.2		31.9	35.1
S ₉	39.7		33.4	36.5	39.7		32.7	36.2
Mean	37.3		32.0		36.8		31.1	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.624	0.450	0.863	0.547	0.47	0.39	0.69	0.47
CD (P=0.05)	2.68	0.910	2.88	1.28	2.01	0.78	2.30	11.04

4.6.3. 3. Potash uptake in plants (Table 75)

The potash uptake was more in M_1 (147.6 kg ha^{-1}) followed by M_2 (126.8 kg ha^{-1}). Under sodicity condition, among the sub plot treatments, S_7 increased the potash uptake with 148.1 kg ha^{-1} followed by S_9 (144.5 kg ha^{-1}), S_8 (141.6 kg ha^{-1}) and S_5 (139.3 kg ha^{-1}). Whereas, the control recorded 128.3 kg ha^{-1} . There was a significant interaction between varieties and seed priming cum foliar spray treatments. M_2S_7 and M_1S_9 registered the highest potassium uptake of 160.7 and 156.8 Kg ha^{-1} , respectively. While, M_2S_1 registered the lowest uptake of 117.8 Kg ha^{-1} .

Under salinity condition, potash uptake significantly differed among the treatments. M_1 enhanced the potash uptake in plants with a value of 146.0 kg ha^{-1} than M_2 (123.6 kg ha^{-1}). Among the sub plot treatments S_9 increased the K uptake (143.4 kg ha^{-1}) followed by S_7 (141.0 kg ha^{-1}) and S_8 (139.2 kg ha^{-1}). Whereas, the control recorded (125.3 kg ha^{-1}) There was a significant interaction between seed priming cum foliar sprays and varieties. M_1S_9 registered the highest uptake of 157.1 kg ha^{-1} followed by M_1S_7 (153.0 kg ha^{-1}). Whereas, M_2S_1 registered the lowest uptake of 114.1 kg ha^{-1}

Table 75. Effect of seed priming and foliar spray on total potash uptake (kg ha⁻¹) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

Treatments	Sodicity				Salinity			
	M ₁		M ₂	Mean	M ₁		M ₂	Mean
S ₁	138.7		117.8	128.3	136.5		114.1	125.3
S ₂	140.0		119.6	130.0	134.0		118.0	127.9
S ₃	145.6		126.1	136.0	146.0		125.0	135.2
S ₄	141.7		123.0	132.3	140.5		121.3	130.9
S ₅	148.6		130.1	139.3	149.0		126.0	137.3
S ₆	143.6		126.2	135.0	143.5		123.0	133.2
S ₇	160.7		135.4	148.1	153.0		129.0	141.0
S ₈	152.4		130.8	141.6	152.0		127.0	139.2
S ₉	156.8		132.1	144.5	157.1		130.0	143.4
Mean	147.6		126.8		146.0		123.6	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	2.615	1.768	3.521	2.166	1.83	1.53	2.74	1.88
CD (P=0.05)	11.25	3.602	11.76	5.09	7.86	3.11	9.15	4.42

Discussion

CHAPTER V

DISCUSSION

Rice is the most important staple food for over two third of population in India. It is a mean of livelihood for millions of rural households and plays vital role in our national food security, hence the slogan “Rice is Life” is most appropriate. (Krishna *et al.*, 2008). Demand for rice is growing every year and it is estimated that in 2025 AD the requirement would be 140 million tones. To sustain the present food self – sufficiency and to meet future food requirements, India has to increase it’s rice production by 3 per cent per annum (Thiyagarajan and Selvaraju, 2001).

Soil salinity has become a severe threat to ensure food security in the developing world. Increasing salinity had significant impact on food production and more agricultural lands are expected to become salt affected due to climate change. Cereals contribute mainly to food production and growing grain crops on saline soils require adoption of different strategies for sustainable crop production. The total world wide area affected with soil salinity is about 190 m ha (FAO, 2010). Good quality soil is a catalyst for increasing the productivity of agricultural crops. In India, the maximum rice producing area is severely affected with salinity and alkalinity stress. Rice is highly susceptible to salt stress (Munns and Tester, 2008) during early seedling stage (Li and Xu, 2007) ultimately resulting in reduction of rice productivity. If it occurs over a longer period, feeding the growing populations would be great challenge in future endeavour.

Strategies for improving the growth and development of crop species have been investigated for many years. Agricultural productivity mainly depends to a large extent on the sowing quality of the seeds. Emergence and establishment are the two basic requirements for quality seeds as they offer scope not only for uniformity in the field stand, but also for full exploitation of yield potential of crops. Presowing seed quality enhancement causes early enhanced germination and growth rate of seedlings (Austin *et al.*, 1973).

Seed priming is a presowing strategy for influencing seedling development by modulating pregermination metabolic activity prior to emergence of the radicle and generally enhances germination rate and plant performance (Bradford, 1986; Taylor and Harman, 1990). It has been

reported that seed priming ameliorates the salinity problems also (Ashraf and Harris, 2004; Afzal *et al.*, 2006) .

Various prehydration or priming treatments have been employed to increase the speed and synchrony of seed germination (Bradford, 1986). Common priming techniques include osmopriming (soaking seeds in osmotic solutions such as polyethylene glycol), halopriming (soaking seeds in salt solutions) and hydropriming (soaking seeds in water). During seed priming the amount of water absorption is controlled so as to allow necessary metabolic activities for germination to take place but prevent radicle emergence by limiting the seed water content, different physiological activities occur within the seed at different moisture levels. (Dell Aquila and Tritto, 1991; McDonald, 2000; Giri and Schilinger, 2003; Kaur *et al.*, 2002)

Research in seed priming especially to withstand the sodic stress is scanty. Hence, research work was initiated to study the effect of seed priming on germination, growth and yield in rice under sodic and saline stress environments.

5.1. Standardization of treatment concentration and soaking duration

The rapid, uniform and early germination are a prerequisite for good establishment and survival of the seedlings in the field condition for any crop species. In the present investigation, seed priming with CaSO_4 1.0% , ZnSO_4 1.0%, FeSO_4 1.0%, GA_3 20 ppm, *Pseudomonas fluorescens* 1.0%, *Azophos* 1.0%, for 18h improved the germination by 8 and 5, 9 and 7, 6 and 5, 11 and 6, 10 and 6 ,11 and 8 per cent over control (Fig.2) in TNAU Rice TRY 3 and I.W.Ponni , respectively.

In addition to higher germination, seedling vigour is also important in deciding the field stands establishment and the productivity of the crops. In the present study, seeds primed with above said treatments also registered higher values for root length, seedling drymatter production and vigour. Seed priming with 1 % *Azophos* and 1 % ZnSO_4 for 18h showed 7.1 and 7.3 per cent in TNAU Rice TRY 3 and 7.3 and 5.0 per cent in I.W.Ponni increase over control in seedling root length, respectively. The above treatments also recorded 20.2 & 15.3 and 19.0 & 15.2 per cent increase over control in vigour index in the above varieties, respectively. Which was followed by 20 ppm GA_3 , 1% *Pseudomonas fluorescens*, 1 % CaSO_4 and 1 % FeSO_4 for 18 h (Fig.3). The relative enhancement of germination and seedling vigour might be attributed to the role of phosphorus solubilising bacteria known as phosphobacteria in enhancing the solubilisation of insoluble phosphorus and making it available to the germinating seed with

consequent enhancement in the metabolic activity which resulted in higher germination (Cooper, 1979). The results of the present study are in agreement with the findings of Ramamoorthy *et al.* (2001) in rice due to seed biofortification with *Azospirillum*. They reported that it enhanced seedling vigour encompassing speed of germination, seedling length and dry weight of high vigour as well as low vigour seedlots. Similar increase in the seedling growth due to liquid phosphobacteria seed treatments was reported by Gomathy *et al.* (2007) in maize, Yousry *et al.* (1978) in pea and Mahfouz and Sharaf-Eldin (2007) in fennel. Rice and Olsen (1992) suggested that liquid formulation was an effective method of seed inoculation of biofertilizer.

In the present study revealed that seed biopriming with *Pseudomonas fluorescens* produced desirable results, both promoting the germination as well as increased the seedling growth and vigour of rice. The results of the present investigation are in agreement with Sunil Kumar *et al.* (2007) in tomato, Begum *et al.* (2010) in soybean, in pearl millet by Umesha *et al.*, 1998; Niranjana Raj *et al.*, 2003a ; Niranjana Raj *et al.*, 2003b; Niranjana Raj *et al.*, 2004; sorghum (Raju *et al.*, 1999) and in rice (Praveen Kumar *et al.*, 2000; 2001). Strains of *Pseudomonas fluorescens* appear to be outstanding in this context, because, in addition to induce resistance, they also promote growth and development of plants (Chen *et al.*, 2000; Ongena *et al.*, 2000; Ramamoorthy *et al.*, 2001; Desai *et al.*, 2002; Gnanamanickam *et al.*, 2002). The enhancement in the seedling growth noticed in this study can be attributed to suppression of deleterious microorganisms and pathogens; production of plant growth regulators such as gibberellins, cytokinins and indole acetic acid; increased availability of minerals and other ions; and more water uptake (Van Loon *et al.*, 1998; Ramamoorthy *et al.*, 2001). Early germination in terms of high speed of germination was observed in the present study due to *Pseudomonas fluorescens* 1% biopriming for 18h, is in agreement with the findings of Srivastava *et al.* (2010) who reported that in tomato, early germination by 2 - 2.5 days was noticed in the seeds bioprimed with *Pseudomonas fluorescens*.

Earl puls and Lambeth, 1974 had concluded the higher seed quality parameters in tomato seeds treated with GA₃ was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growing points and higher activity of enzymes. The growth regulator treatments through enzymatic and hormonal mechanism stimulate metabolic process such as sugar mobilization, protein hydrolysis, oxidation etc. The increase in seedling vigour index and seedling dry weight was due to increased

Fig 2. Effect of seed priming treatments and soaking duration on Germination

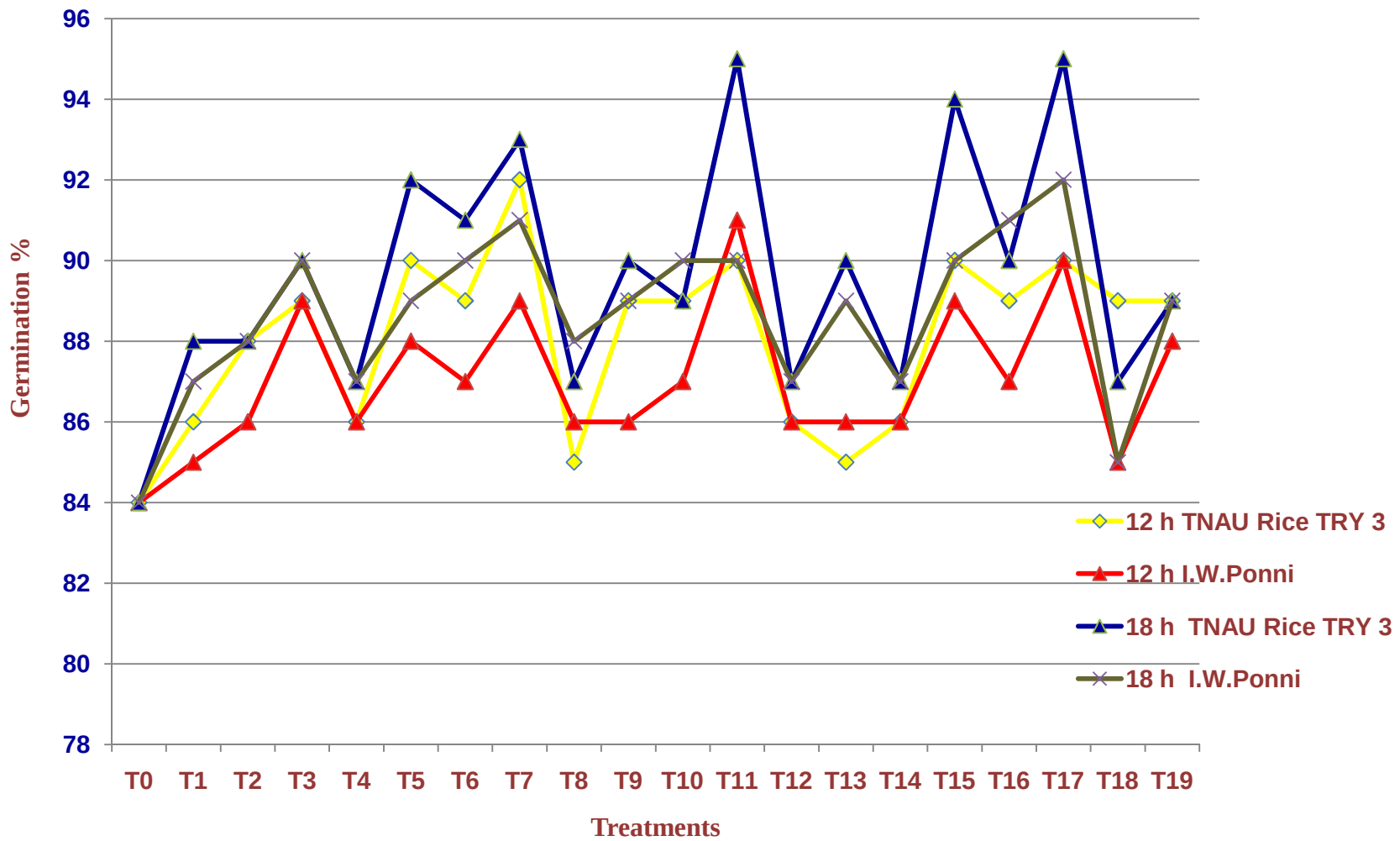
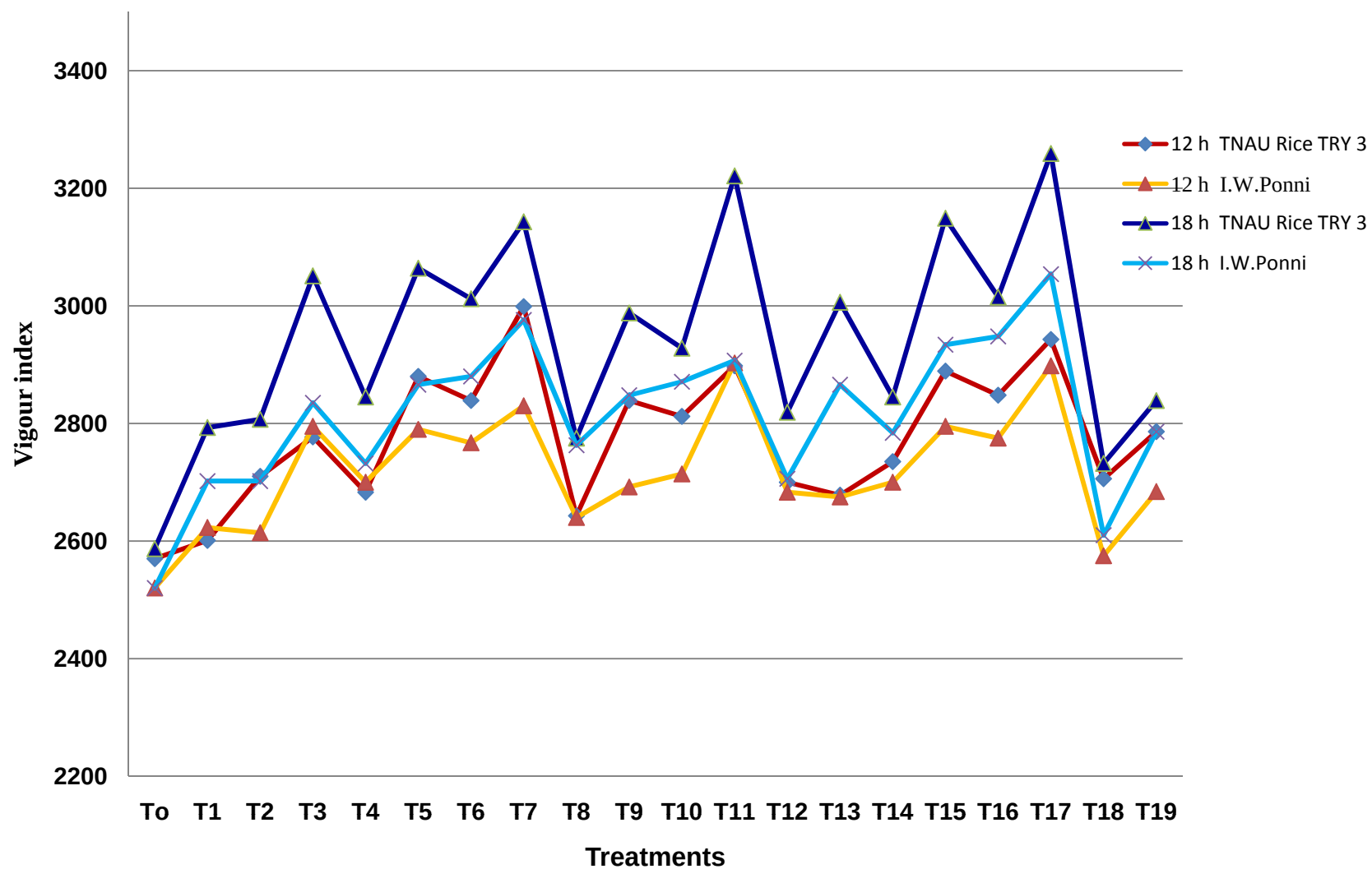


Fig 3. Effect of seed priming treatments and soaking duration on Vigour index



the priming treatments varied with stress levels. Regarding sodicity, 50 mM stress level had an adverse effect on seed germination showing 32 and 36 mean per cent reduction over control in both TNAU Rice TRY 3 and I.W.Ponni varieties, respectively. The same trend was also observed in other seedling quality parameters viz., root length 60 and 65 %, shoot length 66 and 76%, drymatter production 52 and 58 % and vigour index 74 and 81 % over control, respectively (Fig.4).

The results of the present investigation are in agreement with the findings of Akbar and Yabuno (1974) in rice, Garg *et al.* (1988) and Sheoran and Garg (1978) in mung, Nautiyal *et al.* (1989) in *Arachis hypogea*. The decline in germination, root and shoot growth might be attributed to limited water uptake by the seeds under salt stress conditions (Mondal *et al.*, 1988) and inhibition of hydrolysis of endosperm reserves and reduced translocation of food reserves from endosperm to embryo (Misra *et al.*, 1996). The present study also revealed that TNAU Rice TRY 3 maintained better shoot and root growth under extreme salinity and sodicity conditions. This might be attributed to the inherent mechanism of tolerant varieties in the regulation of entire germination process. There are lot of reports state that salinity leads to decline in germination shoot and root lengths, fresh mass and seedling vigour index (Younis *et al.*, 1991 in rice; Promila and Kumar, 2000; Misra and Dwivedi 2004 in mungbean ; Othman *et al.*, 2006 in barely; Zahra khodarahmpour *et al.*, 2012 in maize).

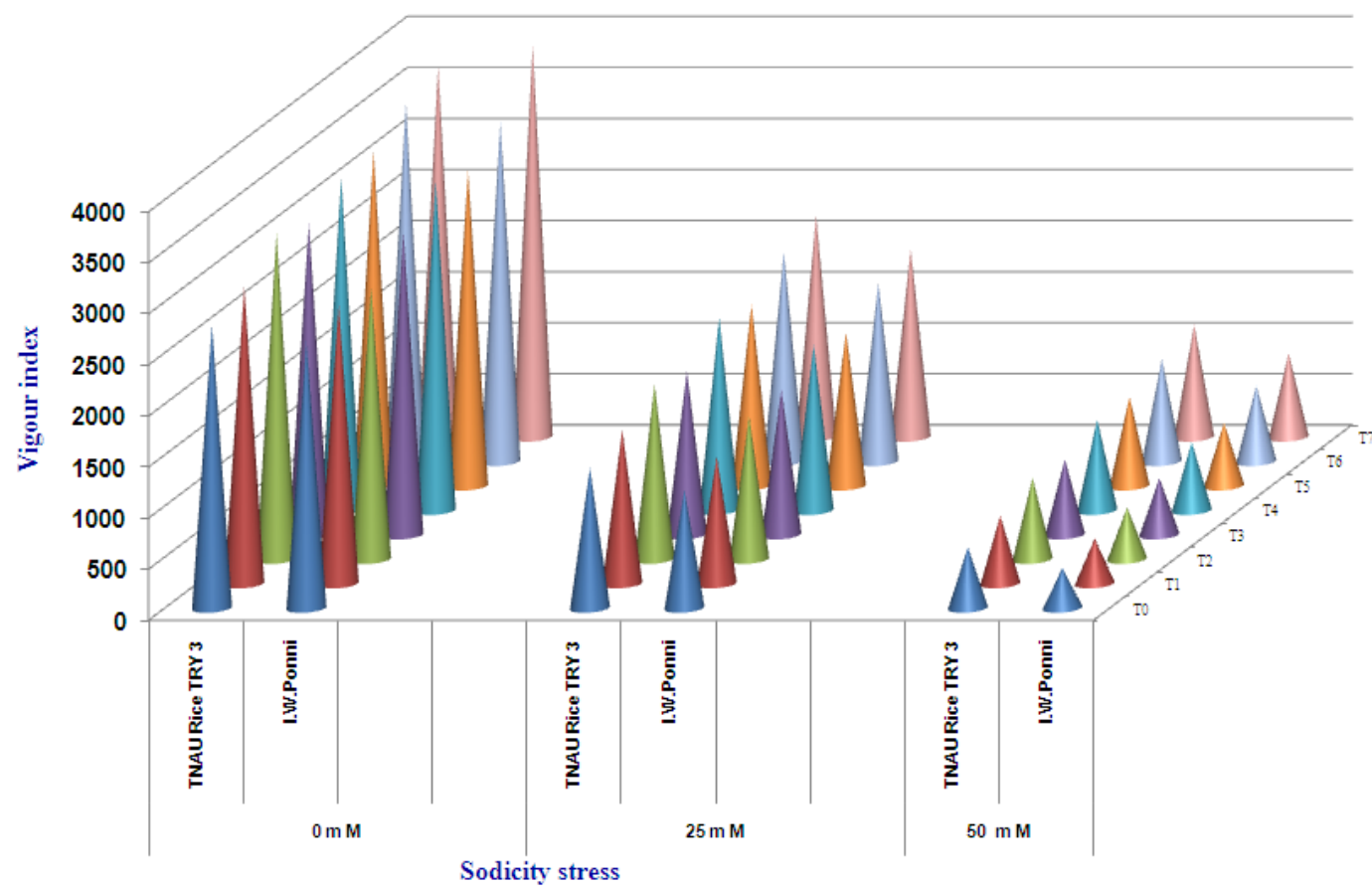
Seed priming improved salt tolerance in wheat at initial germination stage was due to reduced oxidative damage, expression of stress proteins and further activation of metabolic repair (Wahid *et al.*, 2007; Afzal *et al.*, 2011). Seed priming improved germination rates and uniformity of growth following reduced emergence time and increased yields are reported in many field crops including rice (Farooq *et al.*, 2006b; Afzal *et al.*, 2006; Afzal *et al.*, 2011). In the present investigation, seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % recorded 20 and 23 ; 15.3 and 14.5; 36 and 44 ; 37 and 27 and 46 and 47.2 per cent mean increase over control, respectively for seed germination, root length, shoot length, drymatter production and vigour index of TNAU Rice TRY 3 and I.W.Ponni.

The same trend was observed under salinity stress condition. At higher salinity level (150 mM) the reduction in germination from 94 to 66 % and 92 to 62 % ; in root length from 20

to 8.8 cm and 19.1 to 7.4cm ; in shoot length from 14.3 to 7.4 cm and 14.1 to 6.6 cm were recorded in both varieties, respectively. The priming treatments performed under sodicity stress showed same effect in salinity stress also. Whereas, at 100mM level the mean values recorded for germination and seedling vigour were 80 and 78; 1891 and 1739 in both the varieties, respectively, which shows that upto this level the germination and seedling vigour of the both the varieties were not much affected (Plate.1).The mean increase of seed priming with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos1 % + *Pseudomonas fluorescens*1 % was 75 to 85 % and 73 to 85 % for germination ; 10.0 to 12.3 cm and 9.5 to 11.7 cm shoot length ; 0.088 to 0.116 g and 0.064 to 0.083 g drymatter production in both varieties, respectively. Similar increases in germination and seedling growth parameters in various crops were observed due to seed priming by many researchers under stress condition. (Varma *et al.*, 1984; Hays, 1992; Rood *et al.*, 1990; Irfan Afzai *et al.*, 2002; Sakhabutdinova *et al.*, 2003; Ashraf *et al.*, 2008). The same trend was noticed in seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos1 %, 1 % mixture of CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % and 1 % mixture of CaSO₄ + ZnSO₄ + FeSO₄ at 150 mM salinity level. The fore said priming treatments show more than 75 per cent germination under high salinity level. Improvement in germination and seedling vigour under salt stress due to seed priming with growth regulator and nutrients might be due to increased cell division within the apical meristem of seedling root resulted in increase in plant growth (Sakhabutdinova *et al.*, 2003). Osmohardening with KCl and CaCl₂ maintain the osmotic advantage that both K⁺ and Ca²⁺ have an improving cell water status (Farooq *et al.*, 2006), and also they act as cofactors in the activities of numerous enzymes (Taiz and Zeiger, 2002). The present study is also supported by Ashraf and Foolad (2005) and Ashraf *et al.* (2008) who have reported that pre-treatment of seeds with different type of hormones and plant growth regulators is much effective in alleviating stress effects of salinity on the plants at different stages especially at early stage and it has been shown to improve crop germination as reported earlier under salt stress.

In seeds primed with ZnSO₄, activity of degrading enzymes such as α - amylase are increased that cause of accelerated germination rate (Jie *et al.*, 2002). Also in primed seed, increasing of bio-energy level (ATP), increasing of RNA and DNA synthesis and enhancement

Fig 4. Effect seed priming Treatments on vigour index under sodicity stress condition



of mitochondrial performance could have attributed to the better performance in peanut by. Fu *et al.* 1988.

Based on the results of this experiment (5.2), it is concluded that, the seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4$, 1% mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1%, 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1% and 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1.0% + *Pseudomonas fluorescens* 1% found to be performed better in terms of recording higher germination and seedling vigour under salt stress conditions as compared to other treatment combinations effected.

5.3. Final screening of priming treatments under sodicity and salinity stress conditions

Since the results of the previous experiment (5.2) revealed the severe impact of sodicity and salinity stress levels tried on germination found to be below the prescribed minimum requirements with the production of poor quality seedlings, the stress levels were further refined and fine tuned to evaluate the performance of seed priming treatments on alleviating the effect of stress. The best performing priming treatments of previous experiment were included in this experiment for further study.

In this experiment the sodicity levels of 14, 16, 18 mM and salinity levels of 125, 150 and 175 mM along with control were imparted. In the present investigation, at sodicity level of 18 mM it is observed that the mean values recorded for germination, root and shoot length by TNAU Rice TRY 3 and I.W.Ponni were 81 and 75 %, 19.4 and 18.2 cm ; 13.3 and 12.9 cm, respectively (Fig.5;Plate.2).

Salinity affects the seed germination by creating osmotic stress due to reduced water uptake or through ionic imbalance due to toxic effects of sodium (Na^+) and chloride (Cl^-) ions (Hosseini *et al.*, 2003). Salinity also upsets plant hormone level and reduces the utilization of seed reserves (Ahmad and Bano, 1992). Salinity induced stress inhibited seed germination and production uniform seedling stand in rice (Almansouri *et al.*, 2001) and ultimately diminishes economic yield and quality of produce (Ali *et al.*, 2004).

In the present investigation, seeds primed with 1 % mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % registered the maximum

Plate.1 Performance of seed priming under 100 mM salinity stress level



a.TNAU Rice TRY 3.



b.I.W.Ponni

Fig 5. Screening of seed priming treatments based on root Length under sodicity stress conditions

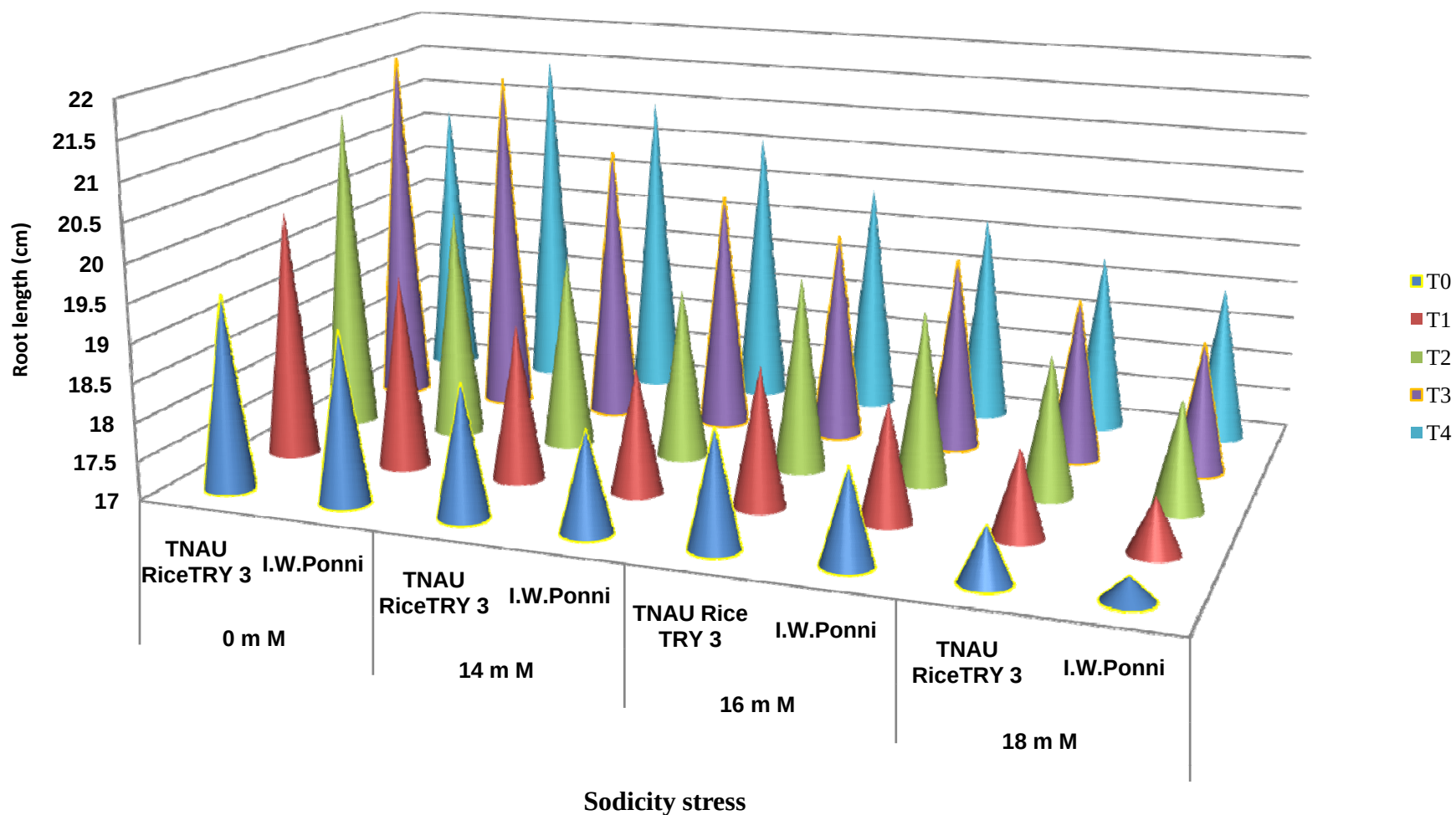
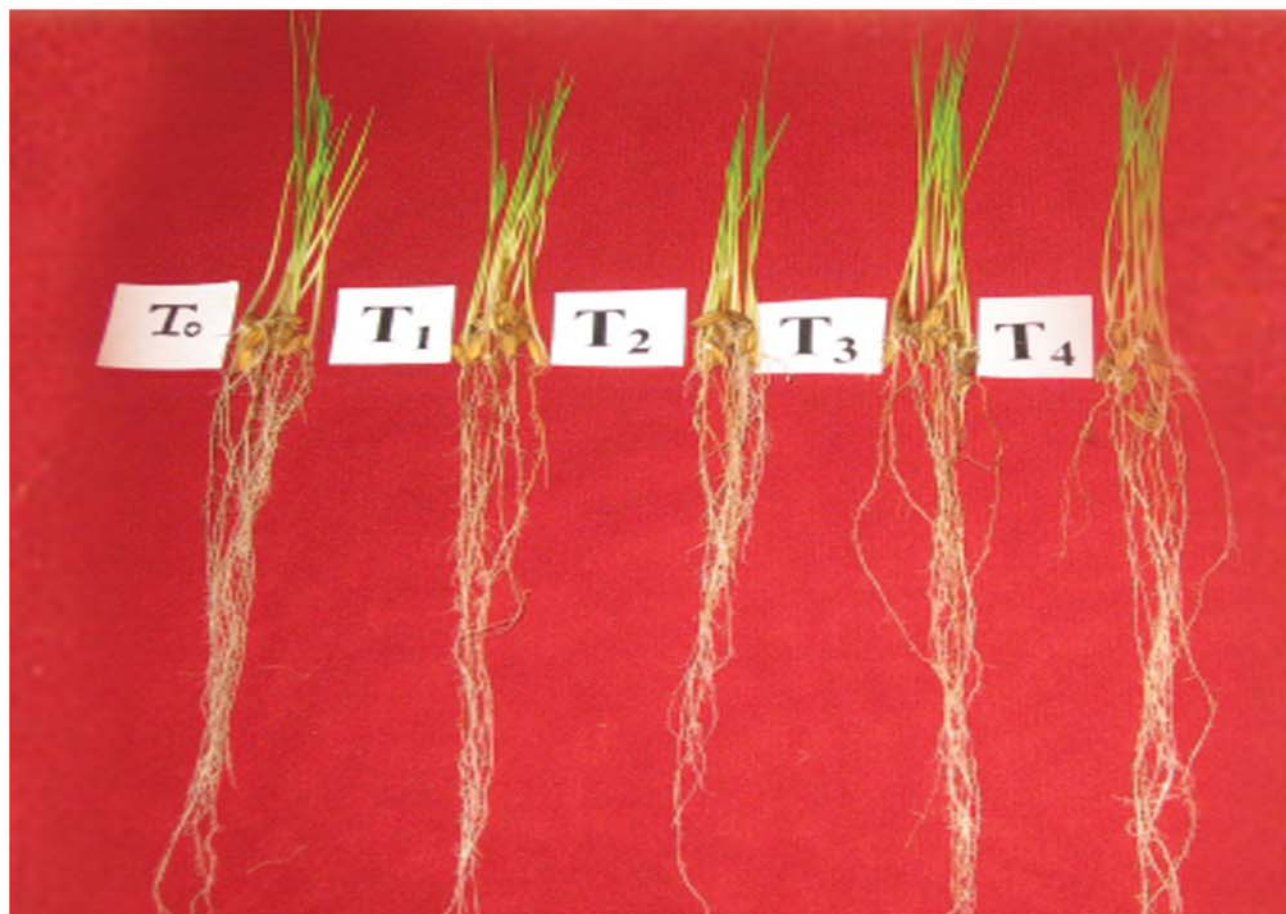


Plate. 2 Performance of seed priming under 18 mM sodicity stress level



a.TNAU Rice TRY 3



b.I.W.Ponni

values. The per cent increase was (10.0 and 10.2), (10.6 and 8.9), (20.2 and 12.3) and (24.0 and 25.0) for seed germination, root length, drymatter production and vigour index over their respective controls for TNAU Rice TRY 3 and I.W.Ponni, respectively. Similar trend was also observed in stress tolerance index.

Under salinity level of 175 mM concentration, all seed quality parameters were reduced. The mean reduction per cent over their respective controls were 42.0 and 48.0 for seed germination; 60 and 68 for shoot length; 69 and 73 for root length and 80 and 85 for vigour index in both varieties. Regarding seed priming, seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % showed increasing trend for all seed physiological parameters. The per cent increase was 18 and 19 for germination; 31 and 30 for shoot length and 38 and 44 for vigour index in both varieties, respectively. The stress tolerance index at this stress level was 27.2 and 14.6 per cent, respectively for TNAU Rice TRY 3 and I.W.Ponni.

Increase in germination percentage might be due to enhanced oxygen uptake and mobilization of nutrients from cotyledon to embryonic axis due to KCl halopriming. (Farooq *et al.* 2006 b) and protection of plants from adverse affects of salt stress and improving the growth of plants by calcium under saline conditions (Hamdia *et al.* 2010).

Priming with GA₃ accelerate metabolic reactions before germination process and made possible seed germination under salinity stress conditions with low moisture (Varma *et al.* 1984).

Zinc plays a fundamental role in protecting and maintaining structural stability of cell membranes (Welch *et al.*, 1982; Cakmak, 2000) and used for protein synthesis, membrane function, cell elongation and tolerance to environmental stresses. (Cakmak 2000). This might be the reasons for increased growth parameters with above treatments under stress conditions.

The results of the present study revealed that the seed germination and seedling growth were not affected upto 18 mM sodicity level and 100 mM salinity level in the both the varieties and beyond which reduction in seed quality parameters was much pronounced. From the present experiment, the following treatments viz., seed priming with 1 % mixture of CaSO₄+ZnSO₄+FeSO₄, seed priming with 1% mixture of CaSO₄+ZnSO₄+FeSO₄ +GA₃ 20ppm +Azophos1%, seed priming with 1% mixture of KCl+ CaSO₄+ZnSO₄+FeSO₄ + GA₃ 20ppm + Azophos 1% and seed priming with 1% mixture of KCl+CaSO₄+ZnSO₄+FeSO₄+GA₃ 20ppm +Azophos 1.0% +*Pseudomonas fluorescens* 1% were forwarded to field experiment to study the

effect of seed priming along with foliar spray of FeSO_4 , ZnSO_4 , DAP and cowpea pulse sprout extract in alleviating salt stress and to enhance the seed set and yield.

5.4. Field experiment

Besides laboratory screening study a field trial was conducted both under sodicity and salinity conditions mainly with the aim of mitigating the adverse effect of salt stress on growth and productivity of rice through the application of seed priming treatment and seed priming along with foliar spray of micronutrients at appropriate growth stages. One tolerant variety (TNAU Rice TRY 3) and a susceptible variety (I.W.Ponni) were employed in this study. The influence of priming treatments on growth characteristics, physiological and biochemical constituents of these two rice varieties were analyzed and discussed here under.

5.4.1. Field performance of seed priming and seed priming cum foliar spray treatment under sodicity and salinity stress conditions

In the present study, days to first flowering, days to 50 per cent flowering, plant height, number of tillers, number of productive tillers, panicle length and the number of seeds per panicle might have contributed for increased productivity in crops by adopting seed priming with foliar sprays when compared to untreated control. This is in line with the findings of Bassiouni, (2011). The reduced yield in untreated seeds could be assigned to poor seedling growth under stress conditions as reported by (Dionisio-Sese and Tobita, 2000; Zhu, 2001 and Ottow *et al.*, 2005). The treatments viz., priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1 % along with 0.5 % foliar spray of ZnSO_4 for sodicity and 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20ppm + Azophos 1% + *Pseudomonas fluorescens* 1% along with foliar spray of 2% cowpea pulse sprout for salinity at active tillering and panicle initiation stages proved beneficial for stress conditions.

The priming cum foliar spray treatments advanced early days to first and 50 per cent flowering by 1-3 days in seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1 % along with 0.5 % foliar spray of ZnSO_4 for sodicity and 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20ppm + Azophos 1% + *Pseudomonas fluorescens* 1% along with 2.0 % foliar spray of cowpea pulse sprout extract for salinity. The results are in conformity with the findings of Vijayalakshmi (2009) in rice. Comparing the varieties TNAU

Rice TRY 3 promoted early flowering by 3 days than I.W.Ponni (Fig.6). The possible reasons for early flowering could be due to induction of early emergence and physiological activation of growth by priming treatments.

The priming cum foliar spray treatments influenced the total tillers and productive tillers (Fig.7).Seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % along with 0.5 % foliar spray of ZnSO_4 showed higher values (19.2 and 17.2) for sodicity and 1% $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2.0 % foliar spray of cowpea pulse sprout extract showed maximum values (18.2 and 15.9) in salinity than other treatment as well as untreated control. This might be due to the various micronutrients present in the treatment allowing effective absorption by the plant at respective subsequent stages which might have increased the activity of enzymes and hormones resulting in better growth and production of productive tillers. (Ramakrishna Reddy *et al* .1984; and Sheudzhen,1991). Comparing varieties, TNAU Rice TRY 3 excelled than I.W.Ponni in terms of recording productive tillers.

Observations made on yield attributing factors also revealed that under sodic condition seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages recorded the maximum values for panicle length (Fig.8), number of seeds panicle⁻¹, seed set per cent(Fig.9) and 100 seed weight. The values were 15.4, 9.1, 9.0 and 9.8 per cent higher than control, respectively. Under saline condition, 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages showed maximum values for above said characters with 11.2, 10.6, 9.8 and 8.5 per cent higher than control respectively. Similar findings was reported by Vijayalakshmi (2007) in rice.

Seed yield was significantly increased due to seed priming cum foliar spray. The seed yield was enhanced by 15.4 per cent over control in seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages under sodic condition and 14.0 per cent in seed priming with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm+ *Azophos* 1% + *Pseudomonas*

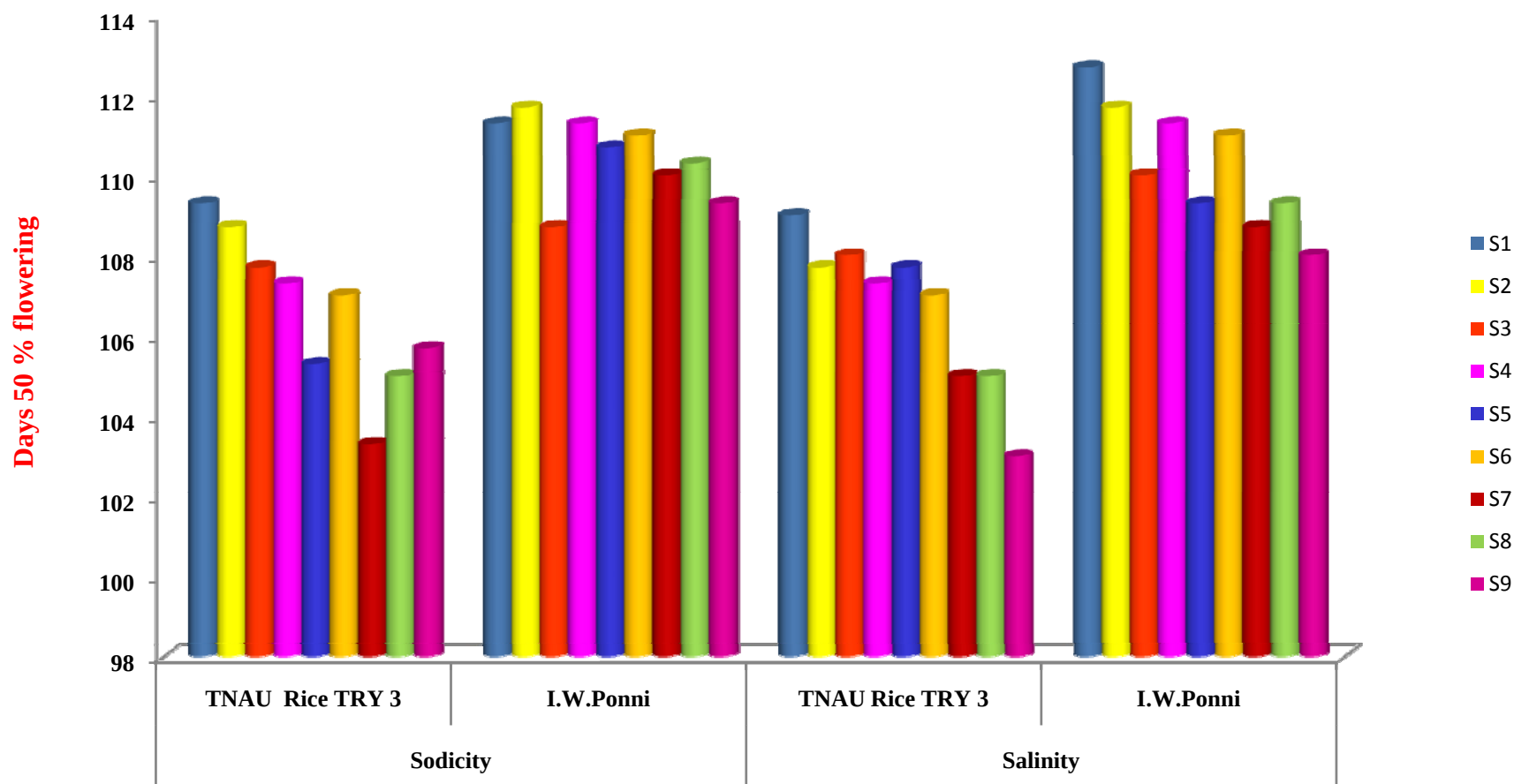


Plate.3 A General View of Field Experiment at ADAC & RI, Trichy



Plate.4 A General View of Field Experiment at KVK, Sikkal

Fig 6. Effect of seed priming and foliar spray on days to 50 per cent flowering in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions



fluorescens 1% along with 2 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages under saline soil condition. This might be due to the foliar application of higher concentration of the micronutrients at critical growth stage which increased the growth and yield parameters. This result is corroborating with the findings of Savitha -Tripathi *et al.* (1995) and Yong Fang *et al.* (2007). Comparing two varieties, TNAU Rice TRY 3 recorded higher yield of 5743 and 5660 kg ha⁻¹ than I.W.Ponni which yielded 4928 and 4789 kg ha⁻¹ under sodic and saline soil conditions respectively (Fig.10;Plate.3and4).

The positive effect of micro nutrients such as CaSO₄, ZnSO₄ and FeSO₄ attributed to the various metabolic activities of plant and higher production of auxin, an important growth promoter regulating the cell elongation and cell enlargement. This is in accordance with the findings of Ramakrishna Reddy *et al.*, 1984; Datta and Dhiman 2001 in rice. Increased activity of enzymes and hormones resulting in better growth and production of productive tillers (Sheudzhen, 1991). Supply of different micronutrients viz., Zn, Cu, Fe, Mn, and B through foliar spraying resulted in better absorption of nutrients and in turn helping in the photosynthetic activities and effective translocation to storage organs which has contributed for the increased yield. This is in accordance with the findings of Tandon (1995) and Datta and Dhiman (2001).

The positive effect of GA₃ might be mainly due to its activation to α -amylase for breakdown of starch stored in the seeds that will be used by the growing embryo during germination, enhancing IAA exertion, promoting cell elongation and division particularly mesocotyle length and internodes of rice seedlings, reducing Na and Cl uptake, increasing N, P and K uptake and enhanced chlorophyll content of rice seedling resulted from seeds soaked in GA₃ leading to high seedling vigour, reasonable plant growth at both early and later stages, improving source-sink relation resulted in high yield contributing components and grain yield under salt stress. (Prakash and Prathapasanen,1990; Singh,1996; Lee *et al.*, 1999; Chen *et al.*, 2005 and Bassiouni, 2008).

The positive effect of cowpea pulse sprout extract attributed to sprouting of pulses enhancing the conversion of complex sugars, proteins and fats to simpler forms, and sprouts are rich source of micro and macro nutrients viz., nitrogen, phosphorous, potassium, iron, zinc and calcium; total antioxidant activity and vitamins (Sangronis and Machado, 2005) which helps to enhance the yield in rice (Vijayalakshmi, 2009).

Fig 7. Effect of seed priming and foliar spray on productive tillers in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

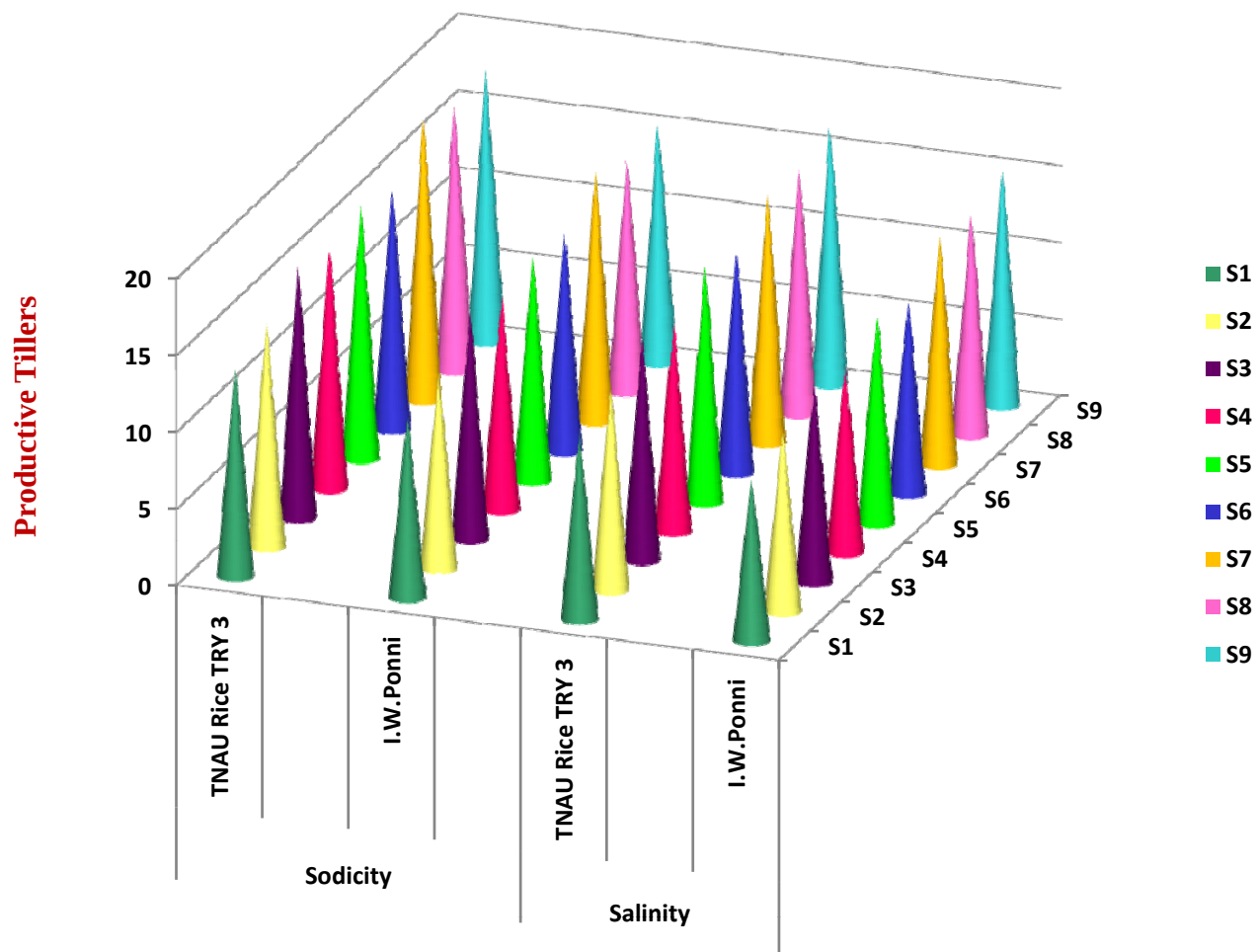


Fig 8. Effect of seed priming and foliar spray on panicle length (cm) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

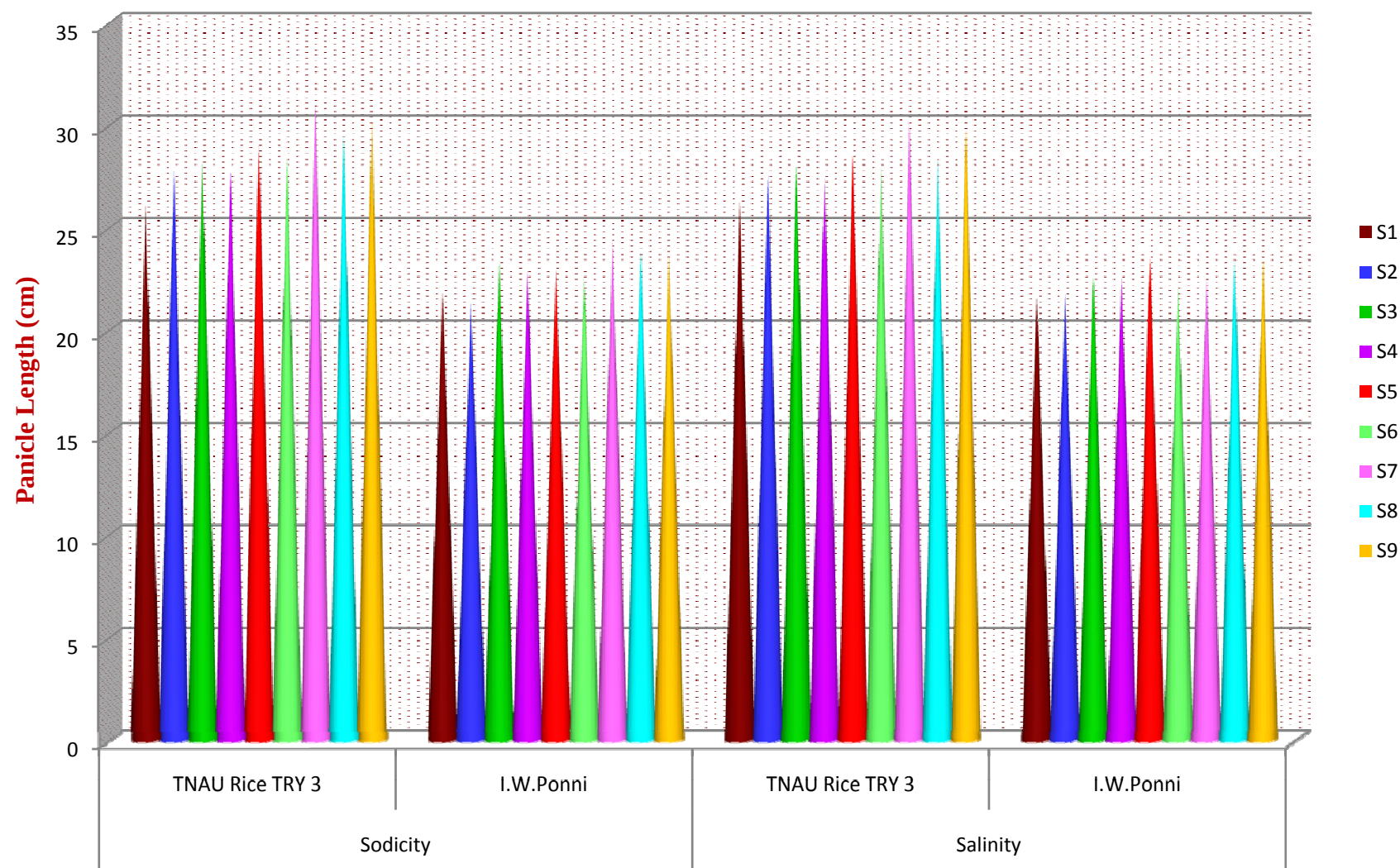


Fig 9. Effect of seed priming and foliar spray on seed set (per cent) in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity conditions

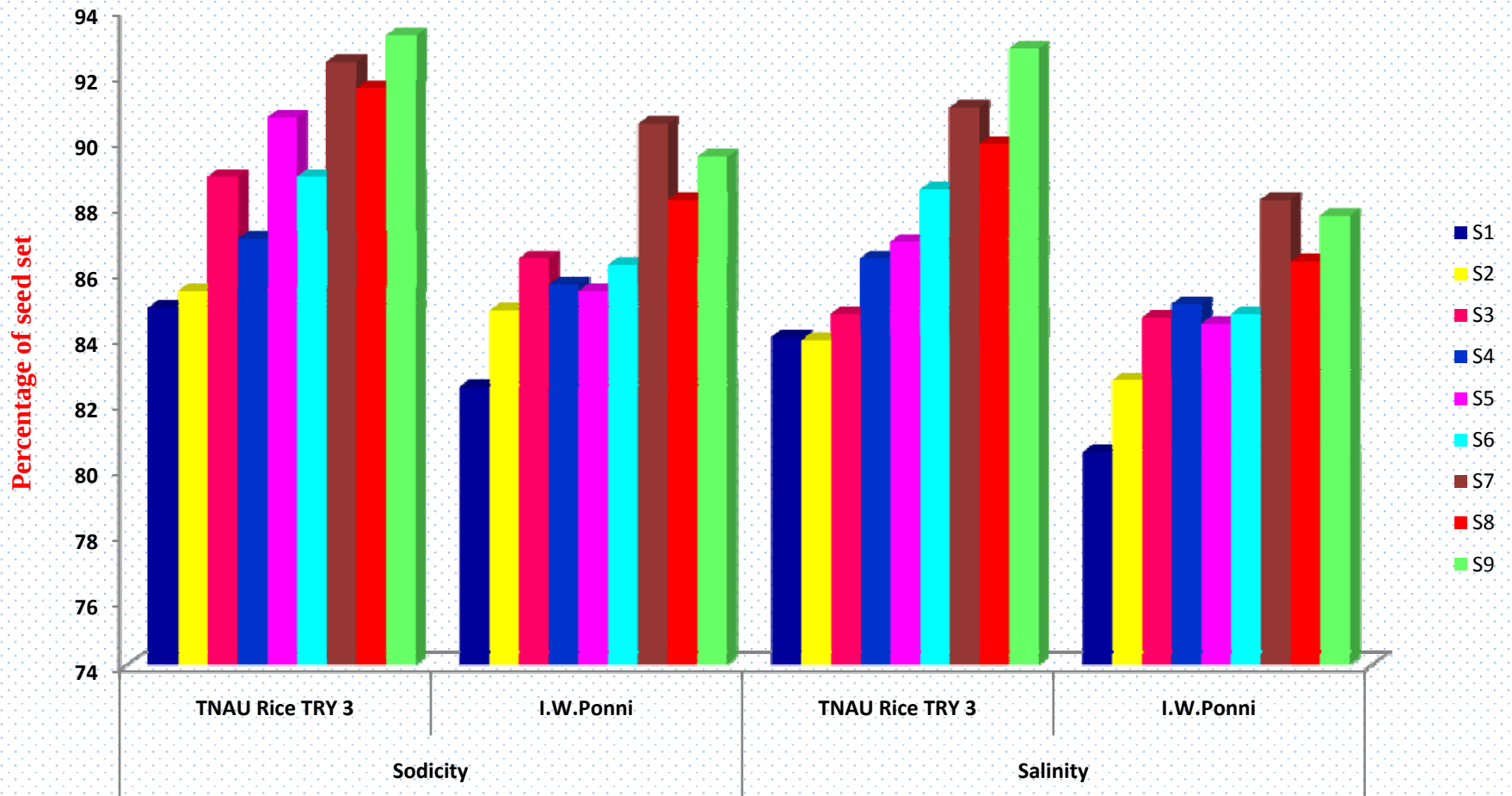
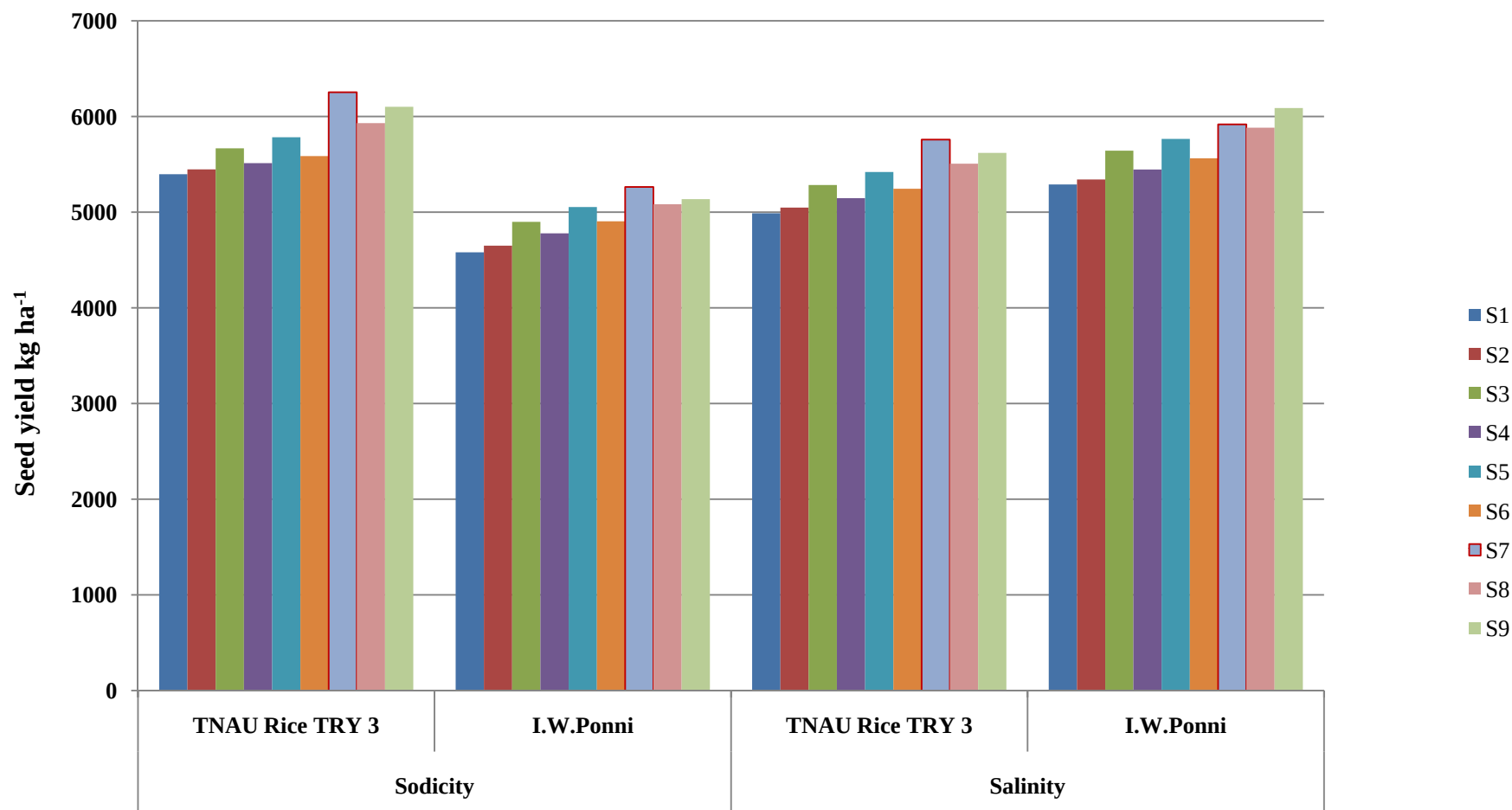


Fig 10. Effect of seed priming and foliar spray on Seed yield kg ha^{-1} in rice varieties TNAU Rice TRY 3 and I. W. Ponni under sodicity and salinity condition



The beneficial effect of *Pseudomonas fluorescens* and *Azophos* in rice exposed to salt stress could be attributed to synthesis of several plant growth substances, gibberellins like compounds and vitamins thereby increasing the root proliferation (Krishna *et al.*, 2008) which in turn contribute to vigorous crop growth.

5.4.2. Effect of priming cum foliar spray treatments on physiological and biochemical constituents

Salinity induced chlorophyll reduction and consequently the reduction in photosynthesis is well established by many researchers (Garg and Garg, 1985 in green gram; Prakash and Prathapasenan, 1989 in rice). Ashraf and Rasul (1988) attributed the reduction in chlorophyll content under salinity stress to suppression of enzymes responsible for synthesis of chlorophyll under higher salt concentrations. Increased chlorophyllase activity and interference of salt ions with *de novo* synthesis of structural component proteins of chloroplast are also known to influence the chlorophyll content under salinity stress (Rao and Rao, 1981; Reddy and Vora, 1986; Sudhakar *et al.*, 1991). Chloroplasts are the primary light absorbing pigments found in the leaves. Chlorophyll 'a' has twice the concentration of chlorophyll 'b' (Parker and Biggins, 1964). The disruption of the fine structure of the chloroplast possibly due to more accumulation of harmful ions or free radicles, instability of the pigment protein complex and enhanced chlorophyllase activity are attributed to reduction in chlorophyll content under saline conditions. The stability of chlorophyll 'b' content for salt stressed plants can be ranged as an index of tolerance, which might lead to increase in carbon assimilation rate and eventually show higher yield (Ganeshan and Jayabalan, 2005). Singh and Jam (1982) reported in chickpea that the chlorophyll 'b' was increased during the salt stress. Hence, the salt tolerant plants would have more chlorophyll 'b' compared to salt susceptible genotypes. Similar type of results was also reported by Hussein *et al.* (2007) in salt tolerant cowpea.

In the present study, TNAU Rice TRY 3 variety registered higher total chlorophyll content than I.W.Ponni in both soil conditions. Under sodicity condition also a remarkable increase in chlorophyll a, b and total chlorophyll content was observed due to seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm+ *Azophos* 1 % along with foliar spray of 0.5 % ZnSO_4 in both the varieties at panicle initiation stage. This treatment resulted in an increase of 36 per cent and 25 per cent in total chlorophyll content of TNAU Rice TRY 3 and

I.W.Ponni, respectively over control. Whereas, in salinity condition, seed priming with 1% mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1% along with foliar spray of 2 % cowpea pulse sprout extract recorded 57 and 34 per cent increase in total chlorophyll content over control in both the varieties, respectively.. This increase in chlorophyll content might be attributed to increase chlorophyll synthesis by PGR present in the priming treatments, promotes cell division and cell expansion in expanding leaves. (Steddart, 1965).

Chlorophyll stability index (CSI) is an important parameter for screening of plant cultivars for abiotic stresses including salinity (Michael Gomez and Rangasamy, 2002). Significant variation was recorded between two varieties as TNAU Rice TRY 3 recorded higher value for CSI indicating its tolerance for salt stress. Under sodicity condition, seed priming with 1 % mixture of CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % along with foliar spray of 0.5 % ZnSO₄ recorded 72.4 and 58.2 per cent higher CSI over control, respectively in both the varieties at panicle initiation stage.

High ion concentrations can injure plant cells by different mechanisms viz., specific ion toxicity, ionic strength, ion imbalance or deficiency and osmotic imbalance. Sodium has specific ion effect, which differs from their osmotic effect. On the other hand, ion concentration can increase to such an extent that protein complexes fall apart due to interference with normal electrostatic interaction. The K content, which acts as an osmoticum under situation of unfavourable environment, invariably keeps the plant to withhold more water even in the presence of higher osmotic potential in the external salt solution. In other words, K aided in the maintenance of osmotic balance. Presence of high K content in the tolerant genotypes of the study resulted in higher yielding ability even under salt environment. This is in accordance with Joshi and Naik (1980).

The tissue concentration of sodium and potassium and the ratio Na/K has been suggested as useful parameters for screening genotypes of any crop under salt stress condition (Boetella *et al.*, 1997; Singh and Singh, 1999). Increase in K content acts as an osmoticum, which prevents Na⁺ influx into the root and its further translocation to the more sensitive shoots (Jacoby, 1999). The high Na/K ratio leads to metabolic disorders such as reduction in protein synthesis and enzyme activities (Brady *et al.*, 1984). In general, variety or genotype which shows high affinity

for K^+ uptake and translocation transporters would be poor in Na^+ uptake. In other words, the lower the Na^+ uptake, the higher the K^+ uptake when rice plants are under salt stress (Munns *et al.*, 2002 and Munns and James, 2003). This could probably explain the negative association between the Na^+/K^+ ratio with salinity tolerance, because in salt sensitive genotypes, more sodium is absorbed at the cost of potassium.

In the present study, I.W.Ponni, being a sensitive variety accumulated significantly higher Na^+/K^+ ratio in the leaves than TNAU Rice TRY 3. However, this undesirable nature of sensitivity to salinity could be overcome by the treatments with seed priming. Under sodicity condition, seed priming with 1 % mixture of $CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + Azophos 1 % along with foliar spray of 0.5 % $ZnSO_4$ in both the varieties at panicle initiation stage showed beneficial effect on decreasing Na^+/K^+ ratio of the leaves with 29.0 per cent over the control. Whereas, in salinity condition seed priming with 1% mixture of $KCl + CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + Azophos 1% + *Pseudomonas fluorescens* 1% along with foliar spray of 2 % cowpea pulse sprout extract recorded 24 per cent decreased Na^+/K^+ ratio over control.

Salinity, by and large, depressed protein synthesis, accelerated their degradation and disturbed the soluble amino acid protein ratio in plants (Strogonov and Lapina, 1964; Nieman and Poulson, 1964; Rauser and Hanson, 1966; Strogonov *et al.*, 1970). Kahane and Poljakoff - Mayber (1968) showed that both uptake and incorporation of amino acids into protein were reduced by the presence of salt in pea roots. Breakdown of polysomes accompanied by an increased level of NRase was demonstrated during salt stress (Nir *et al.*, 1970; Marin and Vieira De Silva, 1972). Moderate salinity in some cases might increase total protein but innumerable reports revealed a decrease in protein and nucleic acid content in root, leaves and embryo axis of mungbean, chickpea, pea and cowpea under $NaCl$ and Na_2SO_4 salinity stress (Garg and Garg, 1980).

The present study also revealed a considerable decline in soluble protein content of the two rice varieties TNAU Rice TRY 3 and I.W.Ponni grown under sodicity as well as in salinity condition without receiving any priming treatments. However, the varieties which were imposed with priming treatments, responded differentially by showing enhanced level of soluble protein. Under sodicity condition, seeds primed with 1 % mixture of $CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20

ppm + *Azophos* along 1 % with 0.5 % foliar spray of ZnSO_4 at panicle initiation stage recorded 18.0 per cent higher soluble protein over control. Under salinity condition, seeds primed with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2 % cowpea pulse sprout extract foliar spray recorded 21.0 per cent increase over control (Fig.11). These results are confirmed by the finding of Rajababu *et al.* (2005) for sodicity and Jha and Singh (1997) for salinity. They reported that the soluble protein content of plants is a deciding factor of drymatter accumulation thereby increasing the yield and could be attributed to the efficiency of RuBpcase at stress level.

Proline accumulation is a universal response of plants to various stresses. Proline acts as an osmolyte and helps the plants to maintain tissue water potential under all kinds of stresses. Proline, as an osmoprotectant, is largely confined to the cytoplasm and is mostly absent from the vacuole (Mc Neil *et al.*, 1999). It plays a key role in the cytoplasm as a scavenger of free radicals as well as a mediator in osmotic adjustment and also increases the solubility of sparingly soluble proteins. (Schoberr and Tschesche, 1978; Caplan *et al.*, 1990; Saradhi *et al.*, 1995). Stewart and Lee (1974) advocated that proline may function as a source of solute for intercellular osmotic adjustment under saline conditions. Stewart (1978) suggested that proline may serve as a storage compound for reduced carbon and nitrogen during stress. Free proline accumulation was generally more in the most tolerant cultivars, suggesting its correlation with salinity tolerance of the plants (Bar Nun and Poljakoff - Mayber, 1979).

In the present study, it could be found that the proline accumulation was maximum at panicle initiation stage of TNAU Rice TRY 3 than I.W.Ponni under sodicity condition. The priming treatments 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % along with 0.5 % foliar spray of ZnSO_4 and 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2 % cowpea pulse sprout extract foliar spray) help to increasing the level of proline accumulation at panicle initiation stage in both the stress conditions when compared to untreated control. The increase was 3.66 and 6.25 %, respectively for sodicity and salinity of both the varieties (Fig.12).

Comparing the two varieties, TNAU Rice TRY 3 exhibits the tolerant nature under salt stress. This finding could reveal the beneficial effect of PGRs in improving the tolerance of the crops through osmotic adjustment by means of proline accumulation as noticed in I.W.Ponni, a

Fig 11. Effect of seed priming and foliar spray on soluble protein activity mg g^{-1} in leaf at panicle initiation stage in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

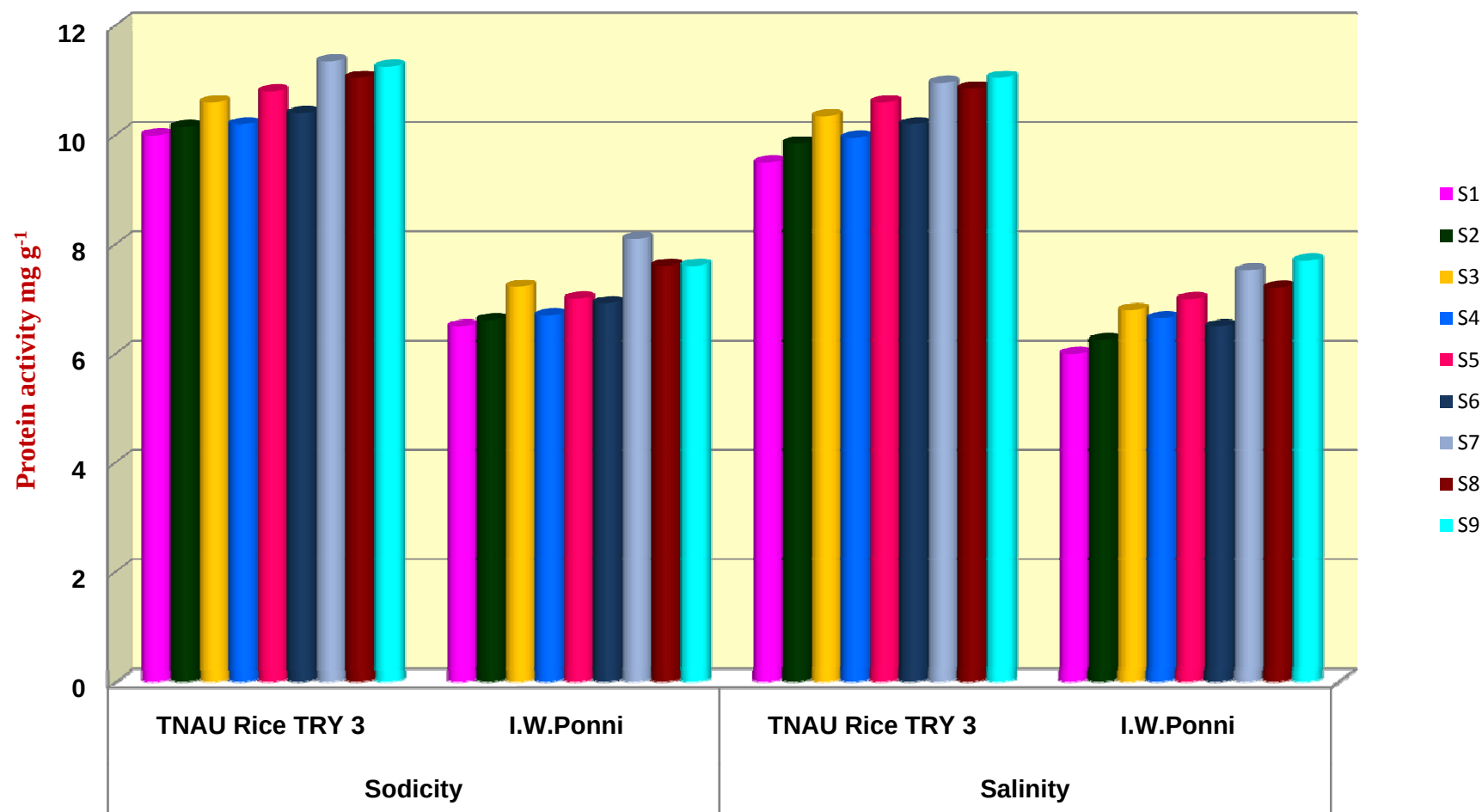
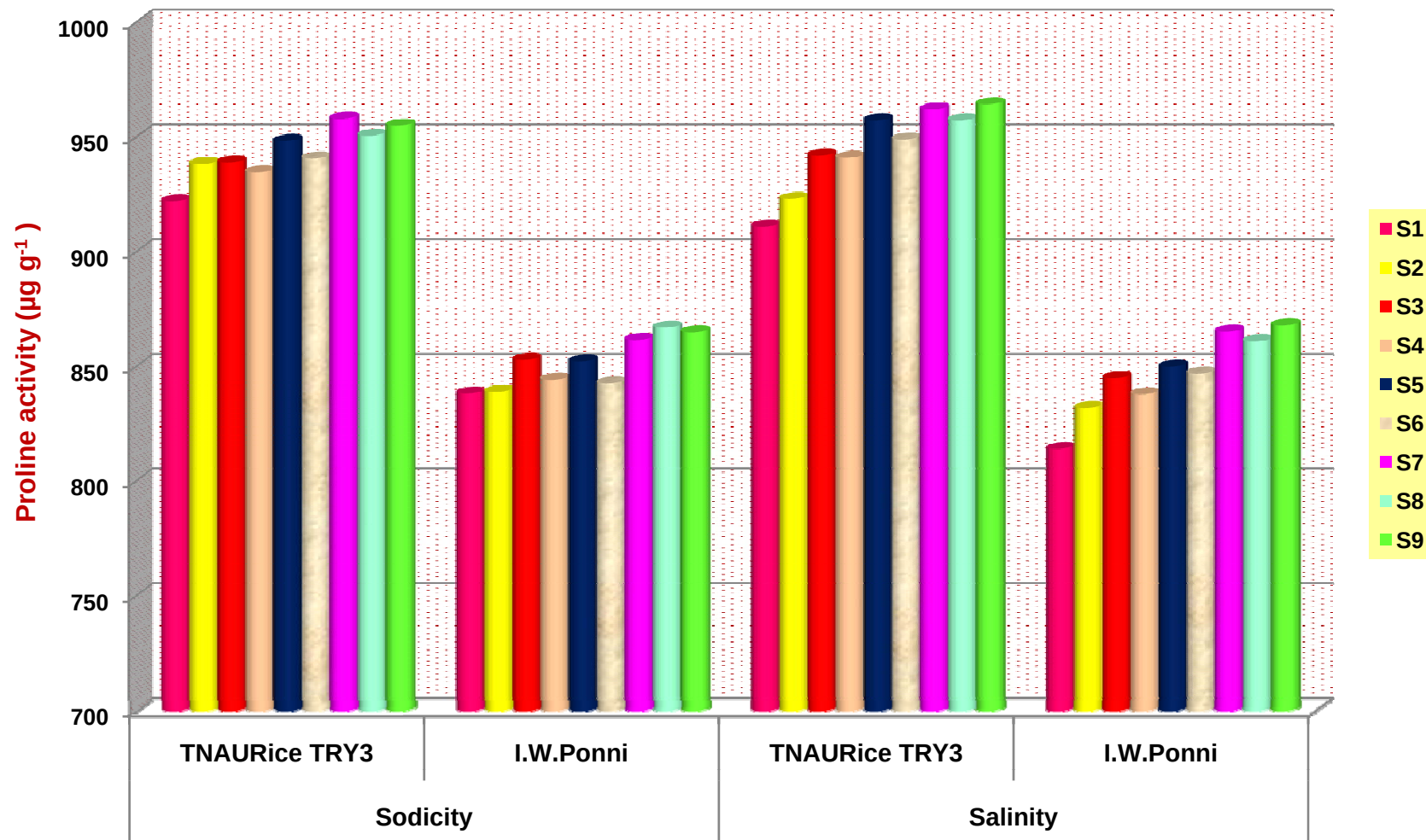


Fig 12. Effect of seed priming and foliar spray on proline activity ($\mu\text{g g}^{-1}$) in leaf at active tillering in leaf at active tillering stage in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions



susceptible variety to sodicity. These findings are supported by the results of Singh and Singh (1999) in chickpea. The maximum proline accumulation could be attributed to non-incorporation of free amino acid, proline into protein synthesis due to salt stress or the breakdown of the existing protein molecules into various constituent amino acids (Mukerjee, 1974).

In plants, nitrogen assimilation is regulated by the activation of the enzyme, nitrate reductase. This enzyme plays a constructive role in nitrogen utilization by the plants through nitrogen metabolism and which is the most affected enzyme by salinity. Plaut (1974) reported a significant decrease in the level of nitrate reductase in both *in vivo* and *in vitro* by the presence of sodium chloride in mutant solution. Similarly, Klyshev (1974) also recorded a suppression of nitrate reductase activity and the effect was significantly higher by sodium chloride than by sodium sulphate. The loading of nitrate into the root is also thought to be a highly sensitive step (Peuke *et al.*, 1996; Tischner, 2000). Salinity may strongly affect the overall nitrate assimilation process because nitrate is required to induce nitrate reductase, the key enzyme of nitrate assimilation process (Campbell, 1999). Nitrate reductase activity in leaves is largely dependent on nitrate flow from roots (Ferrario – Mery *et al.*, 1998; Foyer *et al.*, 1998) and is severely affected by NaCl salt stress (Rao and Gnanam, 1990; Abd - El Baki *et al.*, 2000; Silveira *et al.*, 2001).

As observed in the present study, sodicity stress reduced nitrate reductase activity in leaves of the two rice cultivars, with more adverse effect on I.W.Ponni. Petronia *et al.* (2005) correlated the lower enzyme activity with a decrease in nitrate concentration in salt stressed condition. The priming treatments, particularly PGRs play their beneficial role in improving the overall biochemical processes, which are generally inhibited by stress conditions. Under sodicity condition seeds primed with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1 % along with foliar spray of 0.5 % ZnSO_4 at panicle initiation stage recorded 43.0 per cent increase over the control. Whereas, in salinity condition, 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + Azophos 1% + *Pseudomonas fluorescens* 1% along with foliar spray of 2 % cowpea pulse sprout extract recorded 54.0 per cent increase over control (Fig.13). These results are in conformity with the finding of Rajababu *et al.* (2005) as they reported a considerable increase in soluble protein content in resistant variety than susceptible variety in rice and explained the higher yield of these genotypes under salt stress. The decreased NRase

Fig 13. Effect of seed priming and foliar spray on Nitrate reductase activity (μ moles $\text{NO}_2^- \text{g}^{-1} \text{h}^{-1}$) in leaf at panicle initiation stage in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

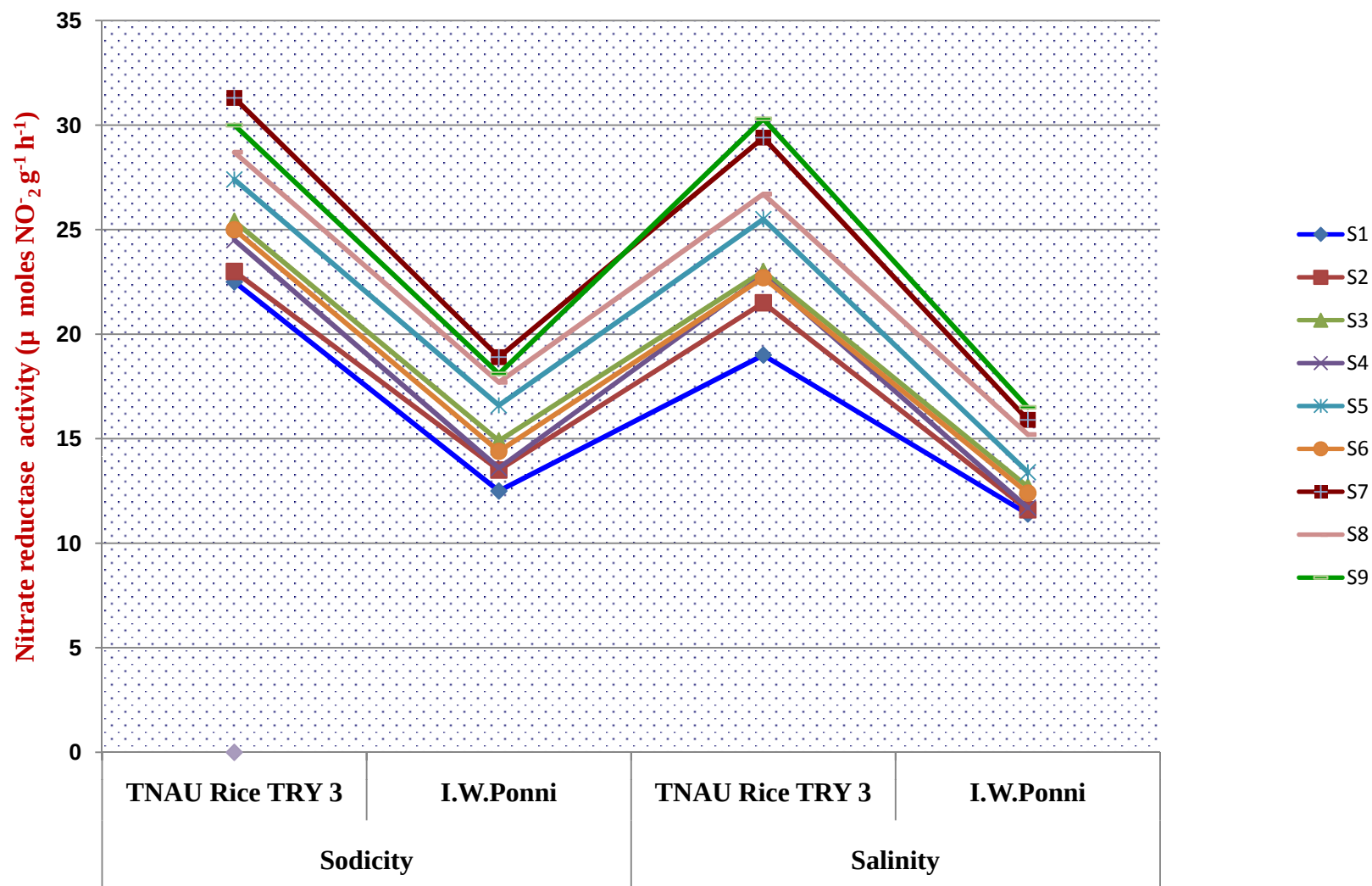


Fig 14. Effect of seed priming and foliar spray on catalase activity $\text{Min}^{-1}\text{g}^{-1}$ in leaf at active tillering stage in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions

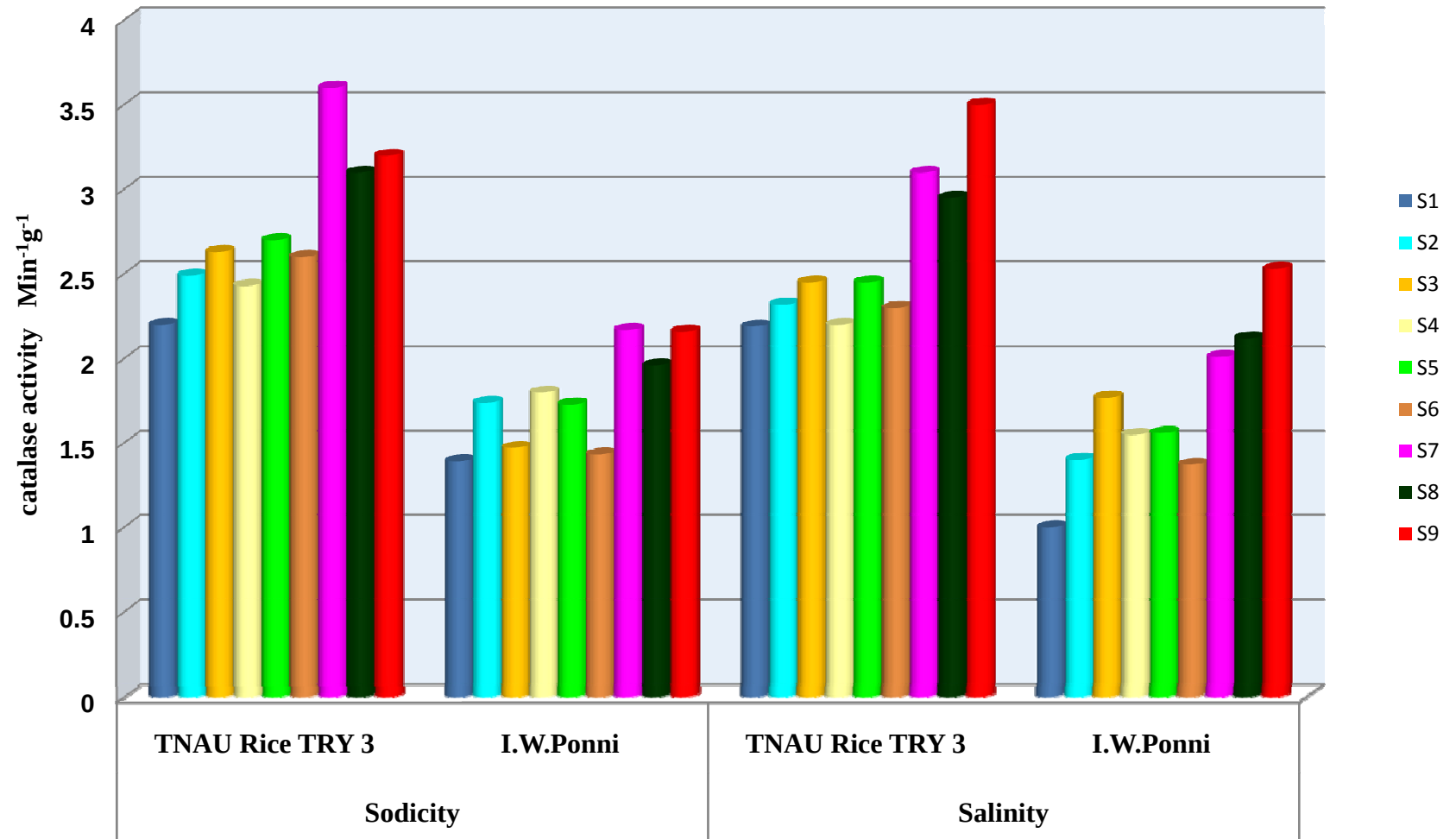
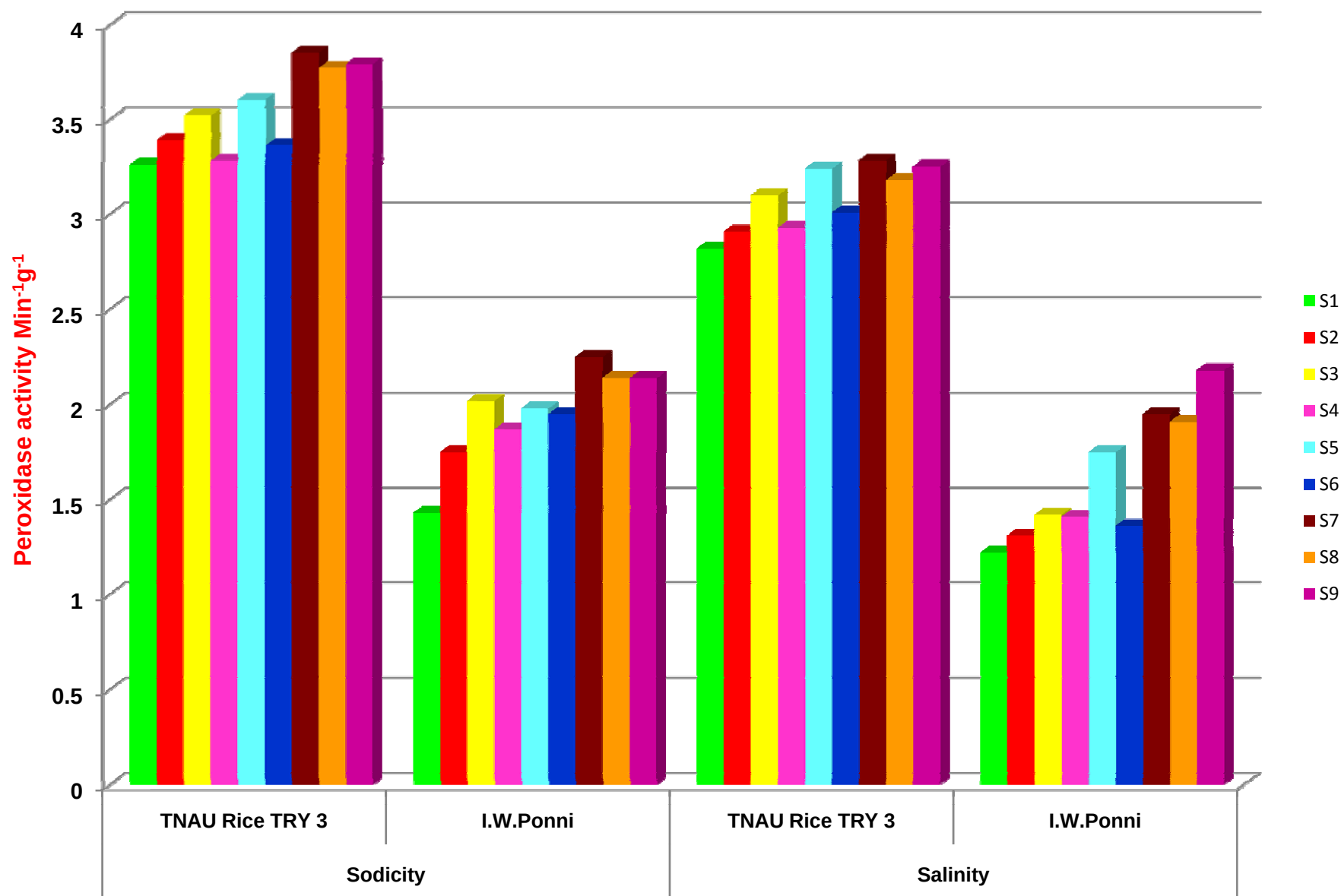


Fig 15. Effect of seed priming and foliar spray on peroxidase activity $\text{Min}^{-1}\text{g}^{-1}$ in leaf at active tillering stage in rice varieties TNAU Rice TRY 3 and I.W.Ponni under sodicity and salinity conditions



activity in salt sensitive rice cultivars is possibly due to the inhibition of enzyme induction under salinization (Katiyar and Dubey, 1992).

Soil salinity increases the catalase and peroxidase enzymes activity among tolerant and sensitive varieties of Cotton (Gossett *et al.*, 1994). The relationship between salinity and antioxidants were studied by Swamy and Reddy (1991) and they reported that O_2^- radical and H_2O_2 could play an important role in the mechanism of adaptation. Shim *et al.* (2003) reported that anti oxidant enzymes (Catalase and Peroxidase) activity is one of the determining factors of salt tolerance in rice. The salt-sensitive cultivars showed more severe decrease in catalase activity compared with the salt-tolerant cultivars. Catalase activity in rice leaf found to be reduced in response to salt stress (Tanaka *et al.*, 1999; Lee *et al.*, 2001; Khan and Panda, 2002 ; Demiral and Türkan, 2004).

Similar findings were observed in the present study, as the priming of seeds with 1 % mixture of $CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + *Azophos* 1 % along with foliar spray of 0.5 % $ZnSO_4$ at panicle initiation stage recorded 41 and 37 per cent increase over control for catalase and peroxidase' respectively under sodicity condition. Whereas, in salinity condition 1% mixture of $KCl + CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with foliar spray of 2 % cowpea pulse sprout extract recorded an increase of 47 per cent catalase and 30.4 per cent in peroxidase activity over control (Fig.14 and 15). This could be attributed that catalase and peroxidase are well known free radical scavengers and they can effectively quench the Reactive Oxygen Species produced during stress conditions as well as in the biosynthesis of cell wall materials including lignifications and suberization which leads to cell wall stiffening and restricted cell growth (Kanlaya Kong– nger *et al.*, 2012). The positive effect observed on productivity of treated seeds had an impact on physiological and biochemical constituents as observed through chlorophyll stability index, sodium potassium content, soluble protein and proline content and catalase activity against control.

Hence, the present study revealed that the ill-effects of sodicity and salinity stress could be mitigated to considerable extent by advocating seed priming with 1 % mixture of $CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + *Azophos* 1 % along with 0.5 % foliar spray of $ZnSO_4$ at active tillering and panicle initiation stages under sodic condition and seed priming with 1% mixture of $KCl + CaSO_4 + ZnSO_4 + FeSO_4 + GA_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1%

along with 2 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages under saline soil condition in rice. The rice variety TNAU Rice TRY 3 performed better than I.W.Ponni in both sodic and saline stress conditions.

Summary

CHAPTER VI

SUMMARY

Priming has been developed and used extensively to improve seed germination and seedling vigour in a wide range of crop species and it was identified as an integrated common seed treatment to reduce the time between seed sowing and seedling emergence and the synchronization of emergence. Studies were carried out with the seeds of TNAU Rice TRY 3 and I.W.Ponni to study the effect of seed priming on germination, growth and yield of rice under sodic and saline stress environments. The findings of the studies are summarized and concluded.

The rapid, uniform and early germination are a prerequisite for good establishment and survival of the seedlings in the field condition for any crop species especially under stress conditions. Keeping this in view an in vitro study was conducted to standardize a suitable seed priming treatment for rice. The seeds of TNAU Rice TRY 3 and I.W.Ponni were primed with CaCl_2 , CaSO_4 , ZnSO_4 , FeSO_4 , *Pseudomonas fluorescens*, *Azophos* and Pungam leaf extract at 0.5 and 1.0 % each ; GA_3 and IBA at both 10 and 20 ppm concentrations for 12 and 18h soaking durations. The seeds were also soaked in water for above durations and the nonprimed seed formed the control.

In the present investigation, seed priming with CaSO_4 1.0% , ZnSO_4 1.0%, FeSO_4 1.0%, GA_3 20 ppm, *Pseudomonas fluorescens* 1.0%, *Azophos* 1.0%, for 18h improved the germination by 8 and 5, 9 and 7, 6 and 5, 11 and 6, 10 and 6 ,11 and 8 per cent over control in TNAU Rice TRY 3 and I.W.Ponni, respectively.

In addition to germination, seedling vigour is also important in deciding the field stands establishment and the productivity of the crops. In the present study, seeds primed with fore-said treatments also registered higher values for root length, seedling drymatter production and vigour. Seed priming with 1 % *Azophos* and 1 % ZnSO_4 for 18h showed 7.1 and 7.3 per cent in TNAU Rice TRY 3 and 7.1 and 5.0 per cent in I.W.Ponni increase in seedling root length over control, respectively. The above treatments also recorded 20.2, 15.3 and 19.0, 15.2 per cent increase in vigour index over control in the above varieties, respectively.

From the standardization study, it is summarized that seed priming with *Azophos* 1.0%, ZnSO_4 1.0%, GA_3 20 ppm, *Pseudomonas fluorescens* 1.0%, CaSO_4 1.0% and FeSO_4 1.0% for

18h are very effective for improving germination and vigour in rice TNAU Rice TRY 3 and I.W.Ponni.

The best performing treatments from the previous experiment were further evaluated in combination by imposing sodicity levels of 25 and 50 mM and salinity stress levels of 50, 100 and 150 mM along with control. In general, it could be observed that decreasing trend in seed quality parameters were observed when the stress levels were increased. The performance of the priming treatments varied with stress levels. Regarding sodicity, 50 mM stress level had an adverse effect on seed germination showing 32 and 36 mean per cent reduction over control in both TNAU Rice TRY 3 and I.W.Ponni varieties, respectively. The same trend was also observed in other seedling quality parameters viz., root length (60 and 65 %), shoot length (66 and 76%), drymatter production (52 and 58 %) and vigour index (74 and 81 %).

In the present investigation, seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % recorded 20 and 23; 15.3 and 14.5; 36 and 44; 37 and 27 and 46 and 47.2 per cent mean increase over control, respectively for seed germination, root length, shoot length, drymatter production and vigour index of TNAU Rice TRY 3 and I.W.Ponni.

The same trend was also observed under salinity stress condition. At higher salinity level (150 mM) the reduction in germination from (94 to 66 % and 92 to 62 % ; in root length from 20 to 8.8 cm and 19.1 to 7.4cm ; in shoot length from 14.3 to 7.4 cm and 14.1 to 6.6 cm were observed in both varieties, respectively. Whereas, at 100mM level the mean values recorded for germination and seedling vigour were 80 and 78; 1891 and 1739 in both the varieties, respectively, which shows that upto this level the germination and seedling vigour of the both the varieties were not much affected. The mean increase in germination from 75 to 85 % and 73 to 85 % ; shoot length from 10.0 to 12.3 cm and 9.5 to 11.7 cm and drymatter production from 0.088 to 0.116 and 0.064 to 0.083 g seedlings⁻¹⁰ was recorded in seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % in both varieties , respectively.

In the present investigation, it is concluded that the seed priming with 1 % mixture of KCl+ CaSO₄+ ZnSO₄+ FeSO₄ +GA₃ 20 ppm + Azophos 1.0% +*Pseudomonas fluorescens* 1%

found to be performed better in terms of recording higher germination and seedling vigour under salt stress conditions as compared to other treatment combinations effected.

Since the results of above experiment revealed the severe impact on germination and seedling growth at 25mM sodicity as well as at 150mM salinity among various levels of sodicity (0, 25 and 50mM) and salinity (50,100 and 150mM) tested. Hence, the stress levels were further refined and fine tuned as (0, 14, 16 and 18 mM of sodicity and 125, 150 and 175mM of salinity) for evaluating the performance of seed priming treatments on alleviating the effect of stresses. The best performing treatment namely 1 % mixture of KCl+ CaSO₄+ ZnSO₄+ FeSO₄ +GA₃ 20 ppm + Azophos 1.0% +*Pseudomonas fluorescens* 1% along with other treatments viz., 1 % mixture of CaSO₄+ZnSO₄+FeSO₄, 1% mixture of CaSO₄+ ZnSO₄+ FeSO₄+ GA₃ 20ppm +Azophos 1% and 1% mixture of KCl + CaSO₄+ ZnSO₄+ FeSO₄ + GA₃ 20 ppm + Azophos 1% which were the next best treatments in terms of registering higher germination and seedling vigour from the previous experiment were included in this experiment for further study.

In the present investigation, at sodicity level of 18 mM it is observed that the mean values recorded for germination, root and shoot length by TNAU Rice TRY 3 and I.W.Ponni were 81 and 75 %, 19.4 and 18.2 cm ; 13.3 and 12.9 cm, respectively. Seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % registered the maximum values. The per cent increase was (10.0 and 10.2), (10.6 and 8.9), (20.2 and 12.3) and (24.0 and 25.0) for seed germination, root length, drymatter production and vigour index over control for TNAU Rice TRY 3 and I.W.Ponni, respectively. Similar trend was also observed in stress tolerance index.

Under salinity level of 175 mM concentration, all seed quality parameters were reduced. The mean reduction per cent over control were 42.0 and 48.0 for seed germination; 60 and 68 for shoot length; 69 and 73 for root length and 80 and 85 for vigour index in both varieties. Regarding seed priming, seeds primed with 1 % mixture of KCl + CaSO₄ + ZnSO₄ + FeSO₄ + GA₃ 20 ppm + Azophos 1 % + *Pseudomonas fluorescens* 1 % showed increasing trend for all seed physiological parameters. The per cent increase was 18 and 19 for germination; 31 and 30 for shoot length and 38 and 44 for vigour index over control in both varieties, respectively. Similar trend was also observed in stress tolerance index.

The results of the present dissertation revealed that the seed germination and seedling growth were not affected upto 18 mM sodicity level and 100 mM salinity level in the both the varieties and beyond which reduction in seed quality parameters was much pronounced. From the present experiment, the following treatments viz., seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4$, seed priming with 1% mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20ppm + *Azophos* 1%, seed priming with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20ppm + *Azophos* 1% and seed priming with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20ppm + *Azophos* 1.0% + *Pseudomonas fluorescens* 1% were forwarded to field experiment to study the effect of seed priming along with foliar spray of FeSO_4 , ZnSO_4 , DAP and cowpea pulse sprout extract in alleviating salt stress and to enhance the seed set and yield.

The priming cum foliar spray treatment advanced early days to first and 50 per cent flowering by 1-3 days in seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages for sodicity and 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2.0 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages for salinity.

The priming cum foliar spray treatment influenced the total and productive tillers. Seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages showed higher values (19.2 and 17.2) for sodicity and 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2.0 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages showed maximum values (18.2 and 15.9) in salinity than other treatment as well as untreated control

Observations made on yield attributing factors also revealed that under sodic condition, seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages recorded the maximum values for panicle length, number of seeds panicle⁻¹, seed set per cent and 100 seed weight. The values were 15.4, 9.1, 9.0 and 9.8 per cent higher than control, in both the varieties, respectively. Under saline condition, 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2.0 % foliar spray of cowpea

pulse sprout extract at active tillering and panicle initiation stages showed maximum values for above said characters with 11.2, 10.6, 9.8 and 8.5 per cent higher than control.

Seed yield was significantly increased due to seed priming cum foliar spray. The seed yield was enhanced by 15.4 per cent over control in seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages under sodic condition and 14.0 per cent in seed priming with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages under saline soil condition.

The physiological attributes such as total chlorophyll, chlorophyll stability index, sodium, potassium content and sodium-potassium ratio were also improved in the primed seed with above treatment under both stress conditions. Under sodicity condition, seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % along with foliar spray of 0.5 % ZnSO_4 recorded 72.4 and 58.2 per cent higher CSI over control, respectively in both the varieties . Whereas, in saline condition seed priming with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % + *Pseudomonas fluorescens* 1% along with 2 % foliar spray of cowpea pulse sprout extract recorded higher chlorophyll index of 59.2.

The same treatment under sodicity and salinity showed beneficial effect on decreasing Na^+/K^+ ratio of the leaves with 29.0 and 24.0 per cent over control in both the varieties, respectively. The biochemical attributes such as soluble protein content, proline content, nitrate reductase, catalase and peroxidase activity were also improved in the primed seed with above treatments under both stress conditions.

Under sodicity condition, seeds primed with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1 % along with 0.5 % foliar spray of ZnSO_4 recorded 18.0 per cent higher soluble protein over the control. Under salinity condition, seeds primed with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2 % cowpea pulse sprout extract foliar spray recorded 21.0 per cent increased over control. An increase of 3.66 and 6.25 % was recorded in proline content under sodicity and salinity stress condition. The above treatments also recorded 43.0 and 54.0 per cent increase in

nitrate reductase activity as well as 41 and 37 per cent and 47.0, 30.4 per cent increase in catalase and peroxidase.

It is concluded that the ill-effects of sodicity and salinity stress could be mitigated to considerable extent by advocating seed priming with 1 % mixture of $\text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% along with 0.5 % foliar spray of ZnSO_4 at active tillering and panicle initiation stages under sodic condition and seed priming with 1% mixture of $\text{KCl} + \text{CaSO}_4 + \text{ZnSO}_4 + \text{FeSO}_4 + \text{GA}_3$ 20 ppm + *Azophos* 1% + *Pseudomonas fluorescens* 1% along with 2 % foliar spray of cowpea pulse sprout extract at active tillering and panicle initiation stages under saline soil condition in rice. The rice variety TNAU Rice TRY 3 performed better than I.W.Ponni in both sodicity and saline stress conditions.

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* Originals not seen