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Review Article

CADAVERINE : A DIAMINE PRESENCE & ROLE IN PLANTS

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Abstract

Polyamines (PA) like putrescine, cadaverine (diamine), spermidine (triamine) and spermine (tetramine) are lower mass polycationic molecules that are now known as amino molecules for humans and plants. Cadaverine (Cad), among two diamines of growth modulating polyamines that are synthesized completely from the diverse pathway with respect to the other groups, indulged in the growth of the plant, but the anti-stress role is vague. This diamine in its organic nitrogen forms is found as metabolites intermediates of varies pathways in the organism. It might be acting as structural components of macromolecules thereby modifying the metabolism of the organism. The literature survey indicates that the diamine putrescine is being discussed mostly by the plant physiologist, biochemists, molecular biologist for various applications in strategies for crop improvements and the diamine being the precursor of spermine and spermidine, has further drawn the attention of researchers. Further, it is observed that Cad improves the growth of the plant under multiple stress conditions and stress triggered proteins in the presence of Cad may assist the plant to grow under multiple stress conditions.

Keywords: Cadaverine, Plant, Polyamines, Protein, Salinity, Senescence, Stress

Introduction

Importance of Cadaverine in Plants:

Low molecular mass polycations i.e., Polyamines PA (spermidine, putrescine, and spermine) are found in almost all the organisms. These polyamines are widely accepted as a plant growth regulator; nevertheless, they are basically originated from traces of animal and bacteria (Smith, 1985). The role of polyamines and their metabolism has been studied in several plant processes since these have been discovered (Smith, 1985; Evans and Malmberg, 1989; Flores, 1985; Galston and Kaur-Sawhney, 1990; Martin-Tanguy, 2001). It is reported that PA's regulate various plant processes like cell division, regulation of enzyme activities, gene expression, DNA replication, morphogenesis, membrane stabilization, fruit ripening, stress responses, senescence, etc. (Kumar *et al.*, 2004). In plants, Putrescine is the most common diamine that is derived from the decarboxylation of arginine and ornithine in the existence of enzymes arginine decarboxylase (ADC) or ornithine decarboxylase (ODC) respectively that is transformed into spermidine (a triamine) and spermine (a tetramine) in the presence of enzymes like spermidine synthase and spermine synthase respectively. Like in ornithine deficit, ODC can utilize lysine as an alternate substrate for cadaverine biosynthesis (Bhatnagar *et al.*, 2002). Lysine increases the mRNA in CadB178 but by ornithine whereas, putrescine transporter Pot E mRNA increased through lysine (Tanaka *et al.*, 2008).

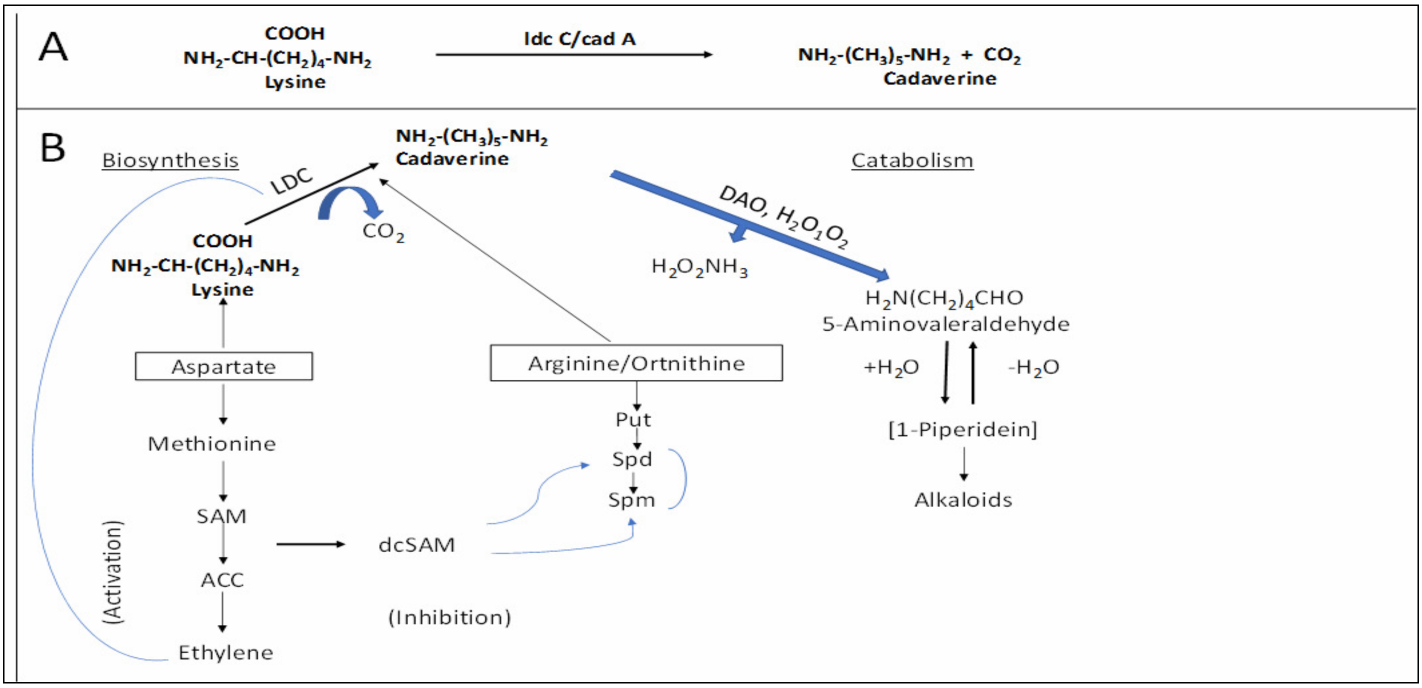

Fig 1. : (A) Picture depicting Cad A and Ldc C genes for biosynthesis of Cad in Bacteria (B) Biosynthesis of Cadaverine and its catabolism in plants; LDC=Lysine Decarboxylase, DAO= Diamine Oxidase. The dotted arrow specifies the probability of biosynthesis in certain cases (Tomar *et al.*, 2013).

However, Cadaverine (Cad), yet another diamine that is synthesized by lysine in the presence of lysine decarboxylase (an enzyme present in the chloroplast) are also included in the family of growth regulators (Bouchereau *et al.*, 1999). The foul odor of deteriorating tissue of cadaver is because of cadaverine. As discussed, the existing review is dedicated to express Cad's existence and functions in higher plants (Kusano *et al.*, 2008). These PAs plays a vital role in several plant processes including seed germination to ripening of the fruit. Though, effects of such PAs are because of their interrelated pathway for their biosynthesis.

The varied acceptance of polyamines involving Cad for anti-senescence action at one side and has no effect on senescence in other cases explain its function in the growth of the plant and under stresses in precise (Martin-Tanguy, 2001; Kumar and Rajam, 2004; Moulin *et al.*, 2006). These polyamines accumulate under stress in a few cases and their role is quite fascinating as a diamine in the metabolism of the plant. Molecular-level studies have also been performed on the role of polyamines recently. The activities of DNA, RNA, proteins and other nucleotide triphosphates are also observed to be modulated by polyamines as they bind to A- or B-DNA form and Cad is able to bind itself with the sugar-phosphate backbone that is anticipated and hence provides the stability to the DNA (Kusano *et al.*, 2008). Modifications in the structure of RNA occurring at diverse concentrations of K^+ and Mg^{2+} explains the main role of polyamines in the cellular functions as almost all the polyamines locate at polyamine–RNA complex in the cells. Protein synthesis is modulated at various levels that include simulation of the assembly of 30 S ribosomal subunits and stimulation of special kinds of protein synthesis (Igarashi and Kashiwagi, 2000). Stimulation of Ile-tRNA formation is still the evidence about Cadaverine (Cad), another diamine of the polyamines family in plants is very rare under stress, specifically under multiple stress conditions. Polyamines/diamines may also be expected to function as nutrition in protozoans (*Trypanosoma cruzi*) (Bryson *et al.* 2002).

Cadaverine clustered in the family of polyamines also acts as a plant growth regulator and follows an independent biosynthetic pathway (Flores *et al.*, 1985). However without obvious explanations and their function in a specified way Cad also has a tendency to collect under salt/osmotic stresses (Bouchereau *et al.*, 1999). In spite of diamine behavior, structural differences may have dissimilar responses in plants under the least known conditions. The amine adipate that is an alternative catabolite for this pathway is associated with osmoprotectant in both plants and bacteria (Moulin *et al.*, 2006).

Nevertheless, salinity is taken as it has no association with levels of Cad in *Oryza sativa* (Lefevre *et al.*, 2001). Under salinity conditions, there was no Cad accumulation in the case of maize; this is either very little change (Lefevre *et al.*, 2001). According to the literature review, it seems that Cad is not assessed extensively like other polyamines in plant growth and development, specifically under multiple stresses in Indian mustard. The exogenous Cad variant responses are also documented on enzymes and metabolites with salinity in Indian mustard stressed (Tomar *et al.*, 2008).

In certain *in vitro* studies, a lack of Cad has detected in cell suspended culture of rice under the insufficiency of K^+ (Sung *et al.*, 1994). Perhaps, it is recommended that catabolic artifact of lysine (Moulin *et al.*, 2000; 2006) is Cad. Lysine catabolites are involved in numerous procedures in a plant's life cycle. Lysine is catabolized in acetyl CoA with intermediates pipecolic acid and glutamate by enzymes like S*accharopine dehydrogenase* (SDS) and *lysine ketoglutarate reductase* (LKR) in case of osmotic stresses in a plant (Stepansky *et al.*, 2006). The PAs are involved in the enhancement of growth and development of the plant under multiple stress conditions (Galston *et al.*, 1990; Mishra *et al.*, 2003; Bouchereau *et al.*, 1999; Liu *et al.*, 2000). However, under metal or salinity stress (Aziz *et al.*, 1997), it was also stated that PA's have the tendency of accumulation. In actual fact, under multiple stresses and is also least explored (Liu *et al.*, 2000) the physiological significance of polyamines rises. In agriculture, abiotic stress management is an actual challenge for plant scientists. For improvement in the growth of the plant under multiple abiotic stresses is yet to be explored for its strategic designs for optimization of its growth, development, and yield. A number of combinations are required to be checked for this.

Occurrence/Presence of Cadaverine in Plants:

The presence of Cad was primarily revealed in legumes but currently discovered in various plants, except axial organs and broad bean cotyledons (Kotova *et al.*, 1996), in Soybean and also cucumber fruit (Mathooko *et al.*, 1995). The hypocotyls and roots of the plants contain Cad while it is absent in nodules (Caffaro *et al.*, 1993). Further, presence of Cad is manifested in table olives (Garcia *et al.*, 2000), sugarcane juice (Armas *et al.*, 1999; Rodriguez *et al.*, 2000) and grape juice (Fernandes *et al.*, 2000). Though, the absence of Cad was described in the ripening of eggplants (Rodriguez *et al.*, 1999).

Seeds of leguminous plants like lupin, chickpea, and broad bean comprise of high quantity of Cad that proliferates while germinating (Ramakrishna and Adiga, 1974; Ramakrishna and Adiga, 1975; Smith, 1975; Villanueva, 1978; Gallardo, 1992; Hamana and Matsuzaki, 1993; Shalaby, 2000). Mostly, the germination of seeds is reported to contain greater contents of Cad. However, exceptions are there as well. In *Vicia faba, P. vulgaris* and *Phaseolus aureus* Cad is not spotted whereas in the seedlings of *Trifolium subterraneum* (Smith and Wilshire, 1975) its occurrence was noticeable.

In roots and leaves of some of the aquatic plants like *Eichhornia crassipes* (water hyacinth), *Spirdela polyrhiza* (duckweed), *Nelumbo nucifera* (lotus) and *Nymphea tetragons* (water Lilly) and as well as in *Phleum pretense,* sorghum, maize, barley, wheat, rye and oat (Hamana *et al.*, 1994) Presence of CAD can be found. Parolo *et al.* (1997) established a decent quantity of Cad in shoots and leaves of *Allium sativum*. Though, the maximum quantity of Cad (165 mg/ dry wt.) is present in eatable mushrooms (*Agaricus bisporus, B. variegatus, Boletus badius*, *B. chrysontereon*) which were lesser than that of Put 1600 mg/dry wt. (Kalac and Krízek, 1997). Cad was reported by Yen (1992) in straw mushrooms.

It has been stated defoliation and shading may affect the accumulation of Cad in mature seed embryos which might cause a stoppage in accumulation of CAD. Another realization is a higher concentration of Cad is found in the upper ground part of leafy vegetables like Chinese cabbage. It appears like the synthesis of Cad may be regulated developmentally. In Cereals like barley etc. the presence of Cad was also reported in the leaves of barley (Makarov *et al.*, 1991). The APC (amino acid/ organocation/ polyamine) superfamily transporters are the distinctive carriers (Jack *et al.,* 2000). In rice, the presence of Cad in its shoot extracts and phloem sap specified the varied distribution Cad in different segments of the plant.

Stress Response and Cadaverine

The higher amount of cadaverine in germinating seed embryo axis is indicative of a role in stress modulation and further development. It was detected that Cad was present in higher concentrations in cut out embryonic axis of *Cicer arietinum* while germination (Gallardo *et al.*, 1994). Besides the existence of Cad in several plants, few higher plant products also contain Cad (Fujihara *et al.*, 1995; Felix and Harr, 1987). The role of Cad in such products is required to be elaborated for physiochemical relevance for example, table olives (Garcia *et al.*, 2000), and juices of sugar cane (Armas *et al.*, 1999; Rodriguez *et al.*, 2000), ripened eggplants (Rodriguez *et al.*, 1999).

Cad may decay progressively as the Carrizo *et al.* in 2001 revealed that Cad titer is age-dependent and established that. In the hairy roots of *Brugmansia candida* these interpretations has been verified. The polyamines exhibit a wide range of applications in anti-senescence activity (Bouchereau *et al.*, 1999; Aziz *et al.*, 1997; Liu *et al.*, 2000) on one hand, conversely, in case of barley, it permits extensive experiments to comprehend its role in the growth of the plant (Srivastava, 1987) and under multiple stresses and Cad has stated to have zero effects on senescence. Cad is also associated with distinct alkaloid biosynthesis (Carrizo *et al.*, 2000).

It is still a question if the Cad exogenous applications under stress expected to provide an identical response or not. These experimentations provide an insight to recognize the regulation mechanism in plant's growth and their influence on the mitigation of toxic responses in plants under stresses. Ohe *et al.*, in 2010 have recently advised that *LDC* genes are diverse and its sequences are articulated differentially for plant growth under different environmental conditions like 9 in rice and 3 in *Arabidopsis.*

Currently, existing information regarding the effect of Cad on growth and physiochemical response towards crop plants depicts the lack of extensive research. Studies reported the establishment of Cad presence in angiosperms. The physio-chemical aspects of these studies are yet to be explored. Induction of Cad under salt stress conditions in maize was found to incite very less effective as compared to other polyamines (Caldeira and Caldeira, 1999). As studied in 1999 by Bouchereau *et al.*, in higher plants Cad production is elevated due to osmotic and salt stresses.

Along with PA tea plants also comprise of Cad. Bouchereau *et al.*, in 1999 recommended that the production of Cad in higher plants can be encouraged by osmotic and salt stresses. The level of Cad in old leaves, stem and roots of ice plant decreased significantly at 47°C for 2 hrs which proves it to be heat-labile (Kuznetsov *et al.*, 2002), whereas Cad increased numerous folds in roots and translocated to shoot due to heat shock (Shevyakova *et al.*, 2000) whereas PA like Put. Vegetable products witnessed the sensitivity of translocation with temperature (Kalac *et al.*, 2002). Apart from conjugation of Cad in *Mesembryanthemum crystallinum* root, it encourages oxidative rupture concurrently deteriorating Cad and its conjugates during root treatment by Cad exogenously (Kuznetsov *et al.*, 2009).

The Cad titer can be diverse in different parts of the plant. Hou and Lin in 1997 detected diverse Cad titers stored in *Ipomoea batatas* sprouts and sprouted roots. Alike responses were witnessed in radish, lentil, and mungbean sprouts. Male and female flowers of *Mimordica charantia* had more Cad than present in its vegetative tissues (Wang *et al.*, 1997). On the basis of dry biomass tobacco hairy roots passed 0.7% of Cad and were commended to be involved in anabasin biosynthesis (Angosto and Matilla, 1993) which defined that inclusive of Cad liable on altitudinal habitation of plants *Festues indigesta* had variations in diamines titres; extra Cad was found in higher altitudinal plants.

Felix and Harr (1987) had revealed that depending on different parts of cereal species Cad titer might differ from < 1 nmol/g FW to 15 mol/g FW and presence of Cad in them. In seedlings of a pea, 3rd internode was found to contain more quantity of Cad (Goren *et al.*, 1980). They suggested that relative quantities variation with age and growth is observed in the PA pattern of each organ-specific. Further Red and far Red light affected these variations.

Effect on Metabolic activity of Plants

Expression of Lysine decarboxylase in *Nicotiana tobaccum* amplified the Cad levels that may result in producing Anabasin 3 fold (Fecker *et al.*, 1993). It is recognized that L-lysin decarboxylation by lysine decarboxylase in plants (Bakhanashvili *et al.*, 1985). Based on its rate of decarboxylation in solvable portions of enzymes research recommended the existence of isoforms in various seedling organs (Bunsupa *et al.*, 2012). The experimentations executed to detect Cad and certain other PA in the root nodules of faba beans, pea plant and from the stem nodules of *Sesbania rostrata* it was discovered that 15 N values in Cad were +1 and +7 per thousand that is nearly related to find with automatic nitrogen and carbon analysis mass spectrometer. Although, very rapid methods of reverse phase HPLC is also recommended post formulation of benzoyl amine with benzoyl chloride derivative, then the detection range was 5.60 to 54.40 pg. using a UV-visible spectrometer at wavelengths 225 and 254 nM (Hornero-Méndez and Garrido-Fernández, 1997).

This is significant to observe that despite several diverse Cad biosynthesis pathways; DFMA (DL-difluoromethylarginine) an inhibitor of Put biosynthesis condensed Cad levels it up to 95%, whereas DFMO (DL-difluoro methyl ornithine) inhibitor of Put synthesis via ornithine, specially under stresses could not amend levels of Cad in rape leaf disc (Aziz *et al.*, 1997). It further suggests the effect of Cad synthesis by an extensive metabolism of PA.

Several growth regulators and other metabolite homeostasis are required for the growth and development of the cell. Homeostasis of Cad is possible by regulating Cad transport in the cells of the plants that are analogous to animals as well (Belting *et al.*, 2003). This is deceptively being additionally supported by the opinion that Cad repressed (Ki 58 μM) homospermidine synthase, primary enzyme of alkaloid precise pathway, that catalyzes the biosynthesis of homospermine by the usage of two molecules of Put in the presence of NAD^+ in roots of *Senecia vulgaris* (Böttcher *et al.*, 1993). Although, berberine biosynthesis in *Thalictrum minus* cell suspension culture does not get affected by Cad and other diamines like Put or spermine but spermidine triggered biosynthesis of berberine is possible via ethylene genera (Hara *et al.*, 1991). Such experimentations advise that metabolism of Cad is indulged in the growth and development of the plant.

Metabolites Interaction with Cad and Physio-chemical Modulation

Structure of Cad is a 5C compound when compared to that of a Put i.e., 4C with two different amino groups that may differ in binding with several biomolecules at multiple active sites. Therefore it could be inferred in a diverse response. Hence, Jackson *et al.* (1995) revealed that the Cad with its progressive homologous aminopropyl cadaverine (APC) and N, N bis (3-aminopropyl) Cad (3APC) were permeated in barley and also in the powdered form of mildew (*Erysiphae graminis* sp. hordei) mycelium while APC and 3APC fabrication was decreased in a barley leaf because of an infection by the powdered mildew. Studies also revealed that the homologous biosynthesis in Barley ingests S-adenosyl methionine decarboxylase & spermidine synthase whereas there is a diverse route in fungus i.e., Schiff base pathway.

According to Torrigiani and Scoccianti, (1995), Put & Cad perform alike while the germination of seeds and the development of seedlings of chickpea at all its developmental stages. The lysine metabolism association in the germination of seeds and its growth is further established.

The *Arabidopsis* genome mapping discovered a total of 12 diamine oxidases genes among which ATAO1 is categorized. During the germination of seeds, the activity of diamine oxidase appears to be developmentally controlled that was hiked constantly on the fifth day (Cona *et al.*, 2006).

The diamines oxidase (128 KD) present in groundnut (*Arachis hypogea*) has a lesser catabolizing Cad rate unlike to the Put (Hagiwara *et al.*, 1994). Hence, the detection that Put analog 1 aminoxy-β aminopropane (APA) at 0.1 mM concentration improved Cad titer in the wheat tissue culture (*Triticum monoccum*), however besides that it is verified lethal, and is dissimilar in response to other PA's (Yakovleva and Dudits, 1993a). While the samples of cultures were straggled for a longer duration, they exhibited an elevation in the activity of enzyme in ADC as well as in ODC resulting in an increment in Cad, spermidine and Put (Yakovleva and Dudits, 1993b). Therefore, it becomes a serious concern about how regulating aspects of Put affects Cad titer. It seems fascinating to annotate features that affect Put biosynthesis prompt Cad biosynthesis remarkably – especially APA can persuade decarboxylases.

Since, Walton, (1994) initiated that Put-N-methyl transferase (PMT), a foremost enzyme of pyrolidine & tropane alkaloids was repressed by Cad (Ki 0.04mM) and so holds a significance in synthesis of all Cad derived alkaloids.

To discover different physiochemical reactions in yeast, 9 transporter proteins are known to perform the role. Though, such studies may infer to understanding the transport of Cad in higher plants (Igarashi, 2006). Cad has zero effects on the outer chloroplast envelope porins (OEP) specially for the transportation of dicarboxylic acids, sugars triose phosphate, charged amino acids, Pi and ATP, but it affects bacterial porins (Pohlmeyer *et al.*, 1998). The elementary information of diamine transportation and its transporter is not generally well elaborated in the eukaryotes. The polyamine transporters are only categorized in *Trypanosoma cruzii* (*TcPAT12*), *Saccharomyces cerevisiae*, and *Leishmania major* (*LmPOT1*)107 at its cellular levels (GeL, 2011; Carrillo *et al.*, 2006; Hasne and Ullman, 2005). As Cad does not influence the uricase enzyme from the leaves of *V. faba*, *Cicer arientinum* and *T. aestivum* (Montalbini *et al.*, 1997), this depicts the enzyme's definite regulation in plants by it. The additional fascinating property of Cad is been prominent that it keeps a check on the degradation of proteins either in the light or in the dark in the leaf of a Chinese cabbage whereas the additional participants of the family-like spermine and spermidine enhanced the deprivation of proteins (Kwon & Kim, 1995). Though dusky triggered senescence of rice, the Cad or 1,3diaminopropane was left identified through HPLC, while additional polyamines were existent (Chen and Kao, 1991). Hereafter, they stated that endogenous levels did not show a substantial part in controlling the dusky triggered senescence in the leaves of rice. The specifications of transportation of polyamines include Cad either extra/Intra cellularity requires to be explained and specifically with the crop plants. In general, these understandings highlight the superiority of the parts which are edible with their pathogenicity, because its proper levels are essential for the growth of the bacteria (Tomitori *et al.*, 2012). Cad itself is indulged in microbial growth and progression. The DFML consumption triggering LDC indicates the inhibition of bacteria's growth because of peptidoglycan biosynthesis (Takatsuka and Kamio, 2004). As perceived, both the diamines Cad and Put fundamentally are essential for peptidoglycan biosynthesis in pathogens. The role of Cad may show clinical importance. Cad inhibits enterotoxins synthesized by Shigella sp. Virulence is acquired during the inactivity of the Cad locus gene that is accountable for the LDC in *enterovasive E.Coli* (EIEC) and *Shigella.* It is proposed as the path adaptive mutations (Jores *et al.*, 2006) since the renewal of the LDC activity post the complementation of Cad operon in a negative strain which was detected with the condensed adherence (Torres *et al.*, 2005) in the tissue culture. Under hyperthermic surroundings, cadaverine quickly conveyed in the basipetal path which was gathered with no heated *Mesembryanthemum crystallinum* roots (Shevyakova *et al.*, 2001).

Experimentations implemented in intact leaves of rice while senescence also got unsuccessful to exhibit the existence of Cad (Chen & Kao, 1991b). In contradiction to the above, Grzesik, (1993) henceforth established a noticeable upsurge in Cad while germination of seeds in *Helichrysum bracteatum* which leads to an increase in electrolytes outflow with a minimal influence on the germination (Grzesik, 1993). While endogenous Cad content is correlated with endo and exopeptidase activity throughout the regrowth of stolons and roots of *Trifolium response*. Cad repressed the endopeptidase changes in the stolons unlike roots excluding early stages during growth (Desjouis *et al.*, 1996).

The study shows Cad plays a distinct part in the senescence, depends upon the tissues, genotype, physiological and other conditions. The injury in chicken pea internodes improved Cad levels extraordinarily without disturbing spermidine and spermine and confirmed an intact relationship amongst lingo-submerization catalyzed by POD and oxidation of Cad catalyzed by DAO (Scalet, 1991). The function is dispensed in the Cad to prevent closure and opening of the stomata in the *Vicia faba* (Liu *et al.*, 2000).

Interaction of Cad with other Regulators of Plant Growth

Synthesis of the Cad is distinct in different plants by ethylene application. Cad is associated with inhibition of ethylene in the ripened fruit of tomato (Ponnampalam *et al.*, 1993). In plants, indulgence of ethylene for Cad level regulation is suggested under stresses (Shevyakova *et al.*, 2001). Exposure with ethylene increased production of Cad in marigold and in separated leaves of ice plants, while ethylene diminishes spermidine and Put. It indicates that the synthesis of Cad is also regulated by ethylene like other polyamines. The mutations can cause a dramatic upsurge in the leaves of Cad but not in the roots of *Arabidopsis thaliana* (Liu *et al.*, 2000; Shevyakova *et al.*, 2000). They proposed Cad formation that is ethylene dependent. Serving cotyledons with spermidine and Cad decreased the levels of Put in sieve-tube sap, represents comparative influence on *Ricinus communis* (Antognoni *et al.*, 1998).

Certain compounds which can be called as the modulator for Cad biosynthesis in *T.monoccum L.* culture, 0.1 mM amino-oxy-3aminopropane amplified the Cad in comparison to non-treated or with the treatment for 1.0mM 1-aminooxy-3-aminopropane (APA) (Yakovleva and Dudits, 1993a). Delayed tissue exposure with ABA could not escalate Cad in the embryonic axis (Gallardo *et al.*, 1992) of chickpea. So, this appears to be dissimilar with the proposal that Cad is anticipated as a signal transducer (Kuznetsov *et al.*, 2002).

Polyamines are mostly metabolized to alkaloids or are bound to be liable to definite alkaloids biosynthesis. The role of LDC is absolutely associated with the addition of quinolizine alkaloids that utilise Cad as the precursors (Schoofs *et al.*, 1983). The recommendation states that lysine decarboxylation to Cad is surely the initial step forward for quinolizidine alkaloid synthesis (Wink *et al.*, 1980). Eventually, transgenic *Nicotiana glauca* hairy root cultures comprising the genetic code of bacterial lysine carboxylase exhibited the improved lysine decarboxylase levels, leading to Cad and anabasin alkaloid that is a derivative of Cad (Fecker *et al.*, 1993). Cad is proposed to be a precursor of piperidine alkaloids in *Nicotiana* and the quinolizidine alkaloids in *Lupinus* (Wink and Hartmann, 1982). Henceforth, the Cad was assessed through expending byproducts of the dansyl chlorides and a bit of HPLC in rice (*Oryza sativa* L.) while, lysine decarboxylase (LDC) activity is assessed because of the production of $^{14}CO_2$ from (^{14}C)-lysine. Most probably, précised detection approaches are expensive and are the purpose that a varied range of plants is still under investigation for Cad and LDC (Cassan *et al.*, 2009).

Role of Cad in the development in plants

Depending upon its plant species, the Cad varied titer is diverse in distinct conditions. To foresee, the level of Cad also need to be monitored gradually. With respect to the length of the seedlings in *Malus hupenhensis* (Feng *et al.*, 1998), Cad levels descent steadily. This might because of Cad which has caused an inhibition of around 35%) of lysine decarboxylase in *G.max* (Kim *et al.*, 1998) due to self-inhibition. Possibly, it is simulated that the plants developmental phases also affect distribution of Cad. Further, at the time of seed propagation, the Cad numbers hike but started to drop in pea shoots on an extended growth phase of 6-18 days in sunlight conditions. Therefore, leaves hold seventy folds less Cad than in roots. Higher content of Cad was observed in dark-grown axes (2 µmol/g Fr. Wt.). $CaCO_3$, ammonium treatment or K^+ deficiency did not change Cad in *Phaseolus aureus, P. vulgaris or Vicia faba* (Smith and Wilshire, 1975).

Both Put and Cad participate for a similar arrangement for several activities as both are related to each other with respect to charge distribution. Similarly, both inhibit the parquet influx in the roots of maize whole saplings. Hence, it shows that Cad inhibits arrival of Put competitively (Hart *et al.*, 1992). The total percentage of Cad / polyamines was adversely related with the height in a crab apple (*Malus hupehensis*), while Spd/Cad percentage is firmly interrelated (Bao and Li, 1998). Cad (0.5, 1.0, 2 and 5 mMol/L) repressed seed propagation in rice and sapling growth, particularly in roots (Kong *et al.*, 1996).

Questionably, Gallardo *et al.* (1994) entrenched, the growth of embryonic axes in *Cicer arientinum* is found to be associated with the improved levels of Cad, while the levels of reduction in Spm & Spd reduced. Many phases of the plant growth are interrelated with the Cad. The Non-morphogenic and dedifferentiated wheat cell lines demonstrated very reduced levels of the Cad in comparison to Put. Gamarnik and Frydman (1991) stated, the levels of Cad are extensively huge in embryonic axes if compared to cotyledons of *G.max*. Throughout the initial 24 hours of soybeans propagation was primarily high, which once was lowered because of the difluoro-methyl ornithine (DFMO) otherwise. To define the DFMO (1mM) is not stirring any further polyamines to show a strange development of roots that is triggered by DFMO. This irregularity reversed by 1mM of Cad suggests its precise role in growth of roots. Cad identified in the soybeans embryos with high levels present in roots & hypocotyls, district to *P.vulgare* where the Put amount, spermine & spermidine growing from shoot apex base. 0.5 mM of Cad has a complete potential to encourage flowering in *Pharbitis nil* cv Kidachi as related to that of Put holds a possibility to encourage blossoming up to 98 % (Wada *et al.*, 1994).

Though, Caffaro and Vicente (1994) confirmed, Cad along with further polyamines is nourished in the flowering procedures. Also, certain distinct reactions are observed in an alkaloid biosynthesis. Cadaverine pyruvate transaminase is an important phase in the quinolizidine alkaloid biosynthesis in *Lupinus* cell culturing (Wink and Hartmann, 1982), whereas there was no biosynthesis of tropane alkaloid in datura, whereas tobacco, the alkaloid biosynthesis is normally after serving Cad to cotyledons (Carrizo *et al.*, 2001).

Role of Cad in Pathogenicity of Plants

Generally, polyamines are involved in pathogenicity but levels of Cad simply make no clarity of guild with the development of disease triggered because of *Ustilago scitaminer* in the case of sugar cane (Piñon *et al.*, 1999). SH-Cad high titer in extended leaves, stems, and diseased plants roots in comparison to non-infected gets treatment as signal of *U. scitaminea* to be the reason for smut in sugarcane (Legaz *et al.*, 1998). The pathogenicity is dependent on the structure of polyamines.

Cad role in Anti-stress/ Anti-senescence

The role of polyamine is cited generally in anti-stress and anti-senescence. Three distant concentrations of Cad (0.2 mM, 1 mM, and 10 mM) exhibited zero effects on senescence in the leaves of barley in dark (Srivastava, 1987). Cad constrained the lipoxygenase-1 and not lipoxygenase-2. So, Cad held an improved or closely same inhibitory feedback as correlated to that of Put (Maccarrone *et al.*, 1998). Vassileva and Ignatov, (1999) planned where the Put normally is called as the forerunner of Spd and Spm that shows an inhibitory feedback on interaction may be well-adjusted through Cad. deceptively occurring over the particulars of Cad role on anti-senescence/ anti-stress.

Uniqueness of Cad

Kamio, (1990) recognized as the anaerobic bacterium consists of the Cad associated with peptidoglycan; while minus of a gene for further polyamines considers a particular component of such microbes. Cad has few diverse effects like parquet translocation of perfect maize seedlings (Hart *et al.*, 1992) in roots. In common profile of PA is treated as chemotaxonomy for genus xanthomonas (Yang *et al.*, 1993). Inordinate presence of Cad, absence, proposes; that the usage can be as the marker of chemotaxonomy for leading species of plant. Nevertheless, it accepts the reaction to negotiate in several systems of plants maybe because of the specific potential of polyamines persuaded phosphorylation in proteins confirming that Cad holds very less or zero effects on the phosphorylation and solvable proteins as compared to different polyamines.

Conclusion

The real challenge for plant scientists in agriculture is stress management and so it is ideal to understand the mitigation of plant growth under multiple stresses to optimize the growth and yield of the plant. A group of a new class of growth regulators viz cadaverine diamine an obligate precursor for polyamines such as spermidine and spermine is involved in improvement of plant growth, even in stress conditions. The other naturally appears diamine cadaverine combined in the polyamine group of compounds, having a separate biosynthetic pathway is also treated to be a plant growth regulator. As a literature survey express cadaverine is either least studied or no definite information about plant growth modulation under stress. A very few extensive researches have been carried out related to that of putrescine/ spermine/ spermidine to analyze the plant growth management, especially under multiple stress conditions. It is also assumed hypothetically that the relation between ethylene and polyamines can determine the effects of soil drying during grain filling of rice (Chen *et al.*, 2013). Polyamines (PAs) are said to be nitrogenous molecules that play a crucial role in almost all the cellular processes during the growth and development under multiple biotic and abiotic stresses (Moschou *et al.*, 2012). In few studies, cadaverine titer is noted to be very less under metal stress or K^+ deficiency (Sung *et al.*, 1994) whereas; presence in the leguminous plant is extensively noted (Fujihara *et al.*, 1995; Felix and Harr, 1987). There are few higher plants product also consist of cadaverine for example table olives (Garcia-Garcia *et al.*, 2000), sugar cane juice (Armas *et al.*, 1999; Rodriguez *et al.*, 2000), ripened eggplants (Rodriguez *et al.*, 1999) and leaves of grapevine (Martin-Tanguy and Carre, 1993) but without any meaning for physiochemical relevance except few recent examination like closing and opening of stomata (Liu *et al.*, 2000), inhibition of lipoxygenase 1 and 2 (Maccarrone *et al.*, 1998).

Though polyamines are involved in anti-senescence response (Liu *et al.*, 2000) yet cadaverine diamine is described to be having zero effects on senescence in barley (Srivastava, 1987) or cause differential alkaloid synthesis (Carrizo *et al.*, 2001) and increase membrane permeability of mitochondria. Since the physiological purpose of polyamine hike under stresses is least explored (Liu *et al.*, 2000) cadaverine exogenous application under stress is likely to bring insight to understand the growth mechanism of plants, especially under twin stresses. The endogenous level in leaf & possible level in seeds could be used to find out the nutritional value and quality of vegetable oil. This will be very relevant as nutritional management of cancer patients since polyamines are implicated in the tumor. Possibly the study will be providing an understanding of the mechanism of physiological responses, compared with putrescine. This is under investigation by different workers.

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