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FOLIAR FERTILIZATION OF VEGETABLE AND FRUIT PLANTS – A REVIEW

Rampal Singh[1], Ompal Singh[2]* and H.S. Rathore[3]

[1]*Faculty of Agriculture Science, Aligarh Muslim University, Aligarh-202002 U.P.*

[2]*Chemical Research Unit, Department of Research in Unani Medicine, A.M.U. Aligarh-202002 U.P.*

[3]*Deptt. of Applied Chemistry, Z.H. College of Engineering and Technology, A.M.U., Aligarh-202002 U.P.*

***Corresponding author** (Ompal Singh) **Email :** ompalchem@gmail.com*

ABSTRACT

It is a tough challenge for developing countries to produce sufficient food for growing population, proper growth and protection of plants, animal and human health, and simultaneously conserving the environment. Green revolution technologies have doubled the yield of rice and wheat. Green revolution has been made a success only with the help of agrochemicals such as manures, chemical fertilizers, organic fertilizers and pesticides. Still quantities of food products are limited due to the shortage of rains (drought), climatic changes and growing pests. As a part of green revolution technologies, a recently developed technique, Foliage feeding is a way of feeding plants by applying liquefied fertilizers directly onto the plants leaves and stems. The absorption takes place through their stomata and also through their epidermis. Transport is usually faster through the stomata. It has been investigated that the plant absorbs fertilizers faster through the stomata on their leaves and it makes the leaves an ideal point of entry for the micronutrients that may be difficult to pull out of the soil. Therefore, plants can be grown healthier in turn the yield of vegetables and fruits will increase with the minimum quantity of fertilizer. In this paper various features such different procedures, advantages and disadvantages of this technique have been discussed.

Key words : *Foliar fertilizer, vegetables, fruit plants, pesticides, transport, agrochemicals.*

The manures and fertilizers are the source of nutrients. The essential elements are divided into two groups: the macronutrients including carbon (450,000 ppm, 45%), hydrogen (60,000 ppm, 6%), oxygen (450,000 ppm, 45%), nitrogen (15,000 ppm, 1.5%), phosphorus (2,00 ppm, 0.2%), potassium (10,000 ppm, 1.0%), calcium (5,000 ppm, 0.5%), magnesium (2,000 ppm, 0.2%) and Sulphur (1,000 ppm, 0.1%) and the micronutrients including iron (100pp, 0.01%), chlorine (100 ppm, 0.001%), manganese (50ppm, 0.005%), boron (20ppm, 0.002%), zinc (20ppm, 0.002%), copper (6pmm, 0.0006%) and molybdenum (0.1ppm, 0.0001%). Other essential nutrients, hormones, are produced in one part of a plant and transported to other parts and they are effective in very small quantity. A particular hormone may have different effects because effect depends on the target tissues. Auxin, one of the most important plant hormones is produced by growing stem tips and transported to other parts where it may either promote growth or inhibit. It also retards the abscission (dropping off) of flowers, fruits and leaves. Synthetic auxins are used to initiate adventitious roots from plant cuttings generally in nurseries. Weed control by another synthetic auxin (2,4-dichlorophenoxyacetic acid (2,4-D)) is wide spread as a selective herbicide against broadleaf weeds. Foliar feeding is a particularly useful technique for hormones feed. Foliar sprays (DRH AG SERVICES, 254-265-3699) are useful for delivering fertilizers, fungicides, pesticides and PGR's to plants. Foliar sprays are broadly categorized as either "non-systemic" or "systemic". Non-systemic sprays are useful to treat the problems, present on the surface of the leaf. Most pesticides and fungicides are non-systemic. Some fertilizers, many fungicides PGR's are the common examples of systemic sprays which are absorbed into the plant via stomata and then transported via the vascular system to the parts where they are needed. In the spray solution a wetting agent is also mixed to break the spray in small droplets, to increase the coverage and effectiveness of the feed. Wetting agent lowers the surface tension of the droplets so they collapse and cover a large area in turn easy access to more stomata so that the leaf can absorb more solute. The application of foliar sprays is an important crop management strategy, which may help maximizing crop yield and quality. Foliar pesticide spray is used since long for protecting plants and providing good quality of foodstuffs. Now foliar fertilization is also used as a means of supplying supplemental doses of macro-and micro- nutrients, plant hormones, stimulants and other beneficial substances. Foliar fertilization has increased the yield, provided resistance to diseases and pests, improved drought tolerance, and enhanced crop quality in turn quality of grains, vegetables, fruits etc.

Advantages of Foliar Feeding

Plants take in nutrients more efficiently through their stomata and epidermis (plant pores) in their leaves and stems than they do through root uptake.

It is a quick boost with periodic mists of natural foliar fertilizers. Nutrient uptake via the foliage may be much faster as compared to soil nutrients (Fernandez V. *et al.,* 2013; Sundaram *et al.,* 1987; Craisey *et al.,* 1997; P. Neumann *et al.,* 1988; P.

Manrschner *et al.,* 2011; H. DeWyne Ashamed *et al.,*1986 ; Kuepper G 2003; Wojcik P. *et al.,* 2004; Taiz L. *et al.,* 1998, Weinbaum S. 1988; Lester G.E. *et al.,* 2006).

It is an immediate way to revive and stimulate stressed, tired, or diseased plants. Foliar feeding can very quickly correct disorders caused by nutrients deficiency as well as it also helps to overcome various stresses (Fernandez V. *et al.,* 2013; Kuepper G. 2003; Taiz L. *et al.,* 1998; Franke W. 1986; Pavlova A. *et al.,* 1986; Witek A. *et al.,* 2000) *i.e.,* one of the traditional applications of foliar feeding is to correct nutrients deficiency is plants

Foliar feeding can be 8 to 10 times more effective than soil feeding.

Up to 90% of a foliar-fed liquid can be found in the roots of a plant within one hour of application.

Foliar supplements are an effective way to compensate for soil deficiencies and poor soil's inability to transfer nutrients to the plants.

Foliar feeding is necessary because of the fact that it fulfills the immediate needs of the plant and it is the fastest way to deliver a corrective infusion of micronutrients.

Foliar feeding is especially useful in the soil conditions that limit the availability of nutrients. For example, when soil contains the excess of sodium carbonate it inhibits plant ability to absorb iron and manganese. It may be due to complexing (hydrolysis) of iron and manganese with carbonate and phosphate. Under these conditions the foliar feeding is an excellent method for adding iron and manganese to the foliar.

A disease blossom end rot that is related to the deficiency of calcium, a very common disease in tomatoes and peppers sometimes in apple trees, can be controlled by foliar feeding application of water soluble calcium or calcium containing fertilizer.

Foliar feeding can be applied more frequently than soil application.

It may be used to aid plants recovering from transplant shock, hail damage, and other

damaging environmental conditions.

It is proposed that the foliar feeding should be recommended in integrated plant production because it is more environmental friendly and can increase productivity and quality of crops (Palvlova 2009.).

Foliar fertilization can be applied throughout the growing period with small quantity and variable composition of the nutrient liquid appropriate to the specific requirements in different phases of the crop development ((Fernandez V. *et al.,* 20132; Craisey *et al.,* 1997; P. Manrschner *et al.,* 2011; H. DeWyne Ashamed *et al.,* 19869; Kuepper G. 2003; Taiz L. *et al .,* 1998).

Foliar feeding may stimulate the capacity of root system to absorb nutrients from the liquefied soil ((Fernandez V. *et al.,* 2013; Craisey *et al.,* 1997; P. Manrschner *et al.,* 2011; H. DeWyne Ashamed *et al.,* 1986; Kuepper G. 2003; Taiz L. *et al.,* 1998).

Add mixtures of fertilizers with pesticides in order to improve performance of foliar feeding and to enhance the effectiveness of the pesticide in turn reducing the cost of plant protection process (Kuepper G. 2003; Pavlova A. *et al.,* 1986).

The investigations about foliar feeding explore the possibility of foliar feeding as a tool for integrated pest management for the production of vegetables and fruits (Nowosielski O. 1994 and 1998).

Generally foliar fertilizers are 100% water soluble and they should be free from impurities that could damage plants and lead to accumulation of toxic residues in vegetables and fruits (DRH AG SERVICES, Fernandez V. *et al.,* 2013; Kuepper G. 2003). Foliar feeding has a great potential to reduce soil pollution and underground water pollution (Johson S.N. *et al* 2009, carisey N. *et al.,* 1997; Alexander A. *et al.,* 1987).

Foliar feeding shows positive economic effect in growing vegetables and fruits as well as direct impact on increasing yield (Jaskulski D. 2007 and Sarkar N.C. *et al.,* 2008).

Many new foliar feeding formulations have been investigated, recommended and implemented in agriculture and horticulture (El-Fouly M.M. 2002)).It is a new era of research for progressive production of foliar fertilizers in many countries for local use and export. There is a real chaos in the market. For example in Egypt, 554 new fertilizers have been registered during 1990-1995. Out of these 285 are practically used in foliar feeding and the remaining 200 water soluble products are being used for drip irrigation and are partially used as foliar fertilizers.

Foliar feeding is useful to supply part of the necessary nutrients and stimulant nutrients absorption by the root system. It has also been claimed that foliar feeding may change the concentration of some metabolites in the root as a result it helps to improve the solubility of minerals in the soil (El-Fouly M.M. 2002; Pavlova A. *et al.,* 2009).

Foliar feeding increases the physiological activity of the roots by the supply of relatively small amounts of macro-and macro-nutrients (Johnson S.N. *et al.,* 2009).

The increasing use of foliar feeding during the previous years there is a steady trend to reduce (7 fold) the use of mineral fertilizers such as N,P, and K (Fernandez V. *et al.,* 2013).

It has been observed that foliar feeding is an additional device to regular root supply during the growth and development of crops can improve their nutrient balance which may lead in turn can increase in yield and quality (Sundarum K. *et al.,* 1987).

The foliar feeding is the only way to adequately feed plant and trees growing in paved areas.

The foliar feeding is an excellent way to restore vigor to winter-injured plants.

Foliar spraying also stimulates nutrients up take from the soil because the leaves after spraying will generate more carbohydrates that it will transport down to the roots and release as exudates. Which will stimulate the microbial life in the soil and microbes will thrive around the root mass making more nutrients available to the plant. So it is a very good idea to use foliar feeding to get fast and efficient way to provide crops the optimum amount of nutrients into the plant to work hard to produce top quality food.

The foliar feeding is very significant during drought Period or in countries such as India where irrigation is by ground water and water level is going down due to shortage of rains, the nutrients in a dry fertilizer cannot go into the solution in the soil and the plant and the tree is starved (deforestation). Secondly in spring or winter when the soil is ice cold and thirdly in some countries there is thick fogging and clouding due to high level of pollution sun light is not available in turn leaves are inactive , certain nutrients are not absorbed by the roots. The foliar feeding solves all these problems.

Limitations of Foliar Feeding

It is well known that the plant receives most of the nutrients through their root system so primary focus is on feeding the soil. The foliar feeding applications are not practical for macronutrients that plants require in large amount such as nitrogen, phosphorus and potassium.

It is also not normally the most effective method for delivering immobile nutrients such as calcium and boron.

Only water soluble products can be used as foliar feeds.

Foliar feeding works on actively growing plants and may not be used on dormant plants.

Foliar feeding needs a skilled worker because the foliar feeding frequency depends on the nature of the plant and of fertilizer form i.e. for Annuals every 3 weeks, for Fruits every 3to4 weeks, for Perennials every 6 to 8 weeks and for vegetables 1 to 3 weeks during the growing period.

It is time consuming process because of the facts that the spray product should be tested at lower concentration before use. The law of little bits applies i.e. it is better to spray small amount of mild mixtures. Factors such as concentration and frequency of application, as well as the stage of plant growth may also be considered.

The farmer may know that nitrogen may burn the leaves so better to test first on one leaf. In some cases of foliar feeding there is a possibility of causing leaf injury and plant damage (Johnson S.N. *et al.,* 2009, Carisey *et al.,* 1997)

The user may be sure that temperature is below 85F before and after feeding operation.

Avoid foliar feeding when the plant is in the direct sun light, the water droplets act like prisms and it may burn the leaves.

A wetting agent may be added in the feed as it helps in sticking the material to the leaves until good stuff can be absorbed by avoiding the beading up and rolling off.

Foliar applications are often timed to meet the demand of nutrients at specific vegetative or fruiting stages of growth and the fertilizer formula is adjusted accordingly.

The quality control of foliar fertilizers is much more difficult issue than soil fertilizers as the efficiency of foliar feeding depends on many different variables. The quality control criteria are much more complex to approach and most countries do not have special regulations in turn no special quality criteria for foliar feeding (El-Fouly M.M. 2002). Therefore it could be highly considerable and

Recommendable to study the situation in order to make specific suggestions about the quality criteria in order to register the foliar feeding in different countries and to make clear to the customers.

It has been accepted that foliar feeding is an integral part of the whole system for proper feeding plants but it is not an alternative to soil fertilization (P. Neumann 1988).

The foliar feeding is more expensive and time consuming than soil feeding because of the fact that it is to be done many more times during the growing season.

If the foliar feeding material is not in just the right proportion as specified on the package it can burn the leaves.

Effectiveness of Foliar Feeding : Mechanism

The soluble form of the nutrients is absorbed by the plants and solubility of nutrients is pH dependent. Generally, acidic pH improves the penetration of nutrients through leaf surfaces. The pH affects the charge of the cuticle (a waxy layer covering the leaves) and thus its selectivity to ions. The ionic form of nutrients is pH dependent and so it can affect the penetration rate. The pH might affect the phytotoxicity of the sprayed compounds. Therefore, the adjustment of pH of the feed must be made according to the applied nutrients. The presence of surfactants in the feed contributes to a more uniform coverage of the foliar. The surfactants increase the retention of the spray by reducing the surface tension of the spray droplets.

Precautions

(a). It is important to add a tablespoonful of soap powder or detergent to each gallon of solution if leaves are waxy (cutaneous) surface which inhibits the penetration of liquid feed. The presence of soap or detergent in solution disrupts the waxy layer in turn facilitates the penetration of nutrients.

(b). Sometimes, add mixtures of fertilizer and pesticide are used to develop an all-purpose solution. It is a labor-saving procedure but the operator should first check the level s of both the components to make sure that they are compatible. Let us summarize the above discussion in following lines :

Use only water soluble products as foliar feeds

Foliar feeding only works on actively growing plants and do not use on dormant plants

Test the product in diluted form before use

The law of little bits applies! It is better to spray small amounts of mild mixtures

One should note that nitrogen may burn the leaves so better test first on one leaf

Be sure that temperature is below 85F when foliar feed is to be started

Do not spray at night if possible; late evening spray can create a powdery mildew

Do not spray when the plant is in the direct sunlight; the water beads act like prims and may burn the leaves

A wetting agent (Them XIM70) will help the fertilizer "stick" to the leaves until good stuff can be absorbed; no more beading up and rolling off

Plant response is dependent on species, fertilizer form, and stage of plant growth

Foliar applications are often timed to meet the demand of nutrients at specific vegetative or fruiting stages of growth so the fertilizer formula is adjusted accordingly, (DRH AG SERVICES, 254-265-3699). Foliar feeding aids the plants recovering from transplant shock, hail damage and other damaging environmental conditions.

Foliar Feeding Machinery : Already developed and utilized machinery for pesticides application is available for foliar feeding. One of the commonly used devices is sprayer. The sprayer is one which atomizes the spry fluid (may be a suspension, an emulsion or a solution) into small droplets and eject it with little force for distributing properly. It also regulates the amount of feed to avoid excessive application that might prove wasteful or harmful to the plant. The sprayers are classified into four categories on the basis of energy employed to atomize and eject the spray fluid as hydraulic energy sprayer, gaseous energy sprayer, centrifugal energy sprayer and kinetic energy sprayer.

Hydraulic energy sprayer sprays fluid that is pressurized either directly by using a positive displacement pump or by using an air pump to build up the air pressure above the spray fluid in the air tight container. Then the pressurized fluid is forced through the spray lance, which controls the spray quantity and pattern.

In gaseous energy sprayer high velocity air stream is generated by a blower and directed through a pipe at the end of which the spray fluid is allowed to trickle by the action of gravity through a diffuser plate.

In the centrifugal energy sprayer the spray fluid fed under low pressure at the center of a high speed rotating device (flat, concave or convex disc, wire mesh cage or bucket, a perforate sieve or cylinder or brush) and atomized by the centrifugal force as it leaves the periphery of the atomizer. The droplets are carried by the air stream generated by the blower of the sprayer or by the prevailing wind, if the sprayer is not provided with a fan.

In kinetic energy sprayer fluid flows by gravity to a vibrating or oscillating nozzle which produces a coarse fan shaped spray pattern.

The hand sprayer is a small, light and compact unit.

The capacity of the container varies from 500 to 1000 ml. It is used to spray small areas like kitchen garden and experimental laboratory plots. It is a hydraulic energy sprayer that consists of hydraulic pump inside the container with cylinder, plunger and plunger rod. On operating the plunger up the spray fluid in the container is sucked into the cylinder through a ball valve assembly and then pressurized during the downward stroke. The pressurized fluid is then let out through a nozzle and sprayed into fine droplets. If pressure is to be built up inside the container an air pump with cylinder, plunger and plunger and plunger rot is required. When the plunger is pulled up the air is sucked into the cylinder and when pushed down the air bubble releases into the container with 80% of its volume filled with fluid. The air reaches the space above the free fluid surface and presses the fluid. The pressurized fluid is drawn up through a trigger cut of valve to the nozzle where it is atomized and sprayed. In another type of sprayer air pump and container are separate pieces and the pump is attached to the container in such way to release the pressurized air through an orifice at the top pf the container. The fluid is lifted through an office at the top of the container. The fluid is lifted through a capillary tube due to surface tension developed by the high velocity air at the outlet and sheared away by the air and sprayed as droplets.

Foot sprayer is a modified version of rocker sprayer. The pump is fixed in a vertical position with necessary braces. The plunger moves up and down when operated by the pedal. A ball valve is provided in the plunger assembly itself to allow the fluid to across the plunger and getting pressurized in the pressure vessel. The upward motion of the piston fluid is sucked in and pressurized into the pressure vessel and during downward movement the sucked fluid across the plunger enters the pump. The pressure developed is about 17-21 kg/cm^2.

Portable sprayer which is carried on the back of the operator is called knapsack sprayer. It is commonly used manually operated knapsack sprayer will have one hydraulic pump working inside the container. The plunger works inside the replacement well attached at the bottom of the container, for easier maintenance. The pump can be operated through the appropriate linkages by oscillating the handle with spryer carried at the back. An agitator is also provided with the pressure chamber to agitate the fluid so that the particles present in suspension will not be allowed to settle down. A delivery tube is attached on the other end of the pump which carries the pressurized fluid to the spray lance. The flow to the nozzle is controlled by a trigger cut-off valve. In the compressor an air pump is used to build air pressure above the free surface of the fluid in the container and normally the pumping of the air will be made by keeping the unit on the ground and then sprayed till the air pressure comes down. The unit is again brought back to the ground for pumping air and then the spraying is continued as before. The spray fluid which does not require agitation again and again can be sprayed by this type of spray.

Any portable sprayer which is carried on the back of the operator is called knapsack sprayer. It is commonly used manually operated knapsack sprayer will have one hydraulic pump working inside the container. The plunger works inside the replacement well attached at the bottom of the container, for easier maintenance. The pump can be operated through the appropriate linkages by oscillating the handle with spryer carried at the back. An agitator is also provided with the pressure chamber to agitate the fluid so that the particles present in suspension will not be allowed to settle down. A delivery tube is attached on the other end of the pump which carries the pressurized fluid to the spray lance. The flow to the nozzle is controlled by a trigger cut-off valve. In the compressor an air pump is used to build air pressure above the free surface of the fluid in the container and normally the pumping of the air will be made by keeping the unit on the ground and then sprayed till the air pressure comes down. The unit is again brought back to the ground for pumping air and then the spraying is continued as before. The spray fluid which does not require agitation again and again can be sprayed by this type of spray. Battery/ULV sprayer was invented as a result of the desire to reduce the quantum of chemical carried by the operator for application and to eliminate the water as a medium to carry the chemicals. The basic requirements of its spraying are: The narrow and controllable droplet spectrum (100-250 um for fine sprayer, 50-100 um for mist sprayer and 0.1 to 50 um for aerosols, the accurately controllable emission rate and the non-volatile formulation of suitable viscosity and density. The reduction in volume of the spray fluid decreases the time spent in travelling to recharge sprayer, in fetching water, in mixing the feed and filling the tank. ULV sprayer covers about 8 ha in 8 hour while power sprayer covers 3 ha in this time period. A battery operated ULV sprayer has a long handle at the horse power D.C. motor is fitted with a spinning disc and cover. A HDPF bottle is fixed closely to the motor in such a way that spray fluid is allowed to trickle at the center of the spinning disc in operation. The centrifugal energy imparted fluid comes out of the nozzle and atomizes. The centrifugal energy imparted fluid comes out of the nozzle and atomizes. The hand held ULV applicator is so designed to release the spray droplets at 1 m away from the body of the operator. It is recommended that it should be operated only when the spray cloud would be blow away from it by the breeze so as to minimize the risk of contamination. When operation is over the atomizer must be flushed with paraffin to remove the residues. The insufficient cleaning would leave the residues deposit in the feeder stem that may completely or partially block the flow of the feed. The bucket sprayer is designed to pump the fluid from the open container, usually a bucket. The hydraulic pump is placed inside the bucket and is held properly with help of foot rest. As the plumber is pulled up the fluid is passed through the suction ball valve assembly and when the plunger is pressed down the suction valve closes and the fluid enters the pressure chamber through the ball valveassebly as the plunger is continuously worked pressure is built up in the pressure chamber and the delivery hose. As soon as the required pressure is built up the spraying will be done. A pressure of 4 kg/cm^2 is developed in most of the assemblies. All the sprayers which impart the mechanical energy developed by an I.C. Engine on the spray fluid before spraying are called as a power sprayer. The most commonly available power sprayer in India is gaseous energy type knapsack sprayer. In construction it has a back pack stand on with a S.I., and an engine of 1.2 to 3 hp capacity, a spray fluid tank and a petrol tank which are fixed rigidly. A pleated hose is attached to the blower elbow to carry the velocity air and at the end of it a shear nozzle is fixed to allow the spray fluid to trickle in from the spray fluid storage tank with a valve control. From the top of the blower casing an air hose is taken into the spray fluid tank, which carries little quantum of air to press the fluid during operation. For operation the engine is started by keeping the unit on the ground and the carried by operator. The blower sucks the air behind the backrest and forces it into the pleated hose. The valve of the shear nozzle is opened or the shear nozzle with selective opening and discharged through the nozzle. The high velocity air shears off the droplets and atomizes by the impact of diffuse and delivers it on the plant surface. An air current of 2.7 to 9.1 m2/ min is delivered at a velocity of 175 to 320 kmph. The spray fluid tank capacity varies from 7 to 12 liters. The fuel tank capacity varies from 0.75 to 2.25 liters. The spray fluid discharge can be varied from 0.5 to 5 liter/min. The rocking sprayer consists of a pump assembly that is fixed on a wooden platform with an operating lever, a valve assembly with two ball valves, a pressure chamber, suction hose with strainer, and delivery hose with spray lance. When the plunger of this assembly is pulled behind by pulling the lever away from the pump, the spray fluid from the container is sucked through the strainer and pushes the bottom ball valve above the enters the pump. The movement of the lower ball valve is arrested by the upper valve seat. When lever is pushed towards the pump, the sucked fluid is forced to enter the pressure chamber by opening the upper ball valve. The operation continued till the entire suction pipe, ball valve assembly, delivery hose and a portion of pressure vessel is fitted with spray fluid and pump operator finds it difficult to push the piston forward, due to the downward pressure developed by the entrapped compressed air in the pressure vessel. Thereafter, the trigger cut off will be opened to allow the spray fluid to rush through the nozzle and get atomized. Usually 14 to 18 kg/cm2 pressure can be built in the pressure chamber and hence it can be conveniently used for free spray (Ikisan Agri-Informatics).

Foliar Feeding Formulations

Usually water soluble powder or liquid soluble fertilizers are used. Some natural materials such as kelp, compost tea, weed tea, herbal tea and fish emulsion are also being used. Foliar feeding of urea solution has been reviewed by Gooding and Davies (Gooding M.J. *et al.,* 1992). They have suggested that there are several potential benefits such as reduced nitrogen losses due to denitrification and leaching compared with nitrogen fertilizer applications to the soil, the ability to provide nitrogen when root activity is impaired *e.g.,* in saline or dry conditions and uptake late in the season to increase grain nitrogen concentration. Factors that influence the degree of foliar absorption in field conditions, losses to the atmosphere and soil can occur have not been discussed. There is a need for more information about the mechanism and the procedure to prevent losses of nitrogen from foliage, to reduce the phytotoxic influence of sprays and to exploit the reported effects that urea may have on limiting the development of cereal disease. In Bulgaria the liquid fertilizers (Favretti R.J. 1964) have been tried and the results obtained have been studied:

(a). Fertilizers of We usual series (8% N, 8% P_2O_5, 6% K_2O, 0.004% Cu EDTA, 0.02% Fe EDTA, 0.012% Mn EDTA and 0.01Mo EDTA and 0.04% Zn; Aglukon, Germany);

(b). Bulgarian series Fixal (9% N, 9% P_2O_5, 7% K_2O and micro element 0.004% Cu EDTA, 0.02% Fe EDTA, 0.012% Mn EDTA, 0.01% Mo EDTA and 0.004% Zn EDTA; Sipro Ltd. Bulgaria)

(c). Laktofol (21% N, 5% P_2O_5, 10% K_2O, 0.020% B, 0.014% Cu, 0.250% Fe, 0.002 % Mn, 0.002% Mo and 0.018% Zn; Ekofol AD, Bulgaria), Fitona (7.20% N, 5.20% K_2O,1.5% Ca, 0.9% Mg, 0.1% Fe, 0.1% B, Cu, Mn, and Mo Fitotech Ltd. Bulgaro); Hortigrow (20% N, 20% P_2O_5, 20% K_2O,0.06% Fe, 0.02% Zn, 0.01% Mn, 0.01 Cu, 0.02% B, 0.001% Mo and 1% amino acids, Hartland Ltd. Nederland); and many other similar type of add mixtures.(Haytova D 2013) (R2). Haytova has discussed the several research studies carried out on foliar fertilization of pepper (Favretti R.J. 1994 and Karakurt Y. *et al.,* 2009), lettuce (Hussein M.M. *et al.,* 2012), head cabbage (Dimitti I. *et al.,* 2005), melons (Atanasova E. *et al.,* 2007), tomato (37 Kosterna E. *et al.,* and Premsekhar M. 2009), green beans (Ejaz M. *et al.,* 2012; Fawzy Z.F. *et al.,* 2010), carrots(Borowski E. *et al.,* 2011; Smolen S. *et al.,* 2009), onion (Poberezny J. *et al.,* 2012), eggplant (Charbaji T. *et al.,* 2008), peas (Azarpour E. *et al.,* 2012). Okra (Gad E.L. *et al.,* 2012) and cucumber (Mondal M.M.A. *et al.,* 2012) and (30 Favretti R.J. 1964)), have studied (Khan *et.al.,* 2014)), vermiwash (V.W.), a liquid extract obtained from vermicomposting beds , as an organic fertilizer for crop plants. They have investigated the effect of vermiwash foliar spray on the response of bhutjolokia (*Casicumassamicum*) exposed to two different arbuscular mycorrhizal fungi (AMF: Rhizophagus irregularis, R.I. and G. mosseae, G.M.) in acidic soil under naturally ventilated greenhouse conditions. (Alaa El Din *et al.,* 2010), have studied the beneficial effects of compost tea (CT) and filtrate biogas slurry liquid (FLB) on yield and fruit quality of navel orange fruits. (Alaa El Din *et al.,* 2010) R3.Some formulations of plant growth- promoting (PGP) microbe have been developed and tested by S. Gopalakrishnan, *et.al.,* 2016). Several carrier materials have been used in formulation that include peat, talc, charcoal, cellulose powder, farm yard manure, vermicompost and compost, lignite, bagasse and press mud. Each formulation has its advantages and disadvantages but peat based carrier material is widely used in different part of the world (Gopalakkrishnan *et al.,* 2016).Foliar spray of potato plants with phosphonic acid (partially neutralized with potassium hydroxide to pH 6.4, substantially reduced infection of the tubers by Phytophthora infesting that is responsible for late blight, in glass house. Cook & little have also reported that application of phosphonic acid combined with a non-systemic or systemic fungicide had offered the possibility of controlling both foliage and tuber blight and could have a major impact in reducing overwinter survival of P infestants in tubers (D.A Knowles *et al.,* 1998).Stevens (Stevens J.G. *et al.,* 1994) has reported that spray adjuvants can be employed in the foliar feeding of fertilizer to ensure adhesion of aqueous sprays to the waxy surfaces of foliage (wetters) , to improve coverage of spray on foliage (spreaders), to minimize weathering of fertilizer deposits on foliage (stickers/extenders), and to uptake of fertilizer into foliage(humectants, pH modifiers and penetrants) (Stevens J.G. *et al.,* 1994) and Vidhysekaran *et al.,* has developed *Pseudomonas fluorescens* strain Pf_1, inhibitory to the growth of rice blast pathogen *Pyricularia oryzae* in vitro as a talc-based powder formulation. When the rice seeds were treated with this formulation, the bacteria spread to roots, stems and leaves of the plants and protected against leaf infection by *P. orzyae*. When applied as a foliar spray, the bacteria survived on the leaves. In tests as a seed treatment and foliar spray in four field trials it effectively controlled the disease and increased grain yield (Cook *et al.,* 2002). Amazon try Prime (54) has listed many formulations for example, Rinuja Growth Plus+ Plant Growth Promoter 500ML for all crops with 16 Essential Macro and Micro Nutrients (more carbon present), Green Earth Agro Panchagavya Organic Fertilizer and Growth Stimulant for Plants, Allcor Organic Certified Water Soluble Biofertilizer Flower and Yield Booster For All Indoor and Outdoor Plants (100Ml, Yellow), JEEVAN-Organic Plant Growth Supplement (500 ml, White), Valueman Organic GROW VALUE- Nutritional Supplement (Plant Growth Regulator), Fertilizer for home plants. NPK 15 15 15 Complex (P. Vidhyasekaranet *et al.,* 1997).

Some Advantageous Products Recommended for Foliar Feeding

Some products based on natural resources (www.amazon.com) are the following :

Fox Farm Big Bloom : It provides N:P:K of 0.01:03:0.7, it is odorless and gentle for delicate plants and it is derived from bat guano, earthworm castings, rock phosphate, and Norwegian kelp.

Plant Solution : It has N:P:K of 2:0.6:2, it possesses pH of 3.8 and can lower the pH of tank mixes, and it contains calcium, magnesium, iron, manganese, sulfur, and other trace minerals.

Maxocrop Soluble Seaweed Powder : It has N:P:K of 1:0:4; it is derived Norwegian seaweed, it is available in the form of dry powder and it contains more than 70 minerals, vitamins and enzymes.

Maxicrop Liquid Seaweed, Maxicrop Liquid fish Fertilizer : It contains N:P:K of 5:1:1; it is made from Atlantic fish and contains naturally occurring amino acids as well as vitamin B.

Nitrogen Formula A-35 : It contains N:P:K of 0.9:12:2 and calcium, Sulphur, magnesium, manganese, zinc, and copper.

Bountiful Harvest : It contains boron, iron, and zinc plus amino acids; it also contains growth stimulants from naturally occurring bacteria and fungi.

Bioform : It has N:P:K of 4:2:4; it contains 3% Sulphur which helps to lower the pH of soil.

Neptune's Harvest Fish : It has nutrients in cheated form for easier adsorption. It is screened to 150 micron mesh for clog free use and it is derived from fish protein.

Neptune's Harvest Fish and Seaweeds : It contains N:P:K of 2:3:1. It possesses nutrients in cheated form for easier absorption. For clog free use it is screened to 150 micron mesh. It is prepared by combining fish protein and seaweed in one application (www.amazon.com).

Foliar Feeding Facts

Foliar supplements are an effective way to compensate for soil deficiencies and poor soil's inability to transfer nutrients to the plant. Surprisingly, plants take in nutrients more efficiently through stomata (plant pores) in their leaves than they do through root uptake. You can give your growing things a quick boost with periodic mists or sprays of natural foliar fertilizers. Not only are they good for general fertilization, they're an immediate way to revive and stimulate stressed, tired, or diseased plants. Foliar feeding is a technique of feeding plants by applying liquid fertilizer directly to their leaves. Plants are able to absorb essential elements through their leaves. The absorption takes place through their stomata and also through their epidermis. Transport is usually faster through the stomata, but total absorption may be as great through the epidermis. Foliar feeding is the fastest way to deliver a corrective infusion of micronutrients to plants. Periodic foliar feeding will increase the activity in the leaves, increasing chlorophyll production and ease the activity in the leaves, increasing chlorophyll production and photosynthesis which drives increased water and nutrient uptake from the soil. It is well known that the plant receives most of their nutrients through their root system so primary focus is on feeding the soil. Now it has been realized that there are many benefits to periodically making a foliar fertilization in addition to practice of soil fertilization. Hence it is important to understand that foliar applications are not practical for macronutrients that plants require in large amount such as nitrogen, phosphorous, and potassium (N:P:K) and it is also not normally the most effective method for delivering immobile nutrients such as calcium and boron. The foliar feeding is significant because of it fulfills the immediate needs of the plant and it is the fastest way to deliver a corrective infusion of micronutrients. As stated above. The foliar feeding is especially advantageous in the soil conditions that limit the availability of nutrients i.e. when the soil contains a lot of calcium carbonate. Calcium carbonate inhibits plant ability to absorb iron and manganese. It may be due to their complex formation with carbonate or their hydrolysis in presence of carbonate. Under these conditions the foliar feeding is an excellent method for adding iron and manganese to the plant. Another advantage of foliar feeding lies in the fact foliar feeding can be applied more frequently that soil application. However the frequency of foliar feeding depends on the type of plant. Foe example for Annuals every 3 weeks, Fruit every 3 to 4 weeks, Perennials every 6 to 8 weeks and vegetables 1 to 3 weeks during the growing period. It has been investigated that the blossom end rot is related to lack of calcium in the plant and it is more common in tomatoes and peppers but it can also affect apple trees. To get rid of this problem foliar application of water soluble calcium or calcium containing fertilizers may be used. Let us summarize the above discussion in following lines :

Use only water soluble products as foliar feeds

Foliar feeding only works on actively growing plants and do not use on dormant plants

Test the product in diluted form before use

The law of little bits applies! It is better to spray small amounts of mild mixtures

One should note that nitrogen may burn the leaves so better test first on one leaf

Be sure that temperature is below 85F when foliar feed is to be started

Do not spray at night if possible; late evening spray can create a powdery mildew

Do not spray when the plant is in the direct sunlight; the water beads act like prims and may burn the leaves

A wetting agent (Them XIM70) will help the fertilizer "stick" to the leaves until good stuff can be absorbed; no more beading up and rolling off

Plant response is dependent on species, fertilizer form, and stage of plant growth

Foliar applications are often timed to meet the demand of nutrients at specific vegetative or fruiting stages of growth so the fertilizer formula is adjusted accordingly, (DRH AG SERVICES, 254-265-3699.). Foliar feeding aids the plants recovering from transplant shock, hail damage and other damaging environmental conditions. Therefore there is a genuine interest in investigating different technologies of spray and formulations based on fertilizers, pesticides and their admixtures.

CONCLUSIONS

There is increasing interest in foliar feeding because of the facts that foliar feeding is recommended when environmental conditions limit the uptake of nutrients by roots due to high or low soil pH, temperature stress, too low or too high soil moisture, root disease, presence of pests that affect nutrient uptake, nutrient imbalances in soil etc. and partly due to the production of highly water soluble fertilizers. The development of machinery for spraying fungicides, herbicides and insecticides and overhead irrigation further facilitate the application of nutrients to crops in the form of sprays. Advances in agriculture include reduction of crop producing costs, maintaining soil quality, use of nutrients in adequate amounts and the methods of application associated with these devices. As discussed above that foliar feeding cannot substitute soil fertilization but it can be used as supplement of soil applications in sustainable crop production. Furthermore foliar feeding may indeed be an environmental friendly fertilization method since the nutrients are directly delivered to the plant in limited amounts, thereby helping to reduce the environmental impact associated with soil fertilization. Any how the response to foliar feeding is often variable and not reproducible due to existing lack of knowledge of many factors related to the penetration and circulation of the leaf applied liquefied substrates. The main aim of this book is to analyze the current state of the foliar feeding in the area of production of vegetables and fruits and with the latest research trends to indicate future benefits of investigations and their importance for agronomic science s and practice.

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