

Original Research Article

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Assessment the Effect of Nitric Oxide on Yield Parameters of Wheat and Maize under Different Levels of Salt Stress

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ABSTRACT

Maize (*Zea mays*) is the 3rd most important cereal world in the world following wheat, rice. It is grown mainly in the semi- arid areas of the tropics and subtropics. Rice (*Oryza sativa*) is one of the main staples in the world and is cultivated mainly in Asia, Africa, and Latin America. The exogenous application of sodium nitroprusside (SNP), a NO donor, significantly alleviated the oxidative damage of salinity in seedlings of rice enhanced the seedlings growth and increased the dry weight of maize seedlings. In this paper we discuss about Plant Nitric Oxide, because now days the plant tolerate the various types of stresses like salt stress, drought stress, cold stress and oxidative stress also. Nitric oxide (NO), a free radical in living organisms, is considered a phytohormone and a key signalling molecule functioning in various physiological processes of plants. These physiological processes include germination, growth, senescence, and photosynthesis as well as response mechanisms to specific environmental stresses. Plants under salt stress conditions experience oxidative and nitrosative stress; the latter mainly elicited by regulation of NO production. Nitrosative stress describes the molecular or cellular damage promoted by imbalance in NO homeostasis and other reactive nitrogen species. Additionally, depending on its concentration and location in plant cells or tissues, NO might function as an antioxidant and scavenge some other reactive intermediates. Direct or indirect involvement of NO in response mechanisms under water stress, drought, salinity, heavy metal stress, high or low temperature extremities, and ultraviolet radiation has been reported. In this work, the recent findings and current knowledge on the function of NO in plants under salt stress conditions are reviewed briefly.

Keywords

Salt stress, Maize, Paddy, Sodium nitro prusside

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Introduction

Salt-affected soil is one of the serious abiotic stresses that cause reduced plant growth, development and productivity worldwide (Siringam *et al.*, 2011). Addition of salts to water lowers its osmotic potential, resulting in decreased availability of water to root cells.

Salt stress thus exposes the plant to secondary osmotic stress, which implies that all the physiological responses, which are invoked by drought stress, can also be observed in salt stress (Sairam *et al.*, 2002). Growth and yield reduction of crops is a serious issue in salinity prone areas of the world (Ashraf, 2009). Water-deficit and salt affected soil are two

major abiotic stresses which reduce crop productivity, especially that of rice, by more than 50% world-wide (Mahajan and Tutejan, 2005; Nishimura *et al.*, 2011). Salinity is one of the important abiotic stresses limiting rice productivity. The capacity to tolerate salinity is a key factor in plant productivity (Momayezi *et al.*, 2009). More than 800 million ha of land throughout the world are salt-affected (FAO, 2008). In many regions of the world and many areas of Iran, salinity stress may occur when crops are exposed to high levels of Na and Ca salts. Specific effects of salt stress on plant metabolism, especially on leaf senescence, have been related to the accumulation of toxic Na⁺ and Cl⁻ ions and to K⁺ and Ca²⁺ depletion (Al-Karaki, 2000). Salinity associated with excess NaCl adversely affects the growth and yield of plants by depressing the uptake of water and minerals and normal metabolism (Akhtar *et al.*, 2001; Akram *et al.*, 2001). On the other hand, in arid and semi-arid regions, limited water and hot dry climates frequently cause salinity problem that limit or prevent crop production. At low concentrations, salt suppresses plant growth and at higher concentration can cause death (Michael *et al.*, 2004). It has also been reported that under saline conditions, germination ability of seeds differ from one crop to another and even a significant variation is observed amongst the different varieties of the same crop (Asana and Kale, 1965, Maas and Hoffman, 1977). Maize, which belongs to the plants with C4 metabolism, is also classified as moderately sensitive to salinity (Mass and Hoffffman, 1977; Ouda *et al.*, 2008). For maize grown under salinity, reduction in growth characters and yield were observed (Ouda *et al.*, 2008). As suggested by Souza and Cardoso (2000), a marked increase of germination inhibition is expected at higher NaCl concentrations in the substrate. In general, salt stress is directly related with drought stress due to the capacity of the dissolved solutes to retain water.

However, two different mechanisms of salt tolerance enable seeds to germinate at high salt concentrations. Seeds can tolerate the effects of a lower water potential in the substrate (Allen *et al.*, 1983) or they may present specific tolerance to the inhibitory effect of NaCl (Rumbaugh *et al.*, 1993).

One of the controversies which has caused problems over many years is the way in which NO should be measured in plants. Gupta and Igamberdiev (2013) have contributed an opinion paper and propose that at least two different methods should be used to be sure that NO is truly being measured. This is sound advice and hopefully a strategy that will be adopted by many in the field in the future. D'Alessandro *et al.*, (2013) continue this theme of caution with a paper on the use of cPTIO. This compound is often employed as a scavenger to confirm that NO is being detected, but it is also used as a means to measure the presence of NO when coupled to electron paramagnetic resonance (EPR). These authors report a systematic investigation into the scavenging of cPTIO and discuss the reliability of such use and as an EPR probe (Baudouin and Hancock, 2013).

Nitric oxide, NO, is a small, water and lipid soluble gas that in recent years has emerged as a major signalling molecule of ancient origin and ubiquitous importance (Durner *et al.*, 1999). In 1992 it was named 'Molecule of the Year' by *Science* (Koshland, 1992) and since then there has been a huge number of studies on NO biology.

NO emission from plants and its effects on plant growth were described in the early 1970s (Anderson and Mansfield, 1979; Klepper, 1979). However, research on NO and plant signalling was mainly restricted to a few 'pioneers' such as Leshem (Leshem and Haramaty, 1996) and Lamattina (Laxalt *et al.*, 1997) until the two landmark publications in

1998 describing NO as a plant defence signal (Delledonne *et al.*, 1998; Durner *et al.*, 1998). Since then, studies on NO and plant biology have increased dramatically, with some of this work being reviewed relatively recently (Durner and Klessig, 1999; Beligni and Lamattina, 2001; Wendehenne *et al.*, 2001; Neill *et al.*, 2002b).

Nitric oxide (NO) is a gaseous signalling molecule which has attracted much attention because of its diverse functional roles in physiological processes and response mechanisms to various environmental stresses.

NO functions in cellular protection against toxicity of reactive oxygen species (ROS), defense response, and tolerance to abiotic stress (Lamattina *et al.*, 2003; Corpas *et al.*, 2007; Besson-Bard *et al.*, 2008a; Neill *et al.*, 2008).

In plant cells, endogenous NO can be produced by either L-arginine-dependent nitric oxide synthase (NOS)-like activity or nitrate reductase (NR) activity (Moreau *et al.*, 2008). There are also few other enzymatic and non-enzymatic processes which have been proposed to contribute to cellular NO content. NO and a family of related molecules are designated as reactive nitrogen species (RNS) which include S-nitrosothiols (SNOs), S-nitrosoglutathione (GSNO), peroxynitrite (ONOO⁻), dinitrogen trioxide (N₂O₃) and nitrogen dioxide (NO₂) (Corpas *et al.*, 2007).

Materials and Methods

Seeds each of Paddy (C₃) and Maize (C₄) were procured from SHIATS, Allahabad and University of Agriculture science, Karnataka.

Plant height (cm)

Plants were selected from each pot. The height of plants was measured from the ground levels

up to the tip of plant at 30 days intervals on 30,60 and 90 DAS. The average height was then calculated for each observation recorded.

Number of tillers or nodes and internodes /plants

From plants of each pot, number of tillers/ nodes and internodes were recorded at the maturity stage of the crop.

Harvest index

For cereals crops, harvest index (HI) is the ratio of harvested grain to total shoot dry matter, and this can be used as a measure of reproductive efficiency.

Harvest index of the plants from each pot was recorded by using the formula given below

$$\text{Harvest index} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

Summary

The main findings of this investigation are summarized and concluded below:

Plant height at 30 DAS

The percentage response of nitric Oxide was found highest on P-3546, genotype of Maize at 100 mM NaCl with 100 μM SNP and lower reduction at 100 μM SNP also found on Maize with different genotype Macca-3 and better response show on 100 μM SNP.

Plant height at 60 DAS

The percentage response of nitric oxide was found highest on Paddy genotype at 150 mM NaCl with 100 μM SNP and lower response show both Maize genotype Macca-3 and P-3546 at 100 μM SNP.

Fig.1 Effect of nitric oxide on plant height (cm) at 30 DAS of paddy and maize under different levels of salt stress

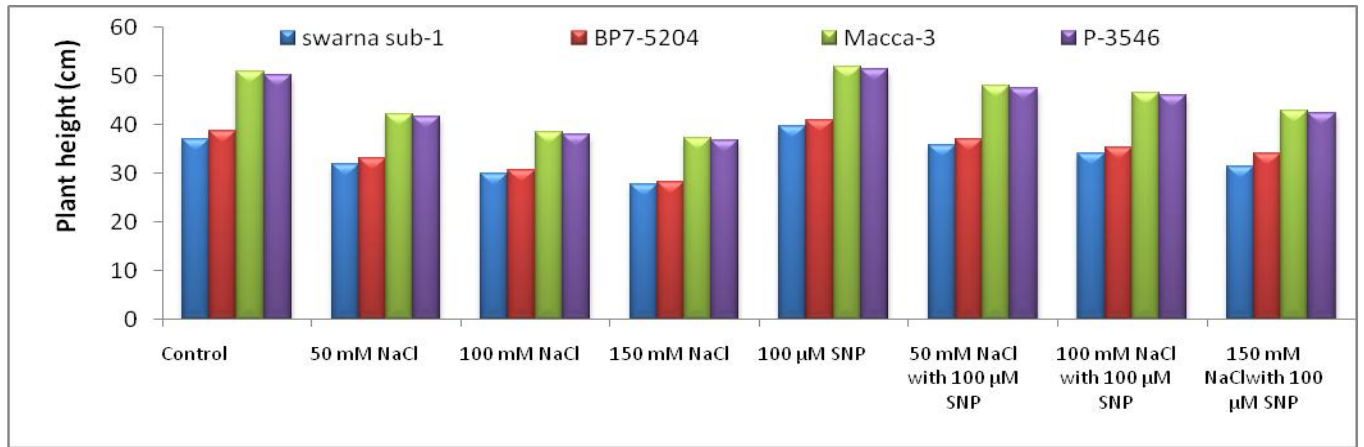


Fig.2 Effect of nitric oxide on plant height (cm) at 60 DAS of paddy and maize under different levels of salt stress

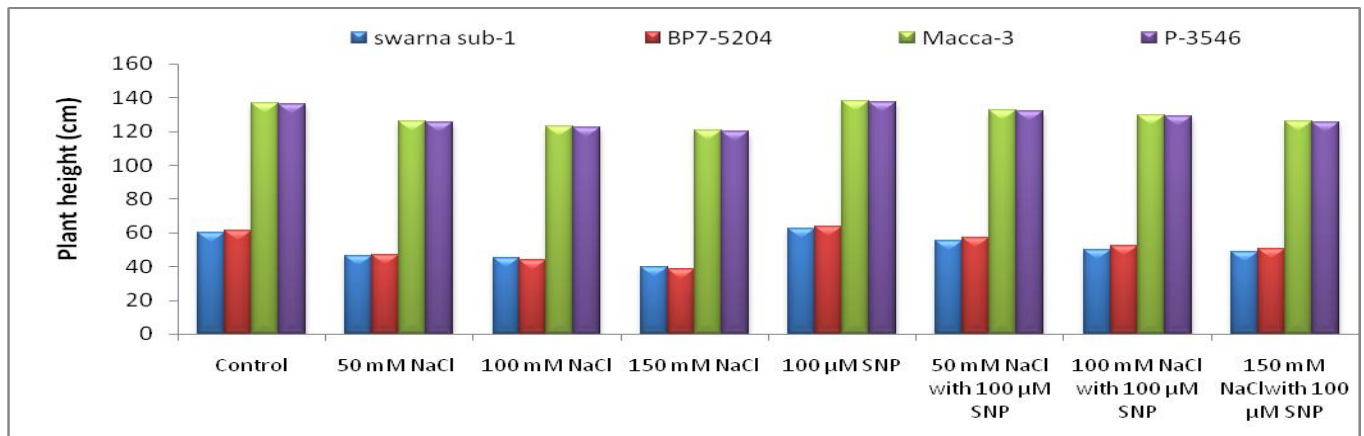


Fig.3 Effect of nitric oxide on plant height (cm) at 90 DAS of paddy and maize under different levels of salt stress

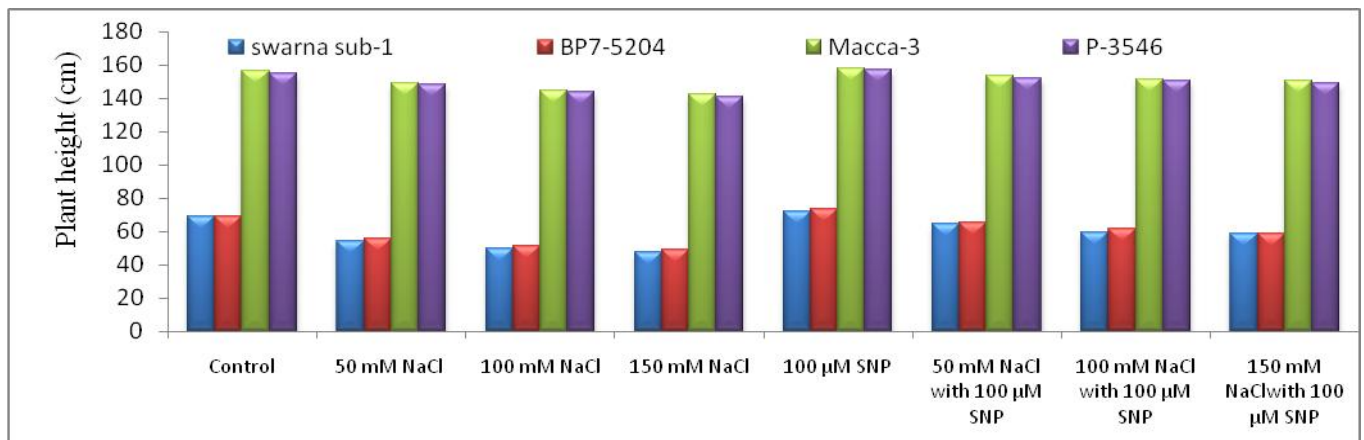


Fig.4 Effect of nitric oxide on No of tillers / nodes at the maturity stage of paddy and maize under different levels of salt Stress

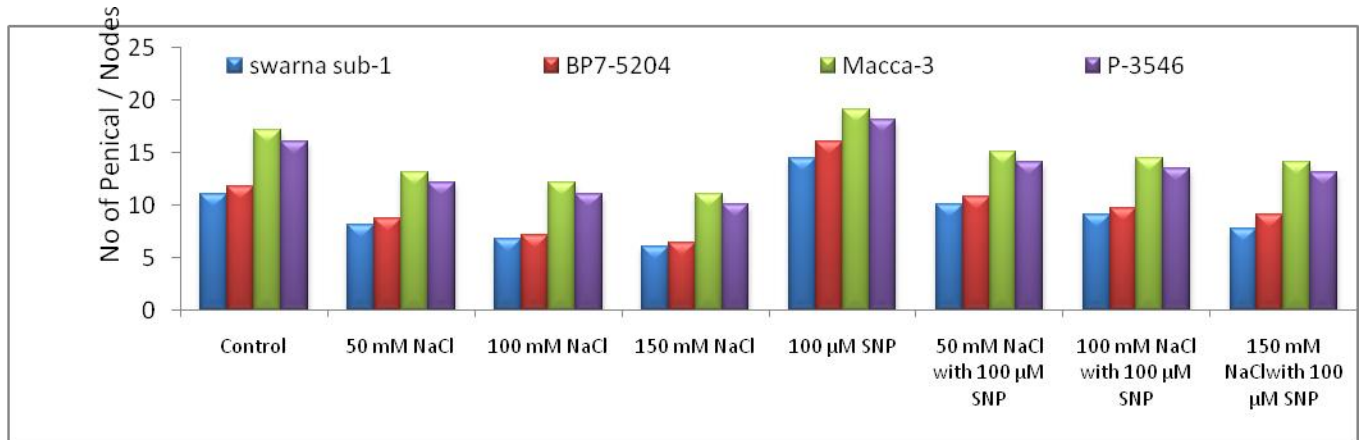
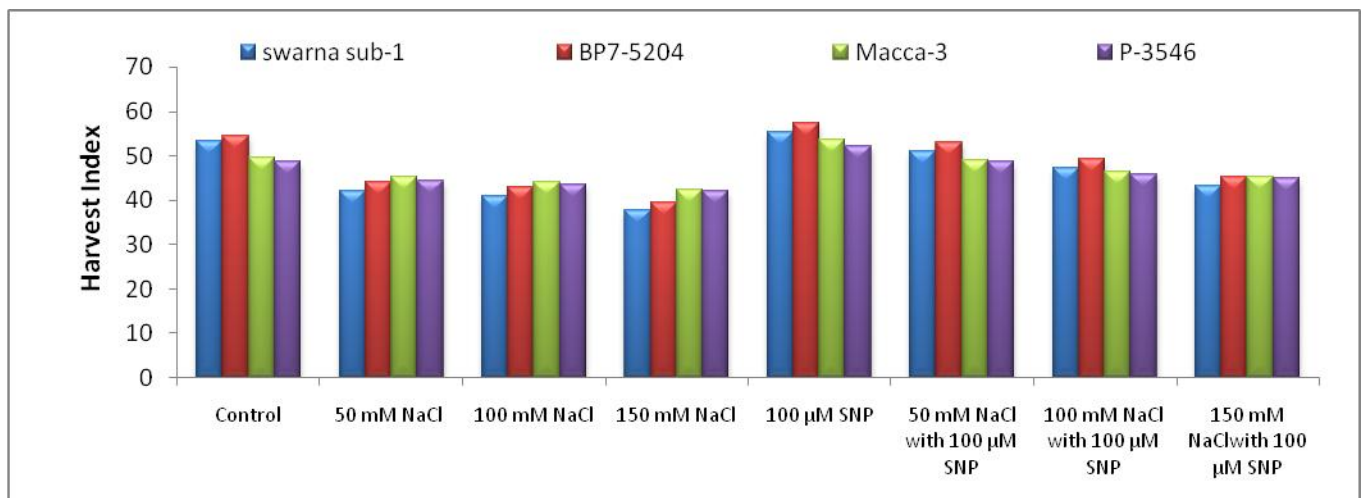


Fig.5 Effect of nitric oxide on harvest index of paddy and maize under different levels of salt stress



Plant height at 90 DAS

The percentage response of nitric oxide was found highest on Paddy genotype swarna sub-1 at 150 mM NaCl with 100 µM SNP and lower response found on both Maize genotype Macca-3 and P3546 at 100 µM SNP.

Harvest Index (%)

The percentage response of nitric oxide was found highest on Paddy genotype swarna sub-1 at 50 mM NaCl with 100 µM SNP, and

lower response show on Paddy genotype swarna sub-1 at 100 µM SNP.

It is well known that abiotic stresses (salinity, water deficit, extreme temperatures, toxic metals, air pollutants etc.) limit plant growth, productivity and yield attribute. Abiotic stress mainly salt stress is estimated to be the primary cause of worldwide crop loss. Several studies have been performed to understand tolerance mechanisms of plants in order to overcome the negative effects of these stresses on yield. There are also studies in

literature supporting the relevance of NO in plants under salt stress conditions. Application of exogenous NO in different levels of salt stress provides certain level of resistance against several types of stresses by activating different biochemical pathways. NO may help plants to survive stressful conditions through its function as a signalling molecule in the activation of antioxidative enzymes or its direct reaction with active oxygen, nitrogen and lipid radicals. Further genetic and proteomic analyses and additional physiological approaches will be required to understand the details of NO metabolism and function in plants. The acquired data will shed light on the sources of NO Functional Role of Nitric Oxide Under Abiotic Stress Conditions and factors affecting its synthesis under abiotic stress, and also will provide in depth information on different strategies which this multifaceted molecule adopts in facing the detrimental effects of abiotic stress.

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