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SALINITY STRESS ALLEVIATION IN FODDER CROPS THROUGH FOLIAR APPLICATION OF JASMONIC ACID – A REVIEW

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SUMMARY

Jasmonic Acid and methyl jasmonate (MeJA) are collectively known as jasmonates. Jasmonic acid (JA) is a potent signal compound that accumulates rapidly and transiently when plants are under biotic and abiotic stress. Various researchers have conducted studies on the role of endogenous and exogenous JA and its metabolites in defense mechanisms against salinity stress and reported that foliar application of JA under the salt stress, improved the salt stress tolerance. Jasmonates activate plant defense mechanisms in response to insect-driven wounding, various pathogens, and environmental stresses, such as drought, low temperature, and salinity. Application of jasmonic acid in form of MeJA increases the number of leaves as other plant growth promoters including gibberellic and salicylic acid under sodium stress, similarly hows positive effect on increase in the number of tillers, improve plant morphological characters, enhances vegetative growth by increasing fresh weight, dry weight, and SPAD value in cereal fodder crops under salt stress. JA application can promote the biosynthesis of proline and putrescine under environmental stresses in fodder crops of Brassica family. JA application improves Na^+ exclusion either by decreasing passive influx or by increasing the active efflux of Na^+. Osmotic stress significantly increased JA levels in root tissues of the salt sensitive fodder maize genotypes. JA and MeJA plays a crucial role in ameliorating the adverse effects of salt stress in cowpea and improve its tolerance to salt stress conditions. In the present review, we discussed the potential role of Jasmonates in alleviating adverse effect of salinity on fodder crop.

Key words : Salinity stress, defense mechanisms, Jasmonic acid, forage crops

A change in climate scenarios is the main reason of biotic and abiotic pressures of a particular agro-ecological zone. Various abiotic stresses all over the world have now been adjudged as the most potential threat for sustainable agricultural productivity (Aziz *et al.,* 2017). Myriads of anthropogenic emissions in the developmental era have further intensified the abiotic stress-induced negative impacts on agricultural productivity. The major abiotic stresses such as metals/ metalloids, salt, ozone, UV-B radiation, temperature extremes, nutrient, flooding, and water deficit are jeopardizing the agriculture system worldwide (Ahammed *et al.,* 2020a and Ahmad *et al.,* 2019). These abiotic stresses can modulate almost all plant physiological, biochemical, and molecular processes starting from the seedling to maturity stage and can ultimately cause severe negative impacts on economic yield of various crop plants (Mantri *et al.,* 2012) while among all abiotic stresses soil salinity is a prevalent stress that alters geographical distribution of plants as it is a major threat to agricultural productivity across the worldand it is a global land degradation issue (Sadiq *et al.,* 2020) and mainly affects coastal areas by developing soil salinity. Salt is accumulated in agricultural soils as a result of various environmental factors such as climate change, excessive use of groundwater, poor drainage associated with massive irrigation and intensive farming, and the use low quality water in irrigation (Machado *et al.,* 2017). Several countries such as USA, Spain, Jordan, China, Greece and Senegal have used various techniques to tackle soil salinity on their farm lands (Kumar *et al.,* 2018). Excess salt in the soil may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects (Khan *et al.,* 2015). Major adverse effects of salinity stress include increased ion-toxicity, osmotic stress, nutritional acquisition, homeostasis, impaired stomatal conductance, increased cell-turgor loss, reduction in leaf water potential, altered physiological/biochemical processes and elevated ROS-caused oxidative stress (Per *et al.,* 2018). Many approaches have been opted to counteract the negative effect of salinity and ultimately enhance growth and development of plants under stress conditions for their survival (Ahmad *et al.,* 2018). These approaches contain modifications in gene expression, biosynthesis of special proteins and secondary metabolites, alterations in hormonal signalling, anti-oxidative activities, morphological and developmental pattern (growth plasticity) as well as physiological and biochemical processes against several stresses (Saud *et al.,* 2014).

As plant species differ in their sensitivity or tolerance to salt stress (Ashraf and Harris, 2004). Plant growth regulators are a group of natural molecules, derived from plant bio-synthetic pathways that can act either locally (at the site of their synthesis) or transported to some other site with in plant body to mediate growth and development responses of both under ambient and stressful conditions (Peleg and Blumwald, 2011). It is thought that the repressive effect of salinity on seed germination and plant growth could be related to a decline in endogenous levels of phytohormones (Debez *et al.,* 2001). Wang *et al.* (2001) clearly defined that ABA and JA will be increased in response to salinity, whereas indole-3-acetic acid (IAA) and salicylic acid (SA) are declined.

In India, there is shortage of fodder to the tune of 35.6, 11.0 and 44.0 per cent for green fodder, dry crop residues and concentrates feed (IGFRI Vision, 2050). The fodder crops which are comparatively tolerant to salinity stress need to be explored. Most of the productive and better quality land is allocated to commercial and food crops; so the possibility to cultivate fodder crop in saline, sodic and other problematic soils be explored. The development of salinity tolerant varieties of fodder crops are one of the main steps which along with better agronomic management including the exogenous application of phytohormons can work as a pragmatic approach to alleviate the salt stress.

Problem of soil salinization

Soil salinization is a widespread problem and a major abiotic constraint affecting the global food and fodder production. The major cations involved are sodium, calcium and magnesium and the major anions are chloride, sulfate and carbonate (Rengasamy 2010). Salinity refers to the total concentration of these salts in both soil and water samples and is measured with the electrical conductivity of water or a soil saturated extract (Payen *et al*., 2016). Salt-affected soils are found in arid and semi-arid climates in more than one hundred countries of the world, where many regions are also affected by irrigation-induced salinization (Glick *et al*., 2007). Salts in the soil occur as ions which are released from weathering minerals in the soil but can also be applied through irrigated water or as fertilizers, or sometimes migrate upward in the soil from shallow groundwater (Blaylock *et al*., 1994). The area under the salt affected soils continues to increase each year due to introduction of irrigation in new areas (Patel *et al*., 2011).

Global extents and distributions of salt-affected soils

Around 1125 m ha of land are affected by salinity worldwide, of which 76 m ha are damaged by salinization and sodification human intervention (Hossain 2019). Middle East soils have more salt damage overall. Argentina, Australia, China, Egypt, India, Iran, Iraq, Pakistan, Thailand, the former Soviet Union, and the United States are among the nations most impacted by land salinization. Nearly 147 m ha of land in India are affected by soil degradation, including 94 m ha due to water erosion, 23 m ha due to salinity, alkalinity, or acidification, 14 m ha due to water logging or flooding, 9 m ha due to wind erosion, and 7 m ha due to a combination of factors brought on by various forces. The country has a salt-affected area of about 6.74 m ha. According to estimates, an additional 10% of land becomes salinized annually, and by 2050, around 50% of the world's arable land will be contaminated by salt. Sodic soils make up 47% of the area in 11 states, whereas saline soils represent 44% of the area in 12 states and one Union Territory (Kumar and Sharma, 2020). Gujarat (2.23 million ha), Uttar Pradesh (1.37 million ha), Maharashtra (0.61 million ha), West Bengal (0.44 million ha), and Rajasthan (0.38 million ha) together make up over 75% of the nation's total saline and sodic soils. The dry region in the state of Rajasthan, Haryana, and Punjab, which is located in the country's north-western side, suffer tremendously from the issue of poor quality water (Singh, 2009).

Effect of soil salinity on plants

Soil salinity is one of the most brutal abiotic factors limiting the growth andproductivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil. (Shrivastava *et al*., 2015). The impacts of salinity includes low agricultural productivity, low economic returns and soil erosions, (Hu and Schmidhalter, 2002). Salinity effects water and nutrient uptake (Akbarimoghaddam *et al*., 2011) even it affects all the aspects of plant development including: germination, vegetative growth and reproductive development. As phosphate ions precipitate with Ca ions, soil salinity considerably lowers plant phosphorus (P) absorption (Bano and Fatima, 2009). Some elements, including sodium, chlorine, and boron, have harmful effects on plants in particular ways. Osmotic stress and cell death can quickly result from an excessive buildup of salt in cell walls (Munns, 2002). If the poisonous element is present in higher quantities in the soil, plants that are sensitive to these elements may be harmed even at relatively low salt concentrations. High salt levels in the soil can disrupt the balance of nutrients in the plant or prevent some nutrients from being absorbed because many salts are also nutrients for plants (Blaylock *et al*., 1994). Salinity also has an impact on photosynthesis, mostly by reducing the amount of leaf area, chlorophyll content, and stomatal conductance, and to a lesser extent by lowering the effectiveness of photosystem II (Netondo *et al*., 2004). Salinity impairs reproductive development by promoting programed cell death in specific tissue types, ovule abortion, and senescence of fertilised embryos. It also inhibits microsporogenesis and stamen filament elongation. Due to a low osmotic potential of the soil solution (osmotic stress), particular ion effects (salt stress), nutritional imbalances, or a combination of these variables, the saline growth medium has various detrimental impacts on plant growth (Ashraf, 2004). All these factors cause adverse effects on plant growth and development at physiological and biochemical levels (Munns and James, 2003) and at the molecular level (Tester and Davenport, 2003). Salt stress mainly triggers osmotic stress, specific ion toxicity and oxidative stress (Reddy *et al*.,2017). For plants to develop in saline medium, osmotic balance must be maintained; failure to do so causes loss of turgidity, cell dehydration, and ultimately cell death. On the other side, poor supply of photosynthetic assimilates or hormones to the growing tissues might also have a negative impact on plant growth (Ashraf, 2004). Ion toxicity is caused by protein conformational changes brought on by Na+ and Cl^-, which replace K^+ in biological processes. K^+ serves as a cofactor for a number of enzymes and cannot be replaced by Na+. For tRNA binding to ribosomes and subsequently protein synthesis, high K+ concentration is also necessary (Zhu, 2002). Salinity adversely affects plant growth and development, hindering seed germination, seedling growth, enzyme activity (Seckin *et al*., 2009), DNA, RNA, protein synthesis and mitosis (Javid *et al*., 2011).

Amelioration of salinity

It is extremely difficult to develop effective, affordable, and adaptive solutions for managing abiotic stress. Around the world, intensive research is being done to create methods for coping with abiotic pressures, including the creation of salt- and drought-tolerant varieties, transgenic crops, altering crop calendars, resource management techniques, etc. (Venkateswarlu and Shanker, 2009). Removal of salts from the root zone (reclamation) is perhaps the most effective and longer lasting way to ameliorate or even eliminate the detrimental effects of salinity. Various molecular approaches such as gene transformation and use of molecular markers can be used to achieve salinity tolerance (Zhang and Blumwald, 2001). One of the adaptative plant responses to salt stress is the production of phytohormones such as abscisic acid, salicylic acid (SA), and jasmonates that might be involved in the alleviation of salinity stress (Wang *et al.* 2001; Yoon *et al.* 2009).Plant hormones are important metabolic engineering targets for producing abiotic stress–tolerant crop plants (Atia *et al*., 2018) and are essential pathways that plants have adopted for regulation of diverse stress responses (Ryu and Cho,2015). Jasmonates also play a role of cellular regulators in the response to stress factors, such as salt, drought, and heavy metal (Poonam *et al.* 2013 and Qiu *et al.* 2014).

Jasmonates

Jasmonic acid and methyl jasmonate (MeJA) are collectively known as jasmonates. Jasmonic acid (JA) is a potent signal compound that accumulates rapidly and transiently when plants are under biotic and abiotic stress (Lehmann *et al.* 1995) and are important cellular regulators involved in diverse developmental processes and also play a role in plant responses to abiotic stresses including drought, salt, and heat stress (Khan *et al*.,2013). Jasmonates modify growth and development through numerous linkages among various signalling pathways rather than a single simple mechanism. For instance, in plant cells, JA typically interacts broadly with salicylic acid and/or abscisic acid (Per *et al*., 2018). In plant cells, JA can be combined with various amino acids, such as isoleucine (Ile), to make Ile–JA, or converted into methyl jasmonate (Me–JA), or other comparable components, after biosynthesis through the octadecanoid route (Wasternack, 2014). In response to insect-driven injury, different diseases, and environmental challenges like drought, low temperature, and salinity, jasmonates activate plant defence mechanisms (Cheong and Choi, 2003, Lehmann *et al.* 1995, Ghassemi-Golezani *et al.*, 2018).

Jasmonic acid to alleviate salinity stress in crop plants

Jasmonates (JAs) play a positive role in the abiotic and biotic stress tolerance of plants. Jasmonic acid (JA) and methyl jasmonate (MeJA), are involved in regulation of the morphological, biochemical, and physiological processes and also alters gene expression under environmental stresses in plant cells (Wasternack and Parthier, 1997) and their exogenous application amends several physiological responses to improve resistance against abiotic stresses (Wani *et al.* 2016). Methyl jasmonate (MeJA) and jasmonic acid (JA) have an ameliorating effect on different plant species under salt stress (Manan *et al.* 2016) as its exogenous application under conditions of high salinity can support the development of biomass yield (Sheteawi 2007, Li *et al.* (2012) and Javid *et al.* (2011)) and also diminish the inhibitory effect of NaCl on photosynthesis rate and enhances the growth and development of plants (Hristova and Popova 2002; Javid *et al.* 2011). Exogenous JA application after salt treatment may change the balance of endogenous hormones, such as ABA, which provides an important clue for understanding the protection mechanisms against salt stress (Kang *et al.*, 2005). Proline, glycine betaine, polyamines and sugars/ sugar alcohols plays a significant role in abiotic stress tolerance in plants by acting as an osmolyte and improving osmotic adjustment by stabilizing macromolecules by protecting them against the severities of ROS (Ahmad *et al.*, 2012), by causes reduction in the redox imbalance and excitation pressure (Kurepin *et al.*, 2015; Sakamoto *et al.*, 2002), by protecting membranes of vital organelles and help plants in scavenging ROS (Nahar *et al.*,2016; Benavides *et al.*,2018; Groppa *et al.*, 2003) and acting as osmo-protectants and improving relative water contents (El-Khallal., 2001; Ghoulam *et al.*,2002; Harpreet *et al.*, 2013). JA-induced improvement in proline, polyamines contents has been reported in several studies such as drought stress (Bandurska *et al.*, 2003), heavy-metal toxicity (Farooq *et al.*, 2016; Poonam *et al.*, 2013), salt stress (Yoon *et al.*, 2009), and UV-B radiation (Fedina *et al.*, 2009; Demkura *et al.*, 2010).

Effect on cereal fodder crops

Oats

JA-Me affects sugar metabolism relating to cellulosic polysaccharides during leaf senescence in oats. In both, the presence and absence of JA-Me, the neutral sugar contents of hemicellulosic polysaccharides altered minimally throughout leaf senescence. Senescence-related reductions in cellulosic polysaccharide content in leaf blades could weaken the mechanical integrity of leaves. Senescence and the loss of chlorophyll in segments of oat leaves are both indicated by a decline in cell wall polysaccharides, particularly cellulosic ones (Miyamoto *et al.*, 2013). Soriano *et. al.*, (2007) revealed that treatment with methyl jasmonate reduced invasion of both nematodes and increased plant mass, compensating for damage caused by the nematodes, and is attributed to the active flavone-C-glycoside in case of oats. Specifically, AsHHT5 exhibited the highest expression following MeJA and ABA co-treatment, indicating that AsHHT5 played a more crucial role in avenanthramide biosynthesis in response to MeJA and ABA co-treatment of germinating oats. These findings suggest that elicitor-mediated metabolite farming using MeJA and ABA could be a valuable method for *Avenanthramide* production in germinating oats (Kim *et al.*, 2021). Foliar Application of jasmonic acid in form of MeJA increased the number of leaves of wheat under sodium stress and shows positive effect on increase in the number of tillers, improve plant morphological characters, enhances vegetative growth by increasing fresh weight, dry weight, spike length, number of grains spike and SPAD value of wheat under salt stress (Islam *et al.*, 2019).

Fodder sorghum

Sorghum is the widely grown cereal forage crop of the country (2.6 m ha) and single cut sorghums account for 23.1% of this, Short duration (60 to 80 days) with its ability to produce high biomass (Satpal *et al.*, 2020) under wide edapho-climatic situations across the country including Andaman & Nicobar Islands (Gangaiah and Kundu, 2020) and saline conditions (Devi *et al.*, 2021) during rainy season.

Memon *et al.* (2007) reported that increasing water salinity progressively decreased biomass (fresh and dry weight) per plant in case of fodder sorghum. Increasing salinity drastically reduced ESI (Emergence stress tolerance index) and PI (Promptness Index) of sorghum, similarly emergence percentage in sweet sorghum was greatly decreased under NaCl salinity conditions (Nimir *et al.* (2015) and Ibrahim *et al.* (2016b). Under salt stress, ROS accumulates in plant cells and superoxide dismutase is the first defense agent against ROS because it is the major scavenger of O_2 (Takahashi and Asada, 1983). Increased SOD activity can reduce damage from oxidative stress induced by salt stress (Anjum*et al.*, 2011; Shan and Liang, 2010). However, JA enhanced the forage sorghum seedlings ability to combat oxidative damage by increasing SOD activity (Bidabadi *et al.*, 2013). NaCl salinity caused a significant reduction in the POD and CAT activities in shoot seedlings of forage sorghum (Qiu *et al.* 2014 and Sekmen *et al.*, 2012) and decrease in CAT activity in stressed plants ultimately results into Haber–Weiss reaction, which is known to damage biological systems (Gill and Tuteja, 2010) while exogenous JA could increase POD and CAT activity in forage sorghum under salt stress. As salinity reduced other parameters except SOD activity and MDA in forage sorghum, therefore, JA and HA can be used in salt-affected soil to sustain forage growth and to increase yield and productivity of crops grown in saline soils. Appropriate combined application of HA and JA could efficiently protect early seedlings from salt stress damage and alleviate abiotic stress (Ali *et al.*, 2019).

Maize

Salinity mainly reduces the shoot and root growth to lesser extent due to decrease in rate of leaf expansion as salt stress inhibits the rate of leaf expansion in two phases, osmotic stress and ion toxicity (Munns, 1993). Maize (*Zea mays* L.) is a salt-sensitive crop that exhibits a similar two-phase growth inhibition under salt stress (Maas and Hoffman, 1997). During the first phase of salt stress, increased salt concentrations lower the soil water potential, resulting in reduced water uptake by roots, which slows the rate of leaf expansion, whereas during the second phase of salt stress, leaf growth is slowed as salts accumulate to toxic levels in the leaf tissues (Munns and Sharp 1993). The levels of JA in plant tissues are also elevated in response to salt and water stress (Tani *et al.*, 2008), and these higher levels are compatible with the activation of genes for JA synthesis (Kiribuchi *et al.*, 2005; Tani *et al.*, 2008), implying that JA is involved in signal transmission. Na+ exclusion is improved by JA treatment by either decreasing passive influx or boosting active efflux of Na+. Osmotic stress significantly raised JA levels in the salt sensitive maize genotype's root tissues. A temporary increase in JA in dehydrated barley leaves (Creelman and Mullet, 1995), after salinity exposure of tomato (Pedranzani *et al.*, 2003) and rice (Moons *et al.*, 1997), and under rice drought stress (Tani *et al.*, 2008) suggests that JA may act as a signal in response to water stress (Balbi and Devoto, 2008). Pretreatment of JA to salt affected seedlings restored the plant growth and biomass in maize plants by regulates ion homeostasis which is similar to the findings of Keramat *et al.*, 2010 and Sirhindi *et al.*, 2016 in which exogenous JA counter abiotic stress constraints and restored growth. Fahad *et al.* (2015) observed that exogenous JA could improve Na^+ exclusion in the root by decreasing Na^+ uptake, facilitating surface salt stress tolerance in two maize genotypes.

Leguminous fodder crops

Legume plants relatively more sensitive to salinity. Tavakkoli *et al.*, (2010) found that salinity treatments reduced both biomass production and water uptake in the faba bean. Helal and Mengel (1981) showed the deleterious effects of NaCl on plant metabolism that retard growth in salt sensitive species of legumes. Growth and biomass yield is reduced infaba beans (Dawood and EL-Awadi, 2015), Hashem *et al.*, (2014) and Ahmad *et al.*, (2018) and pea plant (El Khallal, 2001) by NaCl and this reduction is due to inhibition of cell division and cell elongation (Ahmad *et al.*, 2016) and also due to reduced mineral uptake, generation of reactive oxygen species, enzyme activity inhibition, and hormonal imbalance (Ahanger *et al.*, 2017). Along with growth and biomass yield, NaCl stress also decreases pigment content, and LRWC, but increases H_2O_2, MDA content, EL, and antioxidant enzymes such as SOD, CAT, and GR in faba bean genotypes (Alzahrani *et al.*, 2019). The decreased uptake of Ca^{2+}, Mg^{2+}, K^+ and enhanced accumulation of Na+ by NaCl accompanied with decreased K+ and Ca+ uptake have been reported in many plant species, including mustard (Ahmad *et al.*, 2015) and *Vicia faba* (Ahmad *et al.*, 2018b) JA-Me treatment decreased both stomatal conductance and transpiration rate of pea leaves and pretreatment of pea seedlings with JA-Me decreased Na^+ and Cl^- accumulation in leaves could be one of the reasons for its protective action in salt stress. Salinity damages photosynthetic activity and chlorophyll pigment depending on concentration, duration of stress, and genotype and mainly chlorophyll is used as an indicator for evaluating PS-II integrity under salt stress (Smethurst and Shabala, 2003) and reduction in chlorophyll content indicates oxidative stress symptoms (Smirnoff, 1996). Pre-incubation of *R. Leguminosarum* bv. *viceae* with NA and MeJA signal molecules can increase dry weight, nodule numbers, leaf area, leaf greenness and photosynthetic rate of pea plants under salinity stress (Lee, 2008). JA and MeJA plays a crucial role in ameliorating the adverse effects of salt stress in cowpea plants and make broad bean plant's tolerance to salt stress conditions. Tebayashi *et al*., (2000) reported that JA treatment induced the level of clovamide in red clover. Induction of clovamide accumulation is a part of the root defense system of red clover, in a manner analogous to hydroxycinnamic acid amides in other plants. Kasparova and Siatka (2014) observed best effect of jasmonic acid on the production of flavonoids and isoflavonoids after a 24-hour application of JA at the rate of 50 µmol/L concentration in *Trifolium pratense* L. A transient increase in the concentration of JA occurred immediately following inoculation of *Phaseolus vulgaris* L. seedlings with water or WClMV (white clover mosaic potexvirus), due to wounding. A second increase in JA occurred only in virus-infected leaves (Clarke *et al*., 2000). JA activates plant defence mechanisms in response to various pathogens and environmental stresses.

Other fodder crops

Foliar application of methyl jasmonate (MeJA) mitigated the salinity stress of broccoli plants (*Brassisca oleracea* L. var. Italica) by enhancing plant dry weight, leaf CO_2 assimilation, and root respiration (del Amor and Cuadra-Crespo, 2011). JA treatment also enhanced root:shoot content. It's presumed that JA causes alterations that are mediated by stress proteins generated by jasmonates (Rakwl and Komatsu, 2001). In *Brassica sp*., JA treatment generated stress proteins that were engaged in a variety of growth-related activities (Kaur *et al.* 2017). The accumulation of several pigments and vitamins in *B. napus* and *B. Juncea* plants declined as salt stress increased (Verma and Mishra, 2005), owing to the increased generation of free radicals under salinity stress, which led the degradation of secondary metabolites. Under NaCl stress, the effect of JA on pigments, vitamins, and seedling growth was more pronounced, as JA caused protein accumulation, which raised the tolerance of *Brassica napus* seedlings to NaCl stress (Kaur *et al*., 2017). Under environmental stress, JA can help increase the manufacture of proline and putrescine. In *Brassica sp*., JA was effective in proline accumulation, similar to Walters' findings (2002). Under NaCl stress, the effect of JA on proline, MDA, sugars content, and seedling growth was more pronounced, implying that JA-treated seedlings were less impacted by NaCl because JA caused proline, MDA, and sugar accumulation, which raised the resistance of *Brassica napus* seedlings to NaCl stress. Salinity stress reduced rapeseed fresh and dry biomass, with a stronger effect on shoot growth than root growth, due to a decrease in water use by the plant, resulting in less leaf area development relative to root growth, allowing soil moisture to be conserved to avoid too high salt levels in the soil (Munns and Tester, 2008). Salinity stress, on the other hand, may cause an ion imbalance in plant cells, resulting in oxidative damage and a reduction in plant development (Kepczynski and Bialecka, 1994). Salinity stress has been shown in several studies to diminish N accumulation in plants by generating interactions between Na^+ and $NH4^+$ and/or Cl^- and NO_3, resulting in reduced crop development and yield (Rozeff, 1995). Exogenously applied JA acts as a stressor, causing typical stress reactions such as the accumulation of free Pro, increased photorespiration, and so on (Hasanuzzaman *et al*., 2013). It can alter guard cell behaviour, resulting in stomatal closure and reduced transpiration (Fedina and Tsonev, 1997). After salt treatment, exogenous JA administration may alter the balance of endogenous hormones, offering an essential insight for understanding salt stress defence systems (Kang *et al*., 2005). However, depending on the applied concentration, plant species, and salt level, exogenous application of MeJA either promotes or inhibits plant development under stress conditions (Farooq *et al*., 2016). According to Fedina and Tsonev's investigation, MeJA treatment dramatically reduced water loss at higher NaCl concentrations (1997). To prevent water loss, plants subjected to salt stress reduce leaf area, drop leaves by leaf abscission, or seal stomata (Ali *et al*., 2004). The decrease in photosynthesis rate caused by salt stress could be due to a decrease in some essential ion concentrations in mesophyll cells, such as magnesium and calcium (Netondo *et al*., 2004), a decrease in water potential, or the accumulation of high concentrations of Na^+ and/or Cl^- in chloroplasts (Netondo *et al*., 2004). (Hasanuzzaman *et al*., 2013) Exogenous application of MeJA reduced the CO_2

compensation point and transpiration in rapeseed plants, hence MeJA-induced growth extension in rapeseed plants under salt stress appears to be connected with improved photosynthesis as well (Samira *et al.*, 2012 and Ahmadi *et al.*, 2018).

CONCLUSION

Application of jasmonic acid increases the number of leaves under salt stress and shows positive effect on increase in the number of tillers, improve plant morphological characters, enhances vegetative growth by increasing fresh weight, dry weight, and SPAD value in cereal fodder crops. JA application can promote the biosynthesis of proline and putrescine under environmental stresses in fodder crops of Brassica family which further help in salinity stress alleviation. JA application improves Na^+ exclusion either by decreasing passive influx or by increasing the active efflux of Na^+. Osmotic stress significantly increased JA levels in root tissues of the salt sensitive fodder maize genotypes. JA and MeJA plays a crucial role in ameliorating the adverse effects of salt stress in cowpea and improve its tolerance to salt stress conditions. JA can be used in salt-affected soil to sustain forage growth and to increase yield and productivity of crops grown in saline soil. Exogenous application of JA could increase POD and CAT activity in forage sorghum under salt stress to sustain the plants.

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