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Potential Foliar Chemicals for Enhancing Yield and Drought Tolerance in Leguminous Crops: A Review

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ABSTRACT

In pulse crops, synchronized flowering altered the source-sink relationship due to the rapid translocation of nutrients from leaves to the developing pods. Additional nutrition through foliar feeding plays a vital role in pulse production by stimulating root development, nodulation, energy transformation, various metabolic processes and increasing pod setting, thereby increasing the yield. Many researchers are trying to reduce transpiration losses, flower shedding and maximizing productivity, foliar application of nutrient formulations and growth regulators in pulses. Thus, the foliar application of macro and micronutrients and growth regulators is considered an efficient and economical method of supplementing part of the nutrient requirements and moisture stress tolerance at critical stages. The PPFM (Pink pigmented facultative methylobacteria), when used as a foliar spray, it releases osmoprotectants (sugars and alcohols) on the surface of the plants and it increases chlorophyll content, thereby increasing the photosynthetic efficiency and makes drought tolerance ability of plants. This matrix helped to protect the plants from desiccation and high temperatures. Whereas potassium as spray also enhances drought tolerance in plants by mitigating harmful effects by increasing translocation, maintaining water balance and increasing pod filling. Further, Salicylic acid is an endogenous growth regulator of phenolic nature, which regulates physiological processes to mitigate stress, acts as a chelate for phosphorous uptake, increases pod setting, flowering and grain yield. Pulse wonder decreases flower shedding, increases yield by up to 20% and offers moisture stress tolerance.

Key words: Foliar chemicals, KCL, PPFM, Pulse wonder, Salicylic acid.

In agriculture practices, fertilizer is an important input to increase crop yields. Among fertilizer application methods, one of the best application methods is foliar nutrition because foliar spraying facilitates easy and quick absorption of nutrients by penetrating the stomata or leaf cuticle and entering into the cells (Latha and Nadanassababady, 2023). Due to several concentrations of foliar applications like a quick and proficient response to the needs of plants, less needed products and soil conditions independency, the concentration towards foliar fertilizers is rising daily. It is also determined that during crop growth, supplementary foliar fertilization increases plants mineral content and improves crop yields (Kolota and Osinska, 2001). Foliar application is most effective when roots are incapable of absorbing the required amount of nutrients from the soil due to some reasons like the high degree of fixation, lack of soil moisture, losses from leaching and low soil temperature (Singh *et al*., 1970). The mineral nutrients assimilation rate by plants' aerial parts differs among plant species and many varieties of the same plant species (Wojcik, 2004).

Foliar application of nutrients at proper growth phases is essential for their consumption and improved crop performance (Krishnaveni *et al*., 2004). The presence of nutrients like Nitrogen, Phosphorus, Potassium, Sulphur and Magnesium are essential in balanced form for significant development processes of plants and yield production (Marimuthu and Surendran, 2015). Foliar application is most effective when roots are incapable of absorbing the required amount of nutrients from the soil due to some reasons like the high degree of fixation, lack of soil moisture, losses from leaching and low soil temperature (Singh *et al*., 1970). It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants and

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increase crop yield (Rajesh and Paulpandi, 2013). It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase crop yield (Elayaraja and Angayarkanni, 2005).

Apart from the genetic makeup, the physiological factors, *viz*., insufficient portioning of assimilates, poor pod setting due to the flower abscission and lack of nutrients during critical stages of crop growth, coupled with several diseases and pests were the reasons for the poor yield (Mahala *et al*., 2001). Pulses usually produce many flowers but only a few are retained and developed into pods (Kunjammal and Sukumar, 2019). Supply of nutrients through foliar application during the critical stage ensured a positive source-sink gradient of photosynthates translocation and balanced growth habit (Maheswari and Karthik, 2017). This is attributed to reduced flower shedding and an increase in pod setting, grain filling and, ultimately, the yield. The major disadvantage with the foliar application is that about 10kg N/ha can be applied in a single spray with high volume (500-600 litre/ha) sprayers, available with the farmers, since the highest permissible concentration of urea in the spray solution beyond 3%, leaves get scorched (Senthilkumar *et al*., 2008).

The importance of foliar nutrition can be applied directly to the site of metabolism. It increases yield by up to 15 to 25%. The plant uses more than 90% of the fertilizer. Deficiencies can be corrected within a short period. Foliar applied fertilizers are more effective than soil applied fertilizers. Foliar feeding practices would be more useful in legume crops, which could be combined with regular plant protection programmes.

Importance of foliar nutrition in pulses

It has been well established that most plant nutrients are absorbed through the leaves and absorption would be remarkably rapid and nearly complete. Moreover, foliar feeding practices would be more useful in early maturing crops, which could be combined with regular plant protection programmes. If foliar nutrition is applied, it reduces the cost of cultivation, reducing the amount of fertilizer, thereby reducing the loss and also economizing crop production. Foliar application of N at a particular stage may solve the slow growth, nodule senescence and low seed yield of pulse without involving root absorption at the critical stage (Latha and Nadanassababady, 2023). Selvam *et al.* (1999) reported that top dressing of 10 kg N ha^{-1} to groundnut (as a foliar spray at 2 per cent urea yielded 2.82 t ha^{-1} of pods while the same soil application produced only 2.47 t ha^{-1}. It also increased the oil content significantly.

Foliage applied macro and micronutrients at critical stages of the crop was effectively absorbed and translocated to the developing pods, producing more number of pods and better filling in soybean (Jayabal *et al.,* 1999). Thiyageshwari and Ranganathan (1999) studied the effect of foliar application of nutrients and the recommended dose of nutrients on the soybean's dry matter production and yield. They also reported that foliar application of NPK with $MnSo_4$, $ZnSo_4$, Sodium molybdate and boron yielded the highest seed yield of 1832 kg ha^{-1} followed by foliar application of boron (1398 kg ha^{-1}) as against the recommended NPK (1225 kg ha^{-1}).

Subramani and Solaimalai (2000) reported that poor production of pulses was attributed to poor photo-assimilates, which could be improved through foliar application of macro and micronutrients and growth regulators. In recent years, various chemicals in solution form have been directly sprayed on the leaves of crop plants since they are readily absorbed and utilized more efficiently. When the problem of soil fixation of nutrients exists, foliar fertilization constitutes a more effective means of fertilizer application, especially under water logged conditions. Application of nutrients through foliar spray at the appropriate growth stage is an essential practice for the effective utilization of nutrients and better performance of the crop. Timely supply of nutrients through foliar spray favours positive source-sink gradient of photosynthates translocation and balanced growth habit. This induced more flowers and fruiting and reduced the shedding of flowers and fruits in green gram (Ravisankar *et al*., 2003).

Ganapathy *et al.* (2008) reported that the reproductive efficiency of blackgram, like the number of flowers formed, number of flowers shed and fruit drop percentage, were significantly influenced by various foliar spray treatments. Foliar application of DAP 2% + NAA 40 ppm + micronutrients significantly increased the total number of flowers formed per plant. It decreased the number of flowers shed compared to the control and resulted in a significantly higher number of pods formed and grain yield. Bhowmick *et al.* (2005) opined that as no tillage operation was done for sowing pulses as a relay crop, it is difficult to apply fertilizer either through placement or the top dressing. Therefore, the scope of fertilization becomes confined to foliar nutrition in *rabi* pulses. Foliar application of Bio-gas slurry with panchagavya spray increases grain yield in greengram (Somasundaram *et al*., 2007). Foliar application of nutrients and growth regulator at pre flowering and the flowering stage was seen in reduction in flower drop percentage in greengram (Ganapathy *et al.* 2008). Foliar application of NAA at 40 ppm at pre flowering stage in blackgram influenced growth characteristics by showing increased plant height, more number of branches and a higher Leaf Area Index (Jayakumar *et al.* 2008).

Gupta *et al.* (2011) conducted an experiment to study the effect of biofertilizers and foliar sprays of urea on symbiotic traits, nitrogen uptake and productivity of chickpea. They concluded that applying 20 kg N ha^{-1} + rhizobium + PSB + PGPR + 2% urea spray at flowering and 10 days thereafter resulted in a higher nodule number and nodule dry weight. Foliar nutrients are known to influence a wide array of physiological parameters like alteration of plant archetype, assimilate partitioning, promotion of photosynthesis, uptake of mineral ions, enhancing nitrogen metabolism, promotion of flowering, uniform pod formation, increased mobilization of assimilates to defined sinks, improved seed quality, induction of synchrony in flowering and delayed senescence of leaves (Sharma *et al*., 2013).

Role of potassium on crop growth and stress management

The potassium requirement of pulses is relatively high. Apart from fulfilling other major physiological and biochemical requirements for plant growth. K is a critical major nutrient element for protein in pulses. Foliar application of K augments the synthesis of natural organics like sugar, C3 and C4 acids, betaine *etc*. It favours the accumulation of proline and abscisic acid (involved in withstanding protein denaturation under stress conditions). The application of K helps regulate stomatal opening and controls water loss through osmoregulation. Under saline and alkaline conditions, adequate K competes with Na, maintains a low Na: K ratio and induces tolerance through stabilizing chemiosmotic potential in plants (Suzy *et al*., 2017).

The nutritional status of the plant is the indicator of its response to environmental stress. Potassium plays a significant role in osmoregulation, photosynthesis, transpiration, opening and closing of stomata and protein synthesis. Potassium enhances drought tolerance in plants by mitigating harmful effects by increasing translocation and maintaining water balance (Cakmak, 2005).

Potassium is also vital in translocating photosynthates from source to sink (Cakmak, 1994). Potassium influences the photosynthesis process at different levels, namely, the synthesis of ATP, activation of enzymes involved in photosynthesis, CO_2 uptake, the balance of electric charges needed for photophosphorylation in chloroplasts and the light-induced H^+ flux across the thylakoid membranes (Marschner, 1995).

The impact of foliar application of KCl 0.5 per cent and NAA 40 ppm were compared and it found that crop growth and yield of soybean can be increased by KCl sprays under water stress conditions by maintaining tissue water potential and preventing water loss (Velu, 1999). It also increased the oil content significantly. Application of 1.3 per cent KCl at 45 and 60 DAS significantly increased seed cotton yield (Krishnaveni *et al*., 2004).

Govindan and Thirumurugan (2000) observed that the foliar spray of KCl (1 per cent) + KNO_3 (1 per cent) increased the grain yield of green gram by 21.8 per cent. Ramesh and Thirumurugan (2001) stated that foliar applications of 2 per cent DAP and 1 per cent KCl along with benzyladenine 25 ppm had significantly increased the plant height in soybean. The increased lint yield is due to foliar applied potassium under the low soil potassium condition (Cakmak, 2005). Potassium affects respiration, photosynthesis, chlorophyll development, water content of leaves, carbon dioxide (CO_2) assimilation and carbon movement in mungbean (Sangakkara *et al*., 2000).

Foliar application during flowering increased seed set and prevented pre-mature abortion of embryos. It also improved the keeping quality of seeds in storage with good germination and vigour index. Foliar application of DAP and growth regulator at pre flowering and flowering stage resulted in reduced percentage of flower drop in green gram (Ganapathy *et al*., 2008).

Water deficit at any critical crop growth stage severely restrained the growth and yield of any crop. Foliar application of potassium at all critical stages improved all the yield components (Babu, 2017). The growth of the crop is reduced when potassium is not applied sufficiently (Hermans *et al*., 2006). Kaviti Vijaya Lakshmi *et al*., (2018) reported that 1% KNO_3 twice at pre-flowering and pod filling stages (F3) recorded significantly the highest growth and yield of blackgram when compared with other foliar treatments. Foliar application of 1% Kcl resulted in higher grain yield in blackgram as reported by Uma Maheswari *et al*. (2014).

Importance of salicylic acid on crop growth and stress management

Salicylic acid is ortho-hydroxybenzoic acid and is a secondary metabolite acting as analogues of growth regulating substances. It helps in the protection of nucleic acids and the prevention of protein degradation. Salicylic acid is also known to induce many genes coding for pathogenesis-related proteins in response to biotic and abiotic stresses (Yalpani *et al*., 1994). Foliar application of Salicylic acid increased the indole acetic acid (IAA) content in broad bean leaves (Liu *et al*., 2000). Foliar application of salicylic acid exerted a significant effect on plant growth metabolism when applied at physiological concentration and thus acted as one of the plant growth regulating substances (Kalarani *et al*., 2002).

Salicylic acid plays diverse physiological roles in plants, including plant growth, thermogenesis, flower induction, nutrient uptake, ethylene biosynthesis, stomatal movements, photosynthesis and enzyme activities (Hayat *et al*., 2007). Salicylic acid is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plants such as growth, photosynthesis, nitrate metabolism, ethylene production, heat production and flowering (Hayat Qaiser *et al*., 2010). According to Sujatha (2001), 2% DAP and 100 ppm salicylic acid increased the relative growth rate and net assimilation rate of greengram. Jeyakumar *et al.* (2008) reported that the application of salicylic acid (125 ppm) increased the dry matter production (21.6 g $plant^{-1}$) of blackgram. Bekheta and Talaat (2009) observed that foliar application of salicylic acid on corn and beans increased the plant height due to a higher photosynthetic rate.

P.P. Kurhade *et al*. (2015) reported that RDF + foliar spray of KCl 1.5 per cent (at flowering and 10-15 days after flowering) significantly increased the yield. Application of salicylic acid and GA3 as foliar spray at 25, 40 and 55 DAS improve the physiological efficiency of the crop and result in better growth and yield of blackgram concluded by Manjri *et al*. (2018).

Importance of pink pigmented facultative methylobacteria (PPFM) on PPFM a liquid bio fertilizers/agent for stress management crop growth

The pink pigmented facultative methylotrophs belonging to the genus Methylobacteriumare widely explored for their plant growth promotion and induction of defence mechanisms in the plant. PPFMs are persistently present in the rhizosphere and phyllosphere regions of plants and even on the surface of the seeds of various plants (Corpe and Rheem, 1989). The genus, *Methylobacterium*, is a group of strictly aerobic, facultative methylotrophic, gram-negative and rod shaped bacteria able to grow on a wide range of multi-carbon growth substrates as sole source of carbon and energy (Green, 1992). Holland and Polacco (1992) reported that foliar spraying of PPFM enhanced N and P uptake in blackgram, as they also produced cytokinin, IAA and GA. The increased DMP through the application of PPFM could be explained by the role of methonal as a carbon source to increase carboxylase reaction and enhance photosynthetic rate (Kumar *et al*., 1999). Paulraj (2002) stated that the gibberellic acid produced by PPFM might have increased the chlorophyll content under a stress environment. Further, the roots become more extensive due to the action of auxins. The cytokinins of the plant signal the shoot system to produce more branches in groundnut (Suresh Reddy, 2002)

Holland and Polacco (1992) stated that increasing productivity of a plant under stress by applying PPFM to a plant and subsequently applying an aqueous solution containing methanol to the plant. PPFM have been shown to improve seed germination, crop yield, pathogen resistance and drought stress tolerance. Several beneficial aspects have been investigated, such as the production of urease (Holland and Polacco, 1992), stimulation of seed germination and plant growth (Maheshwari and Karthik, 2017), production of vitamin B_{12} (Basile *et al*., 1985), auxins (Ivanova *et al*., 2001), cytokinins (Lidstrom and Chistoserdova, 2002) and 1-aminocyclopropane-1-carboxylate (ACC) deaminase (Liu *et al*., 2000).

Thangamani and Sundaram (2007) reported that at least two mechanisms by which PPFM can positively affect plants, particularly in dry climates. First, PPFM excretes auxins and cytokinins, plant growth hormones that influence germination and root growth and play a critical role in plant response to water stress. Deep roots may gain a competitive advantage in dry conditions over more shallowly rooted species. Second, PPFM exudes osmoprotectants (sugars and alcohols) on the surface of host plants. This matrix may help protect the plants from desiccation and high temperature. Pink pigmented facultative methylotrophic bacteria are associated with the roots, leaves and seeds of most terrestrial plants and utilize volatile C_1 compounds such as methanol generated by growing plants during cell division in pulses (Irvine *et al*., 2012).

Paulraj, (2002) reported that PPFM spray released osmoprotectants (sugars and alcohols) on the surface of plants. This matrix helped to protect the plants from desiccation and high temperatures. Foliar application of PPFM enhanced the synthesis of growth promoters and the contribution of the IAA, Cytokinin and GA to the enhanced root growth enabling the plants to absorb more nutrients in grapevine ultimately resulting in better growth and dry matter production, was highlighted (Radha *et al*., 2009). Further, it stimulates the division, extension and differentiation of plant cells, enhances plant growth parameters like crop growth rate, number of branches and leaf area index in *Vigna mungo* L (Sivakumar and Priya, 2017).

Abd El-Gawad *et al.* (2015) inferred that PPFM foliar spraying to cotton resulted in significantly higher plant growth parameters than uninoculated plants. Srinivasan and Aananthi (2017) revealed that application of PPFM at 500 ml ha^{-1} at 75 and 90 DAS + KCl (1 per cent) at 78 and 93 DAS with crop residue mulch recorded higher growth, yield characters and seed cotton yield of cotton. Thangamani and Sundaram (2007) confirmed that the facultative methylotrophs are more important in increasing the growth and yield of various crop plants. Keerthi *et al*. (2015) reported that spraying pink-pigmented facultative methylotrophs (PPFM) is also said to influence the crop growth by producing plant growth regulators like zeatin and related cytokinins and auxins. Abd El-Gawad *et al*. (2015) stated that PPFM individually improved the pods quality by increasing their concentrations from amino acids, protein, total sugars and ascorbic acid in snap bean. Jeyajothi and Pazhanivelan (2017) concluded that application of 125% RDF through WSF + Azophosmet under drip irrigation and foliar spray of 1% PPFM with variety of Co(Rg)7 can be recommended for higher yield and nutrient uptake of pigeonpea.

Effect of foliar spray of TNAU pulse wonder for growth and stress tolerance

The TNAU pulse wonder is a booster with macro and micronutrients and promotes better growth and development of the pulse crop. It also replaces the existing practice of diammonium phosphate foliar spray. The TNAU pulse wonder contains water soluble ingredients and facilitates the complete absorption of nutrients. Pulse wonder was recommended as a foliar spray during the peak flowering phase at 5 kg ha^{-1} with 200 litres of water. The application of pulse wonder decreased the flower shedding, increased the drought tolerance and increased the yield up to 20% compared to 2% DAP spray (Bhoopathi, 2012).

Punithavathi (2012) found that foliar spray of pulse wonder @ 1.125% on 15, 30 and 45 DAS registered a significantly higher number of pod clusters per plant, number of pods per plant, pod length, number of seeds per pod, seed test weight, filling percentage and shelling percentage in dhaincha compared to other treatments.

Sathya (2012) stated that combined application of RDF and foliar spray of TNAU pulse wonder @ 1.125% significantly increased the plant height, number of branches plant^{-1}, dry matter production, number of pod clusters per plant, pods per plant, seeds per pod and length of pod with increased seed test weight and in turn produced higher grain yield of Greengram. Arun Raj *et al*., (2018) stated that a maximum plant height of 53.4 cm was recorded in foliar spray of TNAU Pulse wonder at 1.125%.Application of 100%

recommended dose of NPK + 2% DAP + TNAU pulse wonder 5 kg ha^{-1} significantly increased the plant height (37.62 cm), a number of pods per plant (37.15), number of flowers per plant (50.12) and fruit setting percentage (72.55%) in blackgram (Marimuthu and Surendran 2015).

Sivakumar and Priya (2017) reported that foliar spray of pulse wonder @ 1% resulted in more values for plant height, root length and chlorophyll content and yield increase of 13.21% in blackgram as compared to control under saline conditions. Rajeshkumar *et al.* (2017) concluded that raising of blackgram under System of Crop Intensification methodology of crop geometry at 30 × 20 cm spacing with foliar spray of TNAU pulse wonder @ 5.625 kg ha^{-1} twice at flowering and 15 days later proved to be a better option for getting higher productivity and economics under irrigated condition of the southern zone of Tamil Nadu.

Thakur *et al.* (2017) reported that Diammonium phosphate @ 2 per cent + TNAU pulse wonder at 5.0 kg per hectare at 45 days after sowing observed the highest number of pods per plant (37.15), grain yield (1116 kg ha^{-1}) and haulm yield (3351 kg ha^{-1}) in Blackgram. The application of TNAU pulse wonder as foliar spray significantly improved the yield attributing characters by reducing flower shedding, resulting in an increasing number of pods/plant in blackgram (Babu, 2017).

Devaraju and Senthivel (2018) stated that the application of pulse wonder @ 5 kg ha^{-1} spray increased the plant height, dry matter accumulation and yield attributes which resulted in higher yield (870 kg ha^{-1}) higher net returns (Rs 22149 ha^{-1}) with B:C ratio of 2.19. The result was statistically on par with 19:19:19 @ 1% spray in blackgram.

CONCLUSION

Soil application of nutrients is more common and most effective method especially for nutrients which are required in higher amounts and essential plant nutrients are mainly applied to soil to achieve maximum economic yields. However, under certain circumstances, foliar fertilization is more economical and effective. Foliar nutrition increases significantly higher values of growth attributes like number of branches, height, number of flowers and dry matter accumulation. An increase in yield attributes such as number of pods per plant, pod weight per plant, test weight and grain yield per plant observed with liquid fertilizers in green gram. Foliar application of the correct nutrients in relatively low concentrations at critical stages in crop development contributes significantly to higher yields and improved quality.

Conflict of interest: None.

REFERENCES

Abd El-Gawad , H.G., Ibrahim, M.F.M., El-Hafez, A.A. and El-Yazied, A.A. (2015). Contribution of pink pigmented facultative methylotrophic bacteria in promoting antioxidant enzymes, growth and yield of snap bean. American-Eurasian Journal of Agriculture and Environmental Science. 15(7): 1331-1345. DOI: 10.5829.

Arun Raj, M., Sathya, P. and Vignesh, S. (2018). Effect of Foliar Nutrition for maximizing the productivity of Black gram (*Vigna mungo* L.). International Journal of Science, Environment and Technology. 7(6): 2026-2032.

Babu. S. (2017). Enhancement of blackgram productivity through soil and foliar application of nutrients Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar, Chidambaram, Tamil Nadu, India.

Basile, D.V., Basile, M.R., Li, Q.Y. and Corpe, W.A. (1985). Vitamin B12-stimulated growth and development of Jungermannia leiantha Grolle and Gymnocolea inflata (Huds.) Dum. (Hepaticae). Bryologist. 77-81.

Bekheta, M.A. and Talaat, I.M. (2009). Physiological response of mungbean "*Vigna radiata*" plants to some bioregulators. Journal of Applied Botany and Food Quality. 83(1): 76-84.

Bhoopathi, P.M. (2012). TNAU develops a pulse wonder to increase production. The Times of India.

Bhowmick, M.K., Aich, A., Aich, S.S, Shrivastava. M.P., Gupta, S. and Man, G.C. (2005). Crop diversification through paira (utera) cropping with rabi pulses. SATSA Mukhapatra-Annal Technology. 9: 43-60.

Cakmak, I. (1994). Activity of ascorbate-dependent H_2O_2-scavenging enzymes and leaf chlorosis are enhanced in magnesium- and potassium-deficient leaves, but not in phosphorus-deficient leaves. Journal of Experimental Botany. 45(9): 1259-1266.

Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. Journal of Plant Nutrition and Soil Science. 168(4): 521-530.

Corpe, W.A. and Rheem, S. (1989). Ecology of the methylotrophic bacteria on living leaf surfaces. FEMS Microbiology Letters. 62(4): 243-249.

Devaraju, B. and Senthivel, T. (2018). Effect of foliar application of different sources of nutrients on growth and yield of blackgram under irrigated conditions. International Journal of Current Microbiology and Applied Sciences. 7(1): 3105-3109. doi: https://doi.org/10.20546/ijcmas.2018.701.368.

Elayaraja, D. and Angayarkanni A. (2005) Effect of foliar nutrition on the nodulation and yield of rice fallow blackgram. The Andhra Agriculture Journal. 52(3and4): 602-604.

Ganapathy, M., Baradhan, G., Ramesh, N. (2008). Effect of foliar nutrition on reproductive efficiency and grain yield of rice fallow pulses. Legume Research: An International Journal. 31(2): 142-144.

Govindan, K. and Thirumurugan, V. (2000). Response of greengram to foliar nutrition of potassium. Journal of Maharashtra Agricultural Universities. 25(3): 302-303.

Green, P.N. (1992). The genus Methylobacterium. In: The Prokaryotes, a Handbook on the Biology of Bacteria: Ecophysiology, Isolation, Identification, Applications, 2nd edn, vol. 2. Edited by Balows A., Truper, H.G., Dworkin, M., Harder, W. and Schleifer, K.H. Berlin: Springer. pp. 2342-2349.

Gupta, S.C., Kumar, S. and Khandwe, R. (2011). Effect of bio-fertilizers and foliar spray of urea on symbiotic traits, nitrogen uptake and productivity of chickpea. J. Food Legumes. 24(2): 155-157.

Hayat, Q., Shamsul, H., Mohd, I. and Aqil, A. (2010). Effect of exogenous salicylic acid under changing environment: A review. Environmental and Experimental Botany. 68(1): 14-25.

Hayat, S., Ali, B. and Ahmad, A. (2007). Salicylic acid: Biosynthesis, metabolism and physiological role in plants Salicylic acid. A Plant Hormone. pp. 1-14.

Hermans, C., Hammond, J.P., White, P.J. and Verbruggen, N. (2006). How do plants respond to nutrient shortage by biomass allocation? Trends in Plant Science. 11(12): 610-617.

Holland, M.A. and Polacco, J.C. (1992). Urease-null and hydrogenase-null phenotypes of a phylloplane bacterium reveal altered nickel metabolism in two soybean mutants. Plant Physiology. 98(3): 942-948.

Irvine, I.C., Brigham, C.A., Suding, K.N. and Martiny, J.B. (2012). The abundance of pink-pigmented facultative methylotrophs in the root zone of plant species in invaded coastal sage scrub habitat. Plos One. 7(2): e31026.

Ivanova, E.G., Doronina, N.V. and Trotsenko, Y.A. (2001). Aerobic methylobacteria are capable of synthesizing auxins. Microbiology. 70(4): 392-397.

Jayabal, A., Revathy, M. and Saxena, M.G. (1999). Effect of foliar nutrition on nutrient uptake pattern in soya bean. Andhra Agricultural Journal. 46: 243-244.

Jeyajothi, R. and Pazhanivelan, S. (2017). Dry matter, nutrient uptake and yield of short duration pigeon pea (*Cajanus cajan* L.). Varieties under Drip Fertigation International Journal of Current Microbiology and Applied Sciences. 6(11): 3958-3965.

Jeyakumar, P., Velu, G., Rajendran, C., Amutha, R., Savery, M. and Chidambaram, S. (2008). Varied responses of black gram (*Vigna mungo*) to certain foliar applied chemicals and plant growth regulators. Legume Research An International Journal. 31: 110-113.

Kalarani, M.K., Thangaraj, M., Sivakumar, R. and Mallika, V. (2002). Effects of salicylic acid on tomato (*Lycopersicon esculentum* Mill) productivity. Crop Research. 23(3): 486-492.

KavitiVijaya, L., Sree, S.P., Lakshmi, N.V., Vani, P.M. and Chandrasekhar, K. (2018). Effects of irrigation and foliar nutrition on growth, yield and nutrient uptake of blackgram (*Vigna mungo* L.). International Journal of Current Microbiology and Applied Sciences. 7(6): 2425-2432.

Keerthi, M.M., Babu, R., Joseph, M. and Amutha, R. (2015). Optimizing plant geometry and nutrient management for grain yield and economics in irrigated greengram. American Journal of Plant Sciences. 6: 1144-1150. DOI: 10.4236/ajps.2015.68119.

Kolota, E. and Osinska, M. (2001). Efficiency of foliar nutrition of field vegetables grown at different nitrogenrates. In: Proc. IC Environ. Probl. N-Fert. Acta Horticulture. 563: 87-91.

Krishnaveni, S.A., Palchamy, A. and Mahendran, S. (2004). Effect of foliar spray of nutrients on growth and yield of green gram (*Phaseolus radiatus*). Legume Research-An International Journal. 27(2): 149-150.

Kumar, V., Gohil, M.D., Patel, U.G., Patel, S.R. and Subramanyam. (1999). Methanol enhanced productivity in cotton. Indian Journal of Plant Physiology. 4: 105-107.

Kunjammal, P. and Sukumar, J. (2019). Effect of foliar application of nutrients and growth regulator on growth and yield of green gram (*Vigna radiate* L.). Madras Agricultural Journal. 106(10-12): 600- 603.

Kurhade, P.P, Senthi, H.N. and Zadode, R.S. (2015). Effect of different levels of potassium on yield, quality, available nutrient and uptake of blackgram. International Journal of Agricultural Sciences. 11: 175-178.

Latha, M.R. and Nadanassababady, T. (2023). Foliar nutrition in crops-A review. Agricultural Reviews. 24(3): 229-234.

Lidstrom, M.E. and Chistoserdova, L. (2002). Plants in the pink: Cytokinin production by Methylobacterium. Journal of Bacteriology. 184(7): 1818-1818.

Liu, X., Li, Y. and Zhang, S. (2000). Effect of salicylic acid on growth and content of IAA and iPA of broad bean seedlings. Plant Physiology Communications. 36(6): 512-514.

Mahala, C.P.S., Dadheech, R.C. and Kulhari, R.K. (2001). Effect of plant growth regulators on growth and yield of blackgram (*Vigna mungo*) at varying levels of phosphorus. Crop Research. 18: 163-165.

Maheswari, U. and Karthik, A. (2017). Effect of foliar nutrition on growth, yield attributes and seed yield of pulse crops. Advances in Crop Science and Technology. 5: 1-3.

Manjri, Singh, A., Gupta, S.D., Bahadur, R. and Singh, A.K. (2018). Responses of blackgram (*Vigna mungo*) to foliar applied plant growth regulators. International Journal of Current Microbiology and Applied Sciences-Special Issue. 7: 4058-4064.

Marimuthu, S. and Surendran, U. (2015). Effect of nutrients and plant growth regulators on growth and yield of black gram in sandy loam soils of Cauvery new delta zone, India. Cogent Food and Agriculture. 1(1): 1-9.

Marschner, H. (1995). Mineral Nutrition of Higher Plants: 2nd edition. Academic Press: London.

Paulraj, A. (2002). Effect of azophos on raising cardamom seedlings under *in vitro* condition. M.Sc. Thesis. Tamil Nadu Agricultural University, Madurai, India.

Punithavathi, M. and Nethajimariappan, V.E. (2012). Effect of foliar spray of nutrients and growth regulators on the seed yield of dhaincha (*Sesbania aculeata*). Plant Archives. 23(1): 48-50.

Radha, T.K., Savalgi, V.P. and Alagawadi, A.R. (2009). Effect of methylotrophs on growth and yield of soybean [*Glycine max* (L.) Merrill]. Karnataka Journal of Agricultural Sciences. 22(1): 118-121.

Rajesh, N. and Paulpandi, V.K. (2013). Review of foliar nutrition in Redgram enhancing the growth and yield characters. American International Journal of Research in Formal, Applied and Natural Sciences. 2(1): 9-13.

Rajeshkumar, S., Durairaj, S.N. and Kannan, V. (2017). Effect of crop geometry and foliar nutrition on growth and yield of irrigated blackgram (*Vigna mungo* L.). International Journal of Current Microbiology and Applied Sciences. 6(11): 4084-4094.

Ramesh, K. and Thirumurugan, V. (2001). Effect of seed pelleting and foliar nutrition on growth of soybean. Madras Agricultural Journal. 88(7-9): 465-468.

Ravisankar, N., Chandrasekharan, B., Sathiyamoorthi, K. and Balasubramanian, T.N. (2003). Effect of agronomic practices for multi-blooming in greengram (*Vigna radiata* L.) (Cv. Pusa bold). Madras Agricultural Journal. 90(1-3): 166-169.

Sangakkara, U.R., Frehner, M. and Nosberger, J. (2000). Effect of soil moisture and potassium fertilizer on shoot water potential, photosynthesis and partitioning of carbon in mungbean and cowpea. Journal of Agronomy and Crop Science. 185(3): 201-207.

Sathya, K. (2012). Effect of Soil and Foliar application of Nutrients on Growth and Yield of Greengram (*Vigna radiata* L.). M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Selvam, V.S., Rajan, M.S.S. and Rao, G.N.S.N. (1999). Foliar application of urea boosts irrigated groundnut yield. Int. Arachis Newsletter. 6: 12-14.

Senthilkumar, G., Muthukrishnan, P., Ramasamy, S. and Chandragiri, K.K. (2008). Effect of organic and inorganic foliar spray on growth and yield of Blackgram. Madras Agricultural Journal. 95: 57-60.

Sharma, P., Sardana, V. and Kandhola, S. S. (2013). Dry matter partitioning and source-sink relationship as influenced by foliar sprays in groundnut. The Bioscan. 8(4): 1171-1176.

Singh, C., Joshi, R.C. and Katti, G.V. (1970). Soil and foliar application of nitrogen to rainfed cotton. Indian Journal of Agronomy. 15(3): 269-271.

Sivakumar, R. and Priya, S.J. (2017). Effect of PGRs and nutrients on growth, physiological parameters and yield of *Vigna mungo* L. under saline stress. International Journal of Plant and Soil Science. 18(6): 1-10.

Somasundaram, E., Amanullah, M.M., Thirukkumaran, K., Chandrasekaran, R., Vaiyapuri, K. and Sathyamoorthi, K. (2007). Biochemical changes, nitrogen flux and yield of crops due to organic sources of nutrients under maize based cropping system. Journal of Applied Sciences Research. 3(12): 1724-1729.

Srinivasan, G. and Aananthi, N. (2017). Effect of moisture stress management practices on growth, yield and quality of hirsutum cotton. Journal of Cotton Research and Development. 31(1): 82-86.

Subramani, M. and Solaimalai, A. (2000). Influence of plant populations and methods of nutrient application on growth and yield of blackgram. Legume Research. 3: 197-198.

Sujatha, K. B. (2001). Effect of foliar spray of chemicals and bioregulators on growth and yield of greengram (*Vigna radiata* L.). M.Sc. (Agri.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Suresh Reddy, B.V. (2002). Studies on pink pigmented facultative methylotrophs as a new bioinoculant for groundnut (*Arachis hypogaea L.*). (M.Sc. (Agri.) Thesis), Tamil Nadu Agricultural University, Coimbatore.

Suzy, Y.R., Zelmari, A.C., Rob, R.W., Alain, D. and Stephen, D.T. (2017). Potassium in the grape (*Vitis vinifera* L.) berry: Transport and function. Frontiers in Plant Science. 8: 16-29.

Thakur, V., Teggelli, R.G. and Meena, M.K. (2017). Influence of foliar nutrition on growth and yield of pulses grown under North Eastern dry zone of Karnataka: A Review, International Jouranl of Pure and Applied Bioscience. 5(5): 787-795. doi: http://dx.doi.org/10.18782/2320-7051.5800.

Thangamani, G. and Sundaram, S.P. (2007). Potential of facultative methylotrophs in increasing the yield of tomato crop. Recent Trends in Horticultural Biotechnology. 789.

Thiyageswari, S. and Ranganathan, G. (1999). Micronutrients and cytozyme on grain yield and dry matter production of soybean. Madras Agricultural Journal. 86(7-9): 496-498.

Uma Maheswari, M., Karthik, A. and Ajay Kumar, R. (2014). Effect of foliar nutrition on growth, yield attributes and seed yield of pulse crops. International Journal of Current Microbiology and Applied Sciences. 6(11): 4134-4139.

Velu, G. (1999). Impact of soil moisture stress and ameliorants on growth of soybean. Madras Agricultural Journal. 86(4/6): 330-331.

Wojcik, P. (2004). Uptake of mineral nutrients from foliar fertilization. Journal of Fruits and Ornamental Plants Research. Spec. ed., 12: 201-218.

Yalpani, N., Enyedi, A.J., Leon, J. and Raskin, I. (1994). Ultraviolet light and ozone stimulate accumulation of salicylic acid, pathogenesis-related proteins and virus resistance in tobacco. Planta. 193(3): 372-376.