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Abiotic stress impact on moong (*Vigna radiata* L.) and strategies by earthworm enhance soil condition

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Abstract
Moong (*Vigna radiata* L.) generally known as green gram is one of the most important legume and contain a high composition of proteins, vitamin, mineral and thymine, niacin and ascorbic acid. It has wider adaptability to grow short-duration (65-90 days) and requires low input. High or regular increasing temperature will be detrimental for growth functions of various crop plants and increasing demand of Moong during spring/summer season in major growing region in Northern parts of India. Decrease in Moong quality and yield are influenced by abiotic constraints like high temperature, drought, salinity, metal. Photosynthetic activity is recognized as sensitive to elevated temperature and causes loss of chlorophyll and reduction in carbon fixation and assimilation. Aim of study, the role of abiotic stress impact on the growth of moong and the significant role of earthworm to improve the growth and productivity of moong. In the northern plain, India lies in the Indo-Gangetic plain, moong is grown in the summer/spring season for cropping patterns followed by potato, tomato, wheat etc., these are the major crop in Haryana, Punjab and Uttar Pradesh. In heat stress, an adaptation of physiological and biochemical processes gradually may lead to improvement of heat tolerance in plants. Soil conditions manage by agronomic practices at farm for enhance the productivity and quality. Hence, it is necessary to enhance productivity of food grain legumes by available sustainable source i.e. improve soil condition e.g. salinity, ion-extraction. Earthworms play an important role to promote the growth of mung bean and other crop in a sustainable way. Earthworm and its product (vermicompost and vermiwash) aid to overcome in stress condition and provide nutrition to crop.

Keywords: abiotic stress, diseases infection, earthworm, soil condition

Introduction
Moong (*Vigna-radiata* L.) belongs to the *Leguminose* family and it is an important pluses crop grown in an Asian countries like India, it is widely consumed in the form of cooked whole grain, dhal and flour. In Asian countries, moong soup is a popular dish (Li *et al.*, 2012) [27]. India is the world's largest producer as well as consumer of green gram. It produces about 1.5 to 2.0 million tons of moong annually from about 3 to 4 million hectares of area, with average productivity of 500kg per hectare. Green gram output accounts for about 10-12% of total pulse production in the country. Now a day, green gram sprouts are feed all round the world for their health benefits (Zhu *et al.*, 2012) [64]. Moong cultivated on about six million hectare worldwide, the most of which are located in Asia (Nair *et al.*, 2013) [36]. Sharma and Manjeet, (2019) [27] reviewed that the high temperature is most important stress that adversely effect on growth, productivity and quality of fruit crops. The bioactive compound is released from germinating seed into their surrounding medium and depend on their composition and the temperature of the medium. At 45 ^{0}C, polyphenols and protein contents were higher as compared to room temperature during imbibitions (3). Leguminous crops are being cultivated in various crop rotations (cereals-pulses or pulses-cereals) to improve soil fertility (Prakash *et al.*, 2008) [41]. Nitrogen (N), phosphorus (P) and potassium (K) higher use of quantity, however increased crop production several fold higher after the green revolution but this has led to micronutrient deficiency in most of the Indian soils (Singh, 2001; Sahrawat *et al.*, 2010) [48, 45]. In India, condition of Cu and Mo are likely to be critical in the future for sustaining the high yield and growth of plant (Singh, 2004) [49]. Legumes are harvested twice a year and store normally in jute bags and bins or dark large ventilation cemented store rooms.

The post- harvest handling and storage loses of upto 85% of the total productio are quite common. A country-wide study measuring crop losses revealed that 3.9% - 6% cereals, 4.3%-6.1% pulses, 2.8%-10.1% oilseeds, 5.8%-18.1% fruits, and 6.9%-13% vegetables were lost during harvesting, post-harvest activities, handling and storage (Anonymous, 2019) [7]. During storage legumes losses, quality and quantity due to physo-chemical and biological factors like temperature, humidity, micro-organisms, fungi, insects, rodents and birds. The insect (*Callosoburchus chinenis*) is the major caused of weight loss, lower germination and quality deterioration of stored legumes. R. Modgil (2003) [42] showed that the green gram losses quality and quantity if the time of storage more than six month, legumes also becomes unhygienic due to presence of insect excreta and higher amount of uric acid in stored legumes induce gout in the consumers. The present study was planned to discuss the impact of abiotic stress i.e. meteorological factor, soil condition and storage on quality and quantity of green gram (*Vigna Radiata L*.).

Impact of heat stress on moong

At high temperature flower drop, induce male sterility to impair anthesis and shorten grain filling period at reproductive stage. Two different genotypes EC 398889 and LGG 460 were identified which were heat tolerance and heat sensitive at temperature range 37-52 ^{0}C and also sucrose-synthase activity and pollen germination were normal at a temperature beyond 40 ^{0}C in EC 398889 than LG 460 (Basu *et al.*, 2019) [11]. Aboitic stresses are adversely affected green gram adaptability and productivity including heat, drought, salinity and water-logging, which affect crop growth and development by altering physiological process and the plant-water relationship (Suzuki *et al.* 2014; Zandalinas *et al.*, 2017; Landi *et al.*, 2017) [54, 62, 25].

At 30^{0}C and 40^{0}C, green gram thrives most effectively and beyond 40^{0}C was significant for flower, shielding reported that the abscission of reproductive organs is the primary determinant of yield under heat stress (Zinn *et al.*, (2010) [65]; Sita *et al.*, (2017) [52], Rainey and Griffiths, (2005) [43]. The above optimum (>35 ^{0}C) temperature can induce chlorosis sun-burn on vegetative tissues, sencescence and abscission of leaves, inhibition in the growth of root and shoot and finally substantial reduction in seed yield in various plant species (Vollenweider and Gunthardt-Goerg, 2005) [59]. Heat stress casuses several variations at cellular and sub-cellular levels and the responses of the plants depend upon the growth stage intensity and duration of the exposure (Sung *et al.*, 2003) [53]. Ascorbic acid is a powerful antioxidant that depends on the cells from oxidative damage occurring due to photosynthesis, aerobic metabolism and abiotic stress (Upadhyaya *et al.*, 2010) [56]. Egorova *et al.*, (2011) [15] found that heat shock temperature (48-55^{0}C) increases the releasing of cytochrome from mitochondria to cytosol and causes concomitant nuclear DNA fragmentation during the first six hours of heat shock at 50 ^{0}C and 55 ^{0}C. Sub-lethal heat shock (48 ^{0}C) gave rise to non-ladder and lethal shock at 50 ^{0}C and 55 ^{0}C exhibited both ladder and non-ladder DNA degradation. So heat stress induced inhibition in growth and chlorosis was associated with a decrease in leaf water status and elevation of oxidative stress, which could partly be prevented by exogenous application of ascorbic acid for protection against heat stress Kumar *et al.*, (2011) [24]. The reproductive stage is most sensitive to a high temperature which causes loss of flower buds, pods and seed yield. The reproductive stage includes functioning of flowers to achieve pod set *viz*., loss of pollen viability, germination, poor anther dehiscence less pollen load on stigma and its sterility. The stigmatic surface also loses receptivity coupled with poor ovule viability (Kaushal *et al.*, 2013) [22].

Diseases stress on moong

Mungbean yellow mosaic Indian virus (MYMIV) commonly known as a yellow mosaic virus (YMV) appears to be one of the major diseases in green gram. Direct or no definite prophylactics control measures of YMV are available to minimize this loss. Moreover, controlling its insect vector, whitefly (*Bemisia tabaci*), may restrict the dissemination of this YMV (Mandal *et al.*, 1997) [29]. A Gosh, (2008) [1] showed crops under YMV management achieved 65.67% more seed yield producing 11.68q/ha which was significantly higher than the crops under no YMV management. Controlling the vector with insecticide encouraged all the varieties to produce significantly more seed yield compared to those under no vector control measures.

Yelllow Mosaic Diseases (YMD) is the major constraint of mungbean and showed a strong position relation with temperature, relative humidity and rainfall (Parihar *et al.*, 2017) [38]. Yellow Mosaic Diseases is caused by representative species of the genus Begomo virus of the family *Geminiviridae*, which are transmitted by the vector whitefly (*Bemisia tabaci*), and severity of disease depend on the vector population dynamics which is indirectly controlled by external environmental factors and also it has been established that three species of *Begomovirus* mainly caused Yellow Mosaic Diseases that is mungbean yellow mosaic virus (MYMV) Mungbean Yellow Mosaic India Virus (MYMIV) and Horsegram Yellow Mosaic Virus (HgMV) which was also confirmed by PCR based analysis (Naimuddin *et al.*, 2011) [35]. High stress conditions can offer an opening to several insect-pests and several disease conditions which result in the loss of productivity and quality of moong (Singh and Singh, 2011) [50].

Role of soil condition in moong

Green gram responded highly to Molybdenum application in soils below the critical limit, soils with Mo greater than 0.082 mg/kg did not respond as the 0.075 mg/kg gave better yield than others. Mo applications in green gram improve yield and production (Velmurugan *et al.*, 2013) [58]. Earthworm increase soil fertility by their activities and promote overall plant growth. Therefore, they are also called “Friend of framer” (Francisco *et al.*, 2019) [16]. Cast released by earthworm has buffering capacity and this cast have many beneficial microorganism for plant growth. Earthworm form a symbiotic association with different microorganism and provide easily usable Nitrogen, Phosphorous, and Potassium Magnesium etc in their surrounding soil (Chattopadhyay, 2015; Bulgari *et al.*, 2019) [14, 12]. Earthworm maintain the abiotic factor like soil pH, soil porosity, soil moisture etc in such a way that plants will not effected in stress condition. Thus finally increase the plant yield. Earthworm and its product like vermicompost and vermiwash also used to promote the yield of mung bean. The vermiwash of *Eudrilus eugeniae* are also could be a good avenue in achieving good productivity for other legumes and other crop (Mahmoudi *et al.* 2016; Francisco *et al.* 2019**)** [28, 16].

Salinity severely limits the growth and yield of moong worldwide approx. 50 mM NaCl can cause >60% yield losses

(Abd-Alla *et al.*, 1998). Moong is grown in irrigated soils with salt deposit in upper layer due to soil evaporation of water during the dry season that is create water stress and imparts nutrient imbalance that triggers metabolic damage and cell death (Hasanuzzaman *et al.*, 2013 b) [19]. Under high salinity soils are unable to take adequate nutrient or water for metabolic process due to low osmotic potential soil-salt-alkalization complex ion is formed by salt-alkalinzed soil for various ion formation (Lauchli and Luttge, 2002). Alkaline salts ($NaHCO_3$ and Na_2CO_3) were showed a more deteoriate physiological stage of plant as compare to neutral salt (NaCl and Na_2SO_4) (Yang *et al.*, 2007). High NaCl concentration in soil exposed to plant and accumulate Na^+ and Cl^- ion which are damage the plant tissue and also high concentration Na^+ and K^+ uptake, resulting in lower productivity and may even lead to cell death (James *et al.*, 2011; Ahmad and Umar, 2011) [21, 4].

Plant damage various physiological and biochemical mechanism in adaption or survive in high salt concentration soil. Principle mechanisms include ion transport uptake and compartmentalization biosynthesis of osmoprotectants and compatible solute, activation and synthesis of antioxidant enzymes/compounds polyamines and hormonal modulation are not limited (Ray *et al.*, 2003) [44]. Chlorosis, necrosis and decreased content of chlorophyll and carotenoids are symptoms of salt in moong (Wahid *et al.*, 2004; Phillips and Collins, 1979) [60, 39] showed that callus from moong grown in sand culture with Hoagland's nutrient solution supplemented with 0-350 mol/m^3 NaCl tolerance to salt as that of the whole plant appears to have salt tolerance at a cellular level. More and Ghanokar, (1984) [33] determined that the critical level of salinity in irrigation water to cause injury to seed germination in moong was 3.5 m mhos/cm. Germination rate was decreasing under saline soil due to high osmotic pressure (Mudgal *et al.*, 2010) [34]. Growth of plant hazard due to increased NaCl concentration which was damaged the root of plant (Misra *et al.*, 1996) [30]. High salinity causes decreases in total leaf area and stomatal opening (Naimuddin *et al.*, 2002).

Moong showed decreased growth, photosynthesis and yield at a high salinity but postponed pod ripening during the spring resulted in reduced pod shattering (Sehrawat *et al.*, 2013) [46]. Transpiration and CO_2 assimilation rates maintance under heat stress as a direct relationship with heat tolerance mechanisms of active stress (Kumar *et al.*, 2005) [23]. Heat markedly affects the leaf stomatal and CO_2 assimilatory functions driven by photosystem-II-photochemistry (Greer and Weedom, 2012) [18]. Decreases in germination percentage, seedling ermergence, cell size, poor vigor, and reduced radical and plumule growth were the major impacts of heat stress reported in various plant species (Piramila *et al.*, 2012) [40].

Pyrroline-5-carboxylate and y-glutamyl kinase reductase are responsible for the synthesis of glycinebetaine and proline while an enzyme which the facilitate the conversation of proline to glutamate is proline oxidase which reduces the level of proline. During salt conditions decreases proline oxidase increases the proline level due to the absence of calcium in roots and shoots (Misra and Gupta, 2006) [31]. Arulbalachandran, D *et al.,* (2009) [9] observed that the doses of salt (NaCl) concentration for three species of Moong (T44, SML 66, Sarif) after 15 days. The increased salt condition was decreased seedling growth germination percentage relative growth rate and photosynthetic pigment.

Earthworm's activities increase soil fertility by improving soil formation, soil porosity, water infiltration, decomposition of organic material, humus formation, suppression of soil-borne diseases & pests, and by promoting nutrient cycles which ultimately help in plant growth. Due to their beneficial activities, they cause the main change in soil properties; therefore, they are known as "Ecological engineer" (Bartlett *et al.*, 2010; Sinha *et al.*, 2010) [10, 51]. The earthworm has the efficiency to engulf a vast amount of organic material and release cast (earthworm excreta). Earthworm's cast is organic fertilizer because of rich in humus, exchangeable nitrogen (N), phosphorus (P), potassium(K), manganese(Mn), calcium (Ca) and other beneficial microorganisms (MOs) (phosphate solubilizing bacteria, N-fixing bacteria, *Pseudomonas*, actinomycetes) and plant growth hormone (gibberellins, auxin, cytokinin) (Sinha *et al.*, 2010; Adhikary 2012) [51, 3].

Cole of earthworm in moong

Climate change and weather effects plant growth specially legumes. Abiotic stresses strongly affect plant growth, development, and quality of production; final crop yield can be compromised if stress occurs in plants' most sensitive phonological phases (Bulgari *et al.*, 2019) [12]. There is no doubt earthworm and its product (vermicompost and vermiwash) increased the mung bean by reducing stress conditions. Earthworm *Perionyx ceylanensis* increased the overall growth of mung bean (Gopinathan *et al.*, 2015) [17]. Coelomic fluid collected by *Eisenia foetida* and *Eudrilus eugeniae* earthworm has an important role in germination, growth and antioxidant properties in the seed of mung bean. This may be due to provide optimal pH, which is most important for enzymatic properties during seed germination of mung bean (Chattopadhyay, 2015; Vadivu *et al.*, 2020) [14. 57]. Francisco *et al.*, (2019) [16] studied that *Eudrilus eugeniae's* vermiwash application on mung bean improved the number of nodules per plant, pod length, number of seed per pod, seed weight, yield per hectare, and length of roots. In drought stress conditions, mung bean grain yield, biological yield, protein yield, leaf relative water content and membrane stability decrease whereas protein and proline percentage were increased. Vermicompost directly provides nutrition to the mung bean. Vermicompost increased grain yield, biological yield, protein yield, and cell Membrane stability, and reduced the accumulation of proline (Mahmoudi *et al.*, 2016) [28]. The use of treated wastewater for irrigation in mung bean crops is sustainable agriculture but this treated waste water cuse oxidative stress in green mung beans. As a growth and physiological parameter were modified in mung bean. Presence of *Eisenia andrei* earthworm in this particular crop soil protects the mung bean from oxidative stress and stimulates overall growth of mung bean (Mkhinini *et al.*, 2020) [32]. Earthworm and its product not only help in promoting growth of mung bean in strees condition but also promote the growth of other plant. For examples; in maize *Eisenia fetida* earthworm increased the maize salt tolerance by decreasing the salt concentrations, increasing the soil macro aggregate proportions, soil bacterial diversity, maize mineral uptake, and photosynthesis (Zhang *et al.*, 2016) [63]. Thus, we can say that earthworm's important role in mung bean and other plant growth by reducing stress condition.

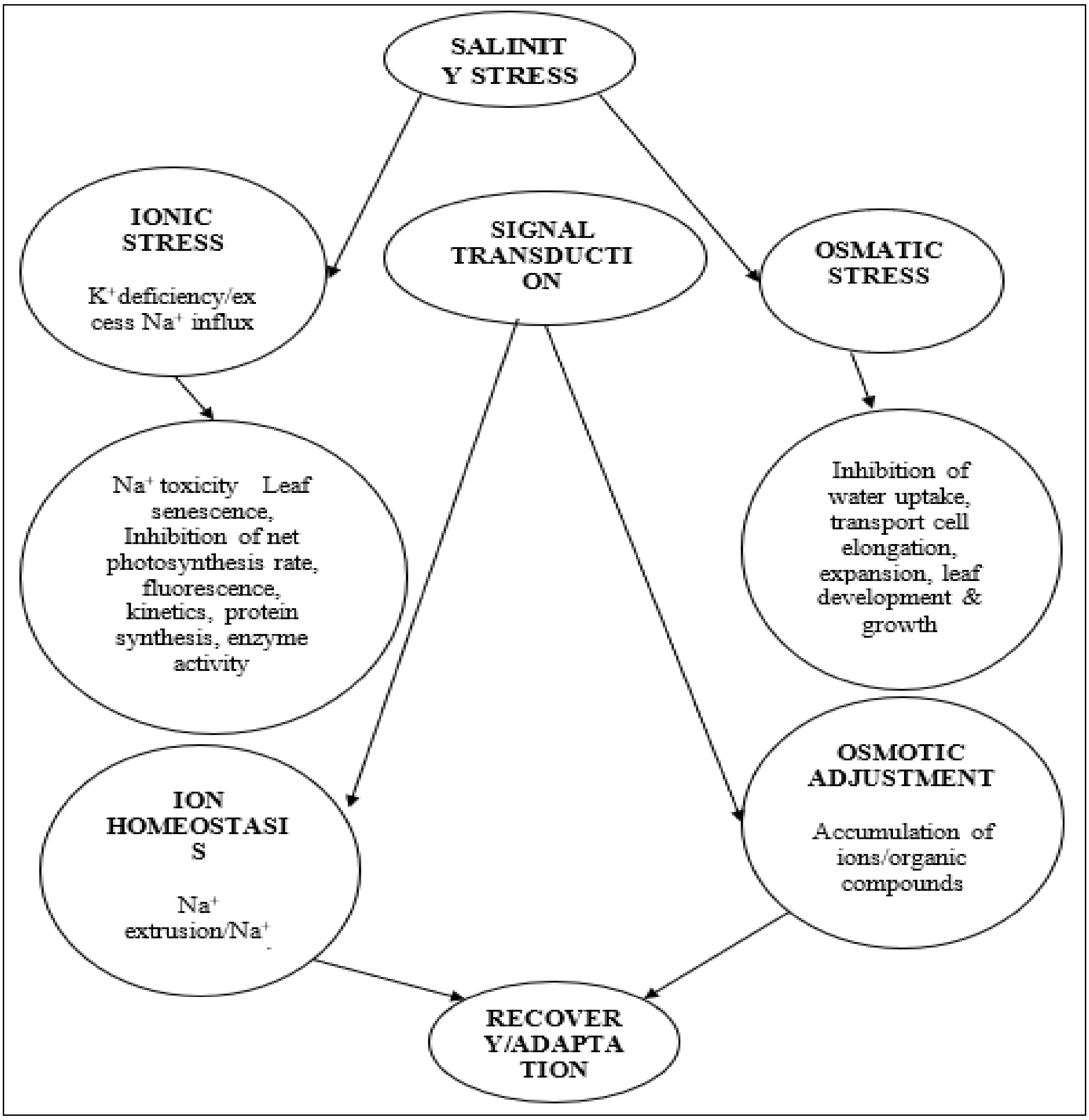

Fig 1: Schematic summary of salinity stress in plants and corresponding intrinsic physiological responses (Horie *et al.*, 2012)

Conclusion

Plant adaptation or tolerance to salinity stress involves complex physiological traits metabolic pathways and molecular or gene network. Plant respond to salinity stress at a different level and an integrated approach combining molecular physiological and biochemical techniques are imperative for developing salt tolerant varieties in salt affected area. Earthworm and its beneficial product (vermicompost and vermiwash) help in the plants to overcome in stress condition. They modified the soil condition directly and indirectly to promote overall plant growth. Crop varieties/genotype varies in their inherent ability to adjust several physiological and biochemical process in responses to salt stress. The management and regulate the use of nutrient is very helpful to develop plant tolerance to temperature stress. Moong has the distinct advantage of being a short duration crop and it can grow un a range of soil and environment as a solo or as a relay crop. To increase the productivity of Moong, to maintain or agronomic /farm managements, results decreases the deteoriation of drought and salinity. It can be done by incorporating abiotic stress tolerated gene in their genotype to increase the quality and yield of the Moong.

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