Combined hydrogen peroxide and nitric oxide priming modulate salt stress tolerance in acclimated and non-acclimated oilseed rape (Brassica napus L.) plants

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Abstract
We examined the combined effects of hydrogen peroxide (H₂O₂) and nitric oxide (NO) on the responses of oilseed rape (Brassica napus L.) plants to salt stress under acclimated and non-acclimated conditions. The results of the shoot and root dry weight traits together with the measurement of malondialdehyde (MDA) indicated that salt acclimation with a low concentration of NaCl (50 mM) could not alleviate the inhibitory effect of high salinity (200 mM NaCl). Under acclimated conditions, seed priming with H₂O₂ or NO resulted in effective protection against salt stress, however, maximum amelioration of salt stress was found by the combined treatments of H₂O₂ + NO. Interestingly, in the salt-exposed non-acclimated plants, only seed priming with H₂O₂ + NO was effective in improving salt tolerance. Pretreatment with H₂O₂ + NO tended to limit Na translocation into photosynthetic organs to prevent salt damages. Additionally, a large increase in salicylic acid content was correlated with phenylalanine ammonia lyase activation and flavonoid biosynthesis was observed when oilseed rape plants exposed to salinity in the presence of H₂O₂+NO. Interestingly, in this study, endogenous NO content of H₂O₂–primed plants exhibited a significant increase under non-saline conditions, indicating that H₂O₂ influences NO accumulation. In addition, oilseed rape plants primed with H₂O₂ + NO exhibited lower MDA and H₂O₂ content, contributing to the better induction of antioxidative enzyme activities. Higher levels of antioxidant enzyme activities maintained the integrity of cell membranes, resulting in better plant growth under salt stress. Taken together, our results revealed that oilseed rape plants pretreated with H₂O₂ + NO exhibited more effective tolerance to salt stress than plants that were pretreated with H₂O₂ or NO alone.

Keywords: Combined priming; Flavonoid; Ion homeostasis; Nitric oxide; Oilseed rape; Salicylic acid; Salinity


Introduction
Salinity stress induces osmotic stress and ion toxicity in plants, which mainly results in oxidative damage due to the production of reactive oxygen species (ROS) (Munns and Tester 2008). Overproduction of ROS ultimately causes membrane damage, which decreases the photosynthetic capacity. Therefore, to protect cells against ROS stress, plants possess several defensive strategies including the stimulation of antioxidant enzymes (Rajabi et al. 2012; Farzane et al. 2020), the accumulation of compatible solutes (Geranpayeh et al. 2017), the alteration in the compartmentalization of ions and the adjustment of photosynthetic processes (Parida and Das 2005).

It has been reported that salt tolerance may be improved by the exposure of plants to the low concentration of salt and subsequent higher levels (Pandolfi et al. 2016). Furthermore, the priming of plants by chemical compounds has been proposed as an effective method in increasing tolerance to different abiotic stresses. Hydrogen sulphide (H₂S) (Li et al. 2013), proline (Islam et al. 2009),
hormones (Li et al. 2014), sodium nitroprusside (SNP), H$_2$O$_2$, melatonin (Mel) and polyamines (PAs) (Savvides et al. 2016) have been used as the priming agents against abiotic stresses. Some studies have suggested that the initial exposure to H$_2$O$_2$ and/or NO at an appropriate level can improve abiotic stress tolerance in plants (Habibi 2019). Several research reports indicated that exogenously applied H$_2$O$_2$ increased salt tolerance of wheat (Li et al. 2011), maize (Gondim et al. 2012, 2013), Suaeda fruticosa (Hameed et al. 2012) and Panax ginseng (Sathiyaraj et al. 2014) seedlings through stimulation of enzymatic and non-enzymatic antioxidants, and by increasing proline, polyamines and soluble sugars in maize seedlings under osmotic stress (Terzi et al. 2014). Additionally, exogenous application of NO increases salt tolerance by improving osmolyte accumulation, ionic homeostasis and antioxidative defense system (Hayat et al. 2012; Khan et al. 2012; Tanou et al. 2012; Egbich et al. 2014), and by increasing the contents of ascorbic acid (AsA), proline and total phenolic under salinity conditions (Ali et al. 2017).

Since the yield of oilseed rape (Brassica napus L.) markedly decreases by salinity, improving salt stress tolerance in this species is important to improve crop productivity for the growing world population. As mentioned above, it has been indicated that appropriate levels of exogenous H$_2$O$_2$ and NO, applied through seed priming, are beneficial to mitigate salt stress, however, few studies have tested the combined effect of H$_2$O$_2$ with NO on salt-exposed plants. In this study, we hypothesized that oilseed rape plants primed with H$_2$O$_2$ + NO will show more effective tolerance to salt stress than plants that are pretreated with H$_2$O$_2$ or NO alone. Furthermore, up to date, no study has focused on the roles of H$_2$O$_2$ + NO in the acclimated plants under salt stress conditions. Therefore, we studied the exogenous H$_2$O$_2$ and/or NO that can mitigate oxidative damage in the salt acclimated oilseed rape plants against subsequent salt stress.

**Materials and Methods**

**Plant materials and treatments**

Seeds of oilseed rape (Brassica napus L. cv. Gabriella) were sown on the cylindrical plastic pots. For the priming treatments, oilseed rape seeds were soaked in aerated solutions of SNP (as the NO donor) and H$_2$O$_2$ for 12 h. The concentrations of NO and H$_2$O$_2$ were chosen according to the effect of different NO (10, 100, 500, 1000, 1500 and 2000 µM SNP) and H$_2$O$_2$ (1, 10, 20, 30, 40, 50, 100 and 200 mM H$_2$O$_2$) concentrations on oilseed rape seed germination as well as on seedling growth in a preliminary study, which exhibited that 1000 µM NO and 20 mM H$_2$O$_2$ priming significantly promoted seed germination and seedling growth (data not shown). Four seeds were planted in each pot (filled with sandy loam soil; pH 7.2), however, the seedlings were thinned to one plant per pot after emergence. Pots had a diameter of 14 cm and a depth of 45 cm. To maintain the 90% field capacity, the seedlings were irrigated with saline distilled water every five days. Nine weeks after sowing, when the plants were about 12 cm tall, the pots were irrigated with 50 mM NaCl solution dissolved in tap water for seven days (ACC; salt acclimation). To impose salt stress, saline
solutions of 0.2-1.0 g NaCl were added to the pots based on Hajiboland et al. (2010). A regression equation was used to determine the amount of NaCl for obtaining different salinity levels. After the acclimation period, the plants were irrigated with 200 mM NaCl (salt stress). Acclimation treatments were as follows: control (non-acclimated, non-stressed), ST (non-acclimated, stressed) and ACC+ST (acclimated, stressed). To obtain similar sizes of acclimated and not-acclimated plants at the beginning of the salinity treatment, the level of salinity concentration for the initial acclimation experiment was selected based on Pandolfi et al. (2016). The EC for control pots was about 1.28 dS m⁻¹. Throughout the experiment, the day/night temperature was 25-30/19-21 °C, relative humidity was 60-65 % and the daily photon flux density was about 350-400 μmol m⁻² s⁻¹.

**Harvest**

Enzymes were measured on the fully expanded leaves after two weeks of treatment with 200 mM NaCl. Shoots and roots were separated, washed with distilled water, dried on filter paper and then the fresh weight was measured. To determine the dry weight of the hoots and roots they were dried at 70 °C for 48 h. The leaf samples were frozen immediately in liquid N₂ and stored for further assays.

**Determination of proline, soluble proteins, soluble sugars and starch**

Proline was determined according to the method of Bates et al. (1973). The total soluble proteins were measured as described by Bradford (1976) utilizing a commercial reagent (Sigma) and BSA (Merck) as the standard. Soluble sugars were measured based on Quentin et al. (2015). Starch was determined using the method of Magne et al. (2006).

**Assay of phenylalanine ammonia-lyase (PAL) activity and related metabolites**

Leaf samples were ground in 50 mM sodium phosphate buffer (pH 7.0) containing 2% (w/v) polyvinylpolypyrrolidon (PVPP), 18 mM β-mercaptoetanol, 0.1% (v/v) triton X-100 and 2 mM EDTA. The modified method of Zucker (1965) was utilized to determine the formation of cinnamic acid by spectrophotometry at 290 nm. Total flavonoid content and total phenolic content were measured using the methods of Meda et al. (2005) and Velioglu et al. (1998), respectively.

**Determination of Na and K content**

All samples were dried at 550 °C for 8 h and the dry powders were extracted with 0.5 M HCl and made up to volume by the double-distilled water. The resulting solution was diluted in distilled water, and the Na and K concentrations were measured by an Inductively-Coupled Plasma-Atomic Emission Spectrometry (ICP-AES, INTEGRA XL2, GBC; Australia).

**Assay of antioxidative enzymes and related metabolites**

The activities of superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) were measured according to methods described elsewhere (Habibi and Hajiboland 2012). Nitrate reductase (NR, EC 1.7.99.4) activity was
evaluated by measuring the amount of nitrite formed in the NR assay buffer according to the method of Robin (1979). NR activity was expressed as µmol nitrite g⁻¹ FW h⁻¹. MDA levels were quantified from a 1, 1, 3, 3-tetraethoxypropane (Sigma) standard curve. The hydrogen peroxide (H₂O₂) content in the leaves was evaluated according to the method of Velikova et al. (2000). The H₂O₂ content was given on a standard curve.

Quantification of NO concentration
Nitric oxide concentration was determined according to Wu et al. (2016). Absorbance was monitored at 540 nm. The NO concentration was calculated using a standard curve plotted with known concentrations of NaNO₂.

HPLC analysis
Extraction and determination of SA were done according to Kadioglu et al. (2011). The leaves (0.5 g) were extracted with a fixative solution containing methanol (3 ml) at room temperature. Subsequently, it was centrifuged at 12,000g for 15 min and then filtered. The calibration curve was performed using methanol to obtain a 1 mg/ml concentration, and the areas of peaks of the compound were quantified by the Agilent Chem Station software. The HPLC analysis was performed on Hichrom C₁₈ column (5µ, 250 mm) at 290.4 nm using Agilent 1100 series system. For the chromatographic assay separation, the total running time was 10 minutes at a flow rate of 1 ml/min.

Statistical analysis
The experiment was carried out as factorial using a completely randomized design with four independent replications. All data were subjected to one-way analysis of variance and significant differences between means were determined by the Tukey’s test (p ≤ 0.05) using the Sigma Stat (3.5) software.

Results
Under non-saline conditions, H₂O₂-primed and H₂O₂+NO-primed plants had significantly higher shoot dry weight than the non-primed plants (Figure 1A). The shoot dry weight was decreased by ACC+ST or the single ST treatment. Interestingly, priming seeds with H₂O₂, NO, or H₂O₂+NO alleviated the deleterious effects of ACC+ST or ST stress on the shoot growth. However, the shoot dry weight was enhanced only by H₂O₂+NO priming under control conditions.

The root dry weight was enhanced to a higher extent in response to H₂O₂ priming than other treatments (Figure 1B). The root dry weight of plants presented a significant decrease in response to ACC+ST or ST treatment, except for H₂O₂+NO-primed plants under ACC+ST. Under ST conditions, while shoot and root Na content was not affected by the exposure to H₂O₂ or NO alone, it was significantly decreased by the combination of H₂O₂ and NO. Shoot and root K
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Figure 1. Effects of salt stress on the shoot and root dry weight of oilseed rape plants primed with hydrogen peroxide and nitric oxide under acclimated (ACC+ST) and non-acclimated (ST) conditions. Bars indicated with the same letter are not significantly different (p≤ 0.05, Tukey’s test). Values are the mean ± SD (n= 4).

Contents were significantly decreased by ACC+ST and ST treatments, as compared to non-salt treatment (Figure 2). However, this decrease in K concentration was slightly prevented in ACC + ST treatment by H₂O₂+NO priming.

Results indicated that priming with H₂O₂ and NO increased soluble sugars while decreasing starch, and further increases were observed in soluble sugars concentrations in plants grown under salt stress (Table 1). Under non-saline conditions, no significant differences in proline content were mainly detected among plants grown with or without the priming agent. However, the highest values of proline contents were observed in salt-exposed acclimated or non-acclimated plants as compared to control.

Under non-saline conditions, phenolic and flavonoids contents and PAL activity were not affected by exposure to H₂O₂ and NO priming (Figure 3). However, phenolic and flavonoids contents were significantly increased by H₂O₂, NO and H₂O₂+NO priming under ACC+ST conditions. Under ST conditions, while the phenol and flavonoids contents, as well as the activity of PAL enzymes, were improved by the H₂O₂+NO priming, they were not affected by exposure to H₂O₂ or NO priming alone, compared with control.

The SOD activity was significantly increased by salt stress, and a further increase was observed under combined salt and priming treatments (Figure 4). A similar observation was recorded for
Figure 2. Effects of salt stress on the shoot and root Na and K content of oilseed rape plants primed with hydrogen peroxide and nitric oxide under acclimated (ACC+ST) and non-acclimated (ST) conditions. Bars indicated with the same letter are not significantly different (p≤ 0.05, Tukey’s test). Values are the mean ± SD (n= 4).

CAT and POD activity patterns in plants exposed to salt and combined priming. The NR activity in the non-primed salt-stressed plants remained unchanged but enhanced in response to NO or H$_2$O$_2$+NO priming under both saline and non-saline conditions.

Both MDA and H$_2$O$_2$ contents were significantly enhanced by the ACC+ST treatment and further increased by the ST treatment, whereas the priming with H$_2$O$_2$, NO, or H$_2$O$_2$+NO reduced the content of these oxidants under salt stress (Figure 5). Furthermore, under ST conditions, H$_2$O$_2$+NO-pretreated plants exhibited the most dramatic decreases in MDA and H$_2$O$_2$ contents than plants that were primed with H$_2$O$_2$ or NO alone.

The results indicated that both SA and NO contents were significantly improved by the priming with H$_2$O$_2$, NO, or H$_2$O$_2$+NO under non-saline conditions (Figure 6). Although higher leaf SA and NO content were detected in the salt-acclimated plants, the plants under the combination of salt and priming treatments had the highest SA content (Figure 6). Oilseed rape plants primed with H$_2$O$_2$+NO showed higher SA and NO content under both ST and ACC+ST conditions than plants that were primed with H$_2$O$_2$ or NO alone.
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Figure 3. Effects of salt stress on the total phenol and flavonoids content and the activity of phenylalanine ammonia-lyase (PAL) in oilseed rape plants primed with hydrogen peroxide and nitric oxide under acclimated (ACC+ST) and non-acclimated (ST) conditions. Bars indicated with the same letter are not significantly different (p≤ 0.05, Tukey’s test). Values are the mean ± SD (n= 4).

Discussion

Exogenous H$_2$O$_2$ and NO pretreatment improved growth of oilseed rape under salt stress

Oilseed rape is considered a moderately salt-sensitive crop, and its growth and yield are reduced at high salinity (Kholghi et al. 2018). In this study, shoot and root dry weight were significantly decreased in oilseed rape plants grown under ACC+ST and ST conditions. These observations were consistent with the findings of Kholghi et al. (2018), who showed that a high NaCl concentration (150 mM) significantly decreased the shoot and root dry weight of oilseed rape genotypes. However, the growth inhibition under ACC+ST was mitigated by H$_2$O$_2$ and NO priming. Similar results were obtained by Ali et al. (2017), who reported that the growth of wheat cultivars seedling was increased by SNP priming under salinity. Additionally, our results were consistent with the findings of Kilic and Kahraman (2016) for barley seedlings, who found that the growth of NaCl-treated plants was enhanced by seed priming with NO. In our study, oilseed rape plants pretreated with H$_2$O$_2$+NO exhibited better growth under ST conditions than plants that were pretreated with H$_2$O$_2$ or NO alone, suggesting that H$_2$O$_2$+NO application was more effective than H$_2$O$_2$ or NO alone for oilseed rape plants exposed to 200 mM NaCl stress.
Primed altered Na distribution in shoots under salt stress

Salt stress causes the accumulation of Na in the leaves and consequently, excessive Na-toxicity decreases plant productivity (Munns and Tester 2008; Habibi 2017; Jiang et al. 2017). This study showed that the shoot and root Na contents were increased under salt stress. However, seed priming with the combination of H$_2$O$_2$ and NO decreased Na in the shoots and roots while increasing K in the roots in oilseed rape plants grown under salt stress. The improvement of the K/Na ratio has also been reported in the salt-stressed wheat plants in response to H$_2$O$_2$ application (Ashfaqe et al. 2014) and salt-stressed sunflower seedlings in response to NO priming (David et al. 2010). Therefore, these results further demonstrated the beneficial effects of H$_2$O$_2$+NO application in the salt-stressed oilseed rape plants, which tended to limit Na translocation into photosynthetic organs to protect them from salt damages.

Exogenous H$_2$O$_2$ and NO pretreatment altered compatible solute content under NaCl stress

Soluble sugars contents increased significantly under salt stress and priming treatments. The
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Figure 5. Effects of salt stress on the concentration of hydrogen peroxide (H$_2$O$_2$) and malondialdehyde (MDA) in oilseed rape plants primed with hydrogen peroxide and nitric oxide under acclimated (ACC+ST) and non-acclimated (ST) conditions. Bars indicated with the same letter are not significantly different (p≤ 0.05, Tukey’s test). Values are the mean ± SD (n= 4).

Figure 6. Effects of salt stress on endogenous salicylic acid (SA) and nitric oxide (NO) contents of oilseed rape plants primed with hydrogen peroxide and nitric oxide under acclimated (ACC+ST) and non-acclimated (ST) conditions. Bars indicated with the same letter are not significantly different (p≤ 0.05, Tukey’s test). Values are the mean ± SD (n= 4).
improvement of soluble sugars and proline has also been reported in the salt-stressed maize seedlings in response to H$_2$O$_2$ application (Terzi et al. 2014). Many plants when exposed to salinity stress accumulate proline in large quantities as the ROS scavenger and osmotic regulator (Chun et al. 2018). In this study, we found that salinity at 200 mM led to high levels of proline, indicating that osmotic stress was occurred (Ma et al. 2016). Ellouzi et al. (2017) reported that H$_2$O$_2$ seed priming increased proline production in Cakile maritima and Eutrema salsugineum grown under salinity. Additionally, Ali et al. (2017) showed that priming of wheat seeds with SNP alleviated the adverse effect of salt stress by increasing the proline content. However, our results showed that the proline content was significantly increased by salt treatment, while it was not mainly affected by priming treatments in non-salt treated oilseed rape plants, suggesting that proline accumulation was not involved in H$_2$O$_2$- and NO-induced salt stress tolerance.

**Priming enhanced phenolic accumulations under NaCl stress**

Previously, several studies have indicated that phenolic compounds play important roles in radical scavenging as well as plant responses to salt stress (Oh et al. 2009; Mahmoudi et al. 2010; Blasco et al. 2013; Su et al. 2018). Similar to these studies, we found an increase in flavonoids content in salt-exposed non-acclimated plants. When salt-exposed acclimated oilseed rape plants were primed with H$_2$O$_2$, NO, or H$_2$O$_2$+NO, a further increase in phenolic and flavonoids contents as well as in PAL activity was observed. These results were in line with the findings of Ali et al. (2017) who showed a large increase in total phenolic content when wheat cultivars subjected to salinity in the presence of 0.1 mM SNP. Since carotenoids and flavonoids have been shown to modulate the ROS level and maintain photosynthetic capacity (Burchard et al. 2000; Xu and Rothstein 2018), we suppose that H$_2$O$_2$+NO mitigated the inhibitory effects of salt stress on the structure of the photosynthetic apparatus by increasing the total phenolic and flavonoids contents of oilseed rape leaves.

**Priming stimulated the antioxidant defense systems during salt stress**

It has been observed that antioxidant enzymes play important role in scavenging salt-induced plant ROS burst (Miller et al. 2010; Yang et al. 2014). In this study, the recorded elevations in antioxidant enzymes’ activities were mainly higher in the primed salt-stressed plants in comparison with non-primed salt-stressed plants. Moreover, priming with H$_2$O$_2$+NO greatly reduced MDA and H$_2$O$_2$ contents, contributing to the better induction of antioxidative enzymes activities in response to salt stress. The present results are in agreement with the previous investigations, which revealed that pretreatment with H$_2$O$_2$ alleviated salt-induced inhibitory effects in Suaeda fruticosa (Hameed et al. 2012), Panax ginseng (Sathiyaraj et al. 2014), Cakile maritima, Eutrema salsugineum (Ellouzi et al. 2017), wheat (Li et al. 2011) and maize (Gondim et al. 2012, 2013) via modulation of the
antioxidative mechanism involved in removing ROS. In addition, our results were consistent with the findings of Egibichi et al. (2014) for soybean and Ali et al. (2017) for wheat cultivars. They reported that NO alleviated salinity stress by enhancing the activities of antioxidant enzymes such as SOD, CAT and POD, which prevented oxidative damage. In the present study, the NR activity was significantly enhanced by single NO or by the combination of \( \text{H}_2\text{O}_2 \)+NO under both saline and non-saline conditions. There are evidences reporting that application of NO stimulates the activities of nitrogen metabolism enzymes such as NR and nitrite reductase in tomato plants under salt-stress conditions (Manai et al. 2014) and wheat seedlings under non-saline conditions (Balotf et al. 2018). Interestingly, oilseed rape plants primed with \( \text{H}_2\text{O}_2 \)+NO exhibited lower MDA and \( \text{H}_2\text{O}_2 \) content under ST conditions than plants that were primed with \( \text{H}_2\text{O}_2 \) or NO alone, showing that combined priming was more effective than \( \text{H}_2\text{O}_2 \) or NO alone in alleviating NaCl stress.

**Priming increased the leaf NO and SA content under salt stress**

In this study, the application of exogenous NO caused an increase in endogenous NO content compared with non-NO-treated plants. The increase in endogenous NO content following exogenous NO treatment was consistent with the findings of Balotf et al. (2018), which reported that exogenous NO caused an increase in leaf NO content in *Triticum aestivum* plants. Interestingly, in this study, endogenous NO content of \( \text{H}_2\text{O}_2 \)-primed plants exhibited a significant increase under non-saline conditions, indicating that \( \text{H}_2\text{O}_2 \) influences NO accumulation. However, future work will need to understand which one is upstream of the other. In this study, the recorded increases in SA levels were higher in the primed salt-stressed plants in comparison with non-primed salt-stressed plants. This increase in SA levels may provide more stress tolerance. Additionally, our results demonstrated that a large increase in SA content was correlated with PAL activation when oilseed rape plants exposed to salinity in the presence of \( \text{H}_2\text{O}_2 \)+NO. These observations were consistent with the findings of Li et al. (2019), which showed that SA increases the activity of PAL, which enhances flavonoid biosynthesis in tea leaves. Regarding relationships of SA and NO, Li et al. (2019) reported that SA acts upstream of NO to enhance flavonoid biosynthesis in tea plants under high CO\(_2\) conditions. However, the involvement of SA in inducing NO content and how it regulates phenolic metabolism in the primed plants under salt-stress conditions are currently unknown.

**Conclusion**

Results showed that salt acclimation with a low concentration of NaCl (50 mM) could not mitigate the inhibitory effect of 200 mM NaCl. Under non-acclimated conditions, maximum amelioration of salt stress was found by only the \( \text{H}_2\text{O}_2 \)+NO treatment. The increased salt tolerance in oilseed rape plants by seed priming with \( \text{H}_2\text{O}_2 \)+NO was attributed to the enhanced compatible solute content and decreased Na\(^+\) transport to the shoot, which could provide osmotic protection to cells. Our data indicated that exogenous \( \text{H}_2\text{O}_2 \)+NO...
increased the SOD and CAT, and caused a large increase in SA content correlated with PAL activation and flavonoid (as non-enzymatic antioxidants) biosynthesis, resulting in better plant growth under salt stress (Figure 7). Regarding the effectiveness of H$_2$O$_2$ and NO priming and their combined treatments, the results exhibited that interplay among H$_2$O$_2$ and NO afforded more effective protection against salt stress. Some research reports have revealed that the interactions between H$_2$O$_2$ and NO are involved in physiological responses to various abiotic stresses (Huang et al. 2015; Shi et al. 2015 Niu and Liao 2016). Increasing evidence suggests that the relationship between H$_2$O$_2$ and NO may be involved in inducing tolerance to heat (Li et al. 2015; Wang et al. 2014), cold (Guo et al. 2014; Tan et al. 2013) and UV-B stress (Tossi et al. 2014). Several studies on plants have demonstrated that the crosstalk among H$_2$O$_2$ and NO signaling regulates plant responses to high salinity (Tanou et al. 2009, 2010; Niu and Liao 2016). However, the effects of multiple priming on photosynthesis and antioxidant machinery of the salt-stressed plants will need to be further analyzed.

**Conflict of interest**

The authors declare no conflict of interest.

![Figure 7. Priming with exogenous H$_2$O$_2$ and NO induces salt-stress tolerance of oilseed rape plants and improves physiological homeostasis and plant growth.](image_url)
References


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یک گل کلزا در شرایط بالا همگامی می‌تواند باعث بهبود تحمل به شوری در گیاه کلزا شود. این اثر توسط پرایمینگ ترکیبی بیاکسید نیتریک (NO) و اکسیژن هیدروژن (O2) به شکل NO با ترکیب H2O2+NO نیز بهبود تحمل به شوری را بهبود می‌دهد. در حیاتی، در شرایط عادت و بدون عادت، رشد گیاه کلزا از سنجش فاکتورهای حساس به سطح سهولت و ریشه به همراه نشاندهنده درمانی مالون دی آلدئید (MDA) در میزان رشد گیاه کلزا را نشان می‌دهد. این اثر مربوط به کاهش انتقال سدیم به اندام هوایی، افزایش مقدار اسید سالیسیلیک، فلاوونوئیدها و فعالیت انزیم فنیلامینیک همراه بوده است. پرایمینگ بذور با پراکسید هیدروژن در شرایط غیرشوری، باعث افزایش مقدار NO باعث تخمین زنی اثرات تنش شوری بر رشد گیاه کلزا شد. همچنین، پرایمینگ بذور با ترکیب NO و H2O2+NO از طریق کاهش MDA و H2O2+NO در داخل سلول و افزایش فعالیت انزیم فنیلامینیک بهبود رشد و رشد گیاه کلزا را می‌تواند بهبودی در شرایط غیرشوری بیاید. نتایج این مطالعه نشان داد که پرایمینگ ترکیبی بهتر از پرایمینگ ترکیبی بهتر از پراکسید هیبریژن و اکسید نیتریک در شرایط عادت و بدون عادت بهبود رشد گیاه کلزا را بهبود می‌دهد.