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THE NOVEL POTASSIC BIO-FERTILIZERS: A PROMISING APPROACH FOR EVERGREEN AGRICULTURE

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Abstract- Nowadays, efficient bio-fertilizers are one of the best modern concepts of sustaining the evergreen agriculture. The efficient microorganisms used as bio-fertilizers which have plant growth promoting characters and enhanced growth, yield, prevent disease in plant through direct and indirect mechanisms. The worldwide most of the farmer's dependence on chemical fertilizer and pesticides for crop production, but unawareness or need of the farmers they applied in imbalanced manner of chemical fertilization due to theses faulty practices ultimately deteriorated the soil fertility, quality and soil-plant-human system health. In this critical context efficient microorganisms have been emerged as the potential alternative for the production in a sustainable way for the global food chain. The carrier-based bio-fertilizers have already proved to be the best over the agrochemicals and have been showing the tremendous effect on the world food production since the past two decades. These bio-fertilizers have been developed which would be the alternative for the cost effective evergreen agriculture. The article focuses on liquid biofertilizer, which provides reliable reasons for their necessity, specificity and emphasizes that the use of agriculturally important microorganisms (AIMs) in different combinations or liquid microbial consortium (LMC) is one of the solutions for restoration of soil health as well as supply nutrient for crop growth and development under evergreen agriculture.

Keywords: Novel biofertilizer, Evergreen agriculture, Efficient microorganisms, Agricultural sustainability, Nutrient mobilizers, Consortium, Mineral potassium, Mica.

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Introduction

The rapidly growing of world populations is the most important challenge for mankind to fulfil their demands of food requirement. The continuous and excess use of chemical/mineral fertilizers and other agrochemicals to increase enhance productivity, may cause ground water contamination and deterioration of soil nutrients, resulting in reduction of crop yield and disturbed soil-plant-environment system [1]. The bio-fertilizers are less expensive and are more eco-friendly as compared to chemical fertilizers. Potassium was first isolated in 1807 by Sir Humphrey Davy. It is a soft, silver white metal and reacts so violently in the presence of water that the metal does not occur in nature. The chemical symbol for the element, K, it is derives from kalium, it is the Latin version of Arabic word which means alkali. In agriculture, potassium is often referred to as potash. The resulting solid would be a mixture of potassium salts, mainly potassium carbonate, chloride and sulphate [2].

As ever increasing population and urbanization cannot allow increased in land area under the cultivation hence, productivity of agricultural land, to achieve sustainability with productivity, the agricultural scientists and researchers have laid more emphasis on improving production through judicious application of fertilizers the crops [3].The most important constraints to crop growth are those caused by the shortage of plant nutrients. During green revolution when higher application of chemical fertilizers with high yielding varieties got higher production per unit area but simultaneously soil as well as environmental health also degraded due to all these problems ultimately human health also deteriorated [4]. However, chemical fertilizer slowly shows their side effects on human and ecosystems.

The rhizospheric efficient microorganisms which promote nutrient uptake of the plants, like N_2 fixation by *rhizobium* or free living bacteria, *arbuscular mycorrhizal* fungi, potassium solubilizing bacteria/rhizobacteria (KSB/KSR) and phosphorous solubilizing bacteria which improved nitrogen, potassium and phosphorous nutrition respectively. Bio-fertilizers differ from fertilizer in the sense that they do not directly supply nutrient to crop plant and are the cultures of some specific microorganisms. These rhizobacterial cultures like *Rhizobium*, *Azospirillum* and *Azotobacter* have the ability to fix atmospheric nitrogen which in turn increases nitrogen supply to crop [5]. Vesicular *arbuscular mycorrhizae* (VAM) also increased nutrient uptakes particularly of P, Zn and other micronutrients due to pro-fused contact of roots from larger soil volume. These bio-fertilizers probably reduce the use of chemical fertilizers. Many times the term biofertilizer is used for various types of materials such as FYM, agricultural waste, composts and some liquid cultures of unidentified microbes [6]. Biofertilizer when applied to soil, mixing with seeds and spray in plant surfaces they colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply of primary nutrients to the host plant [7].

Importance of potassium in agriculture

Potassium (K) is the third major nutrient for most of the crop plant after nitrogen and phosphorous in the fertilization process. Among the minerals, potassium and nitrogen are required in larger quantities than other micro and macro elements [8]. It is generally absorbed as K^+ ions. Potassium helps in formation of strong root because it is present in the meristematic tissues. Potassium enhances disease resistance in plants by stalks strengthening and stems contributes to a thicker cuticle (leaf surface layer) which guards against the diseases, water loss and controls the turgor pressure within plants to prevent wilting and enhances flavour, texture and quality. ~ 60 plant enzymes directly or indirectly operated by potassium [9]. When Potassium and nitrogen applied together they have a beneficial synergistic effect on crop plants, as it turn helps in translocation of plant metabolites from the roots to the shoots and thereby increases the efficiency of nitrogen assimilation resulting this combination will enhance shoot growth which in turn help for productivity [Fig-1].

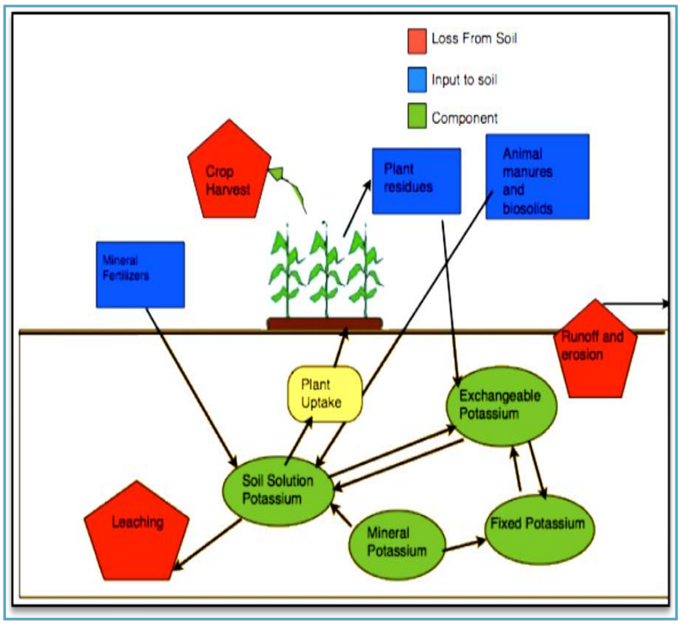

Fig.-1 Balance sheet of input output under the soil-plant system

In plants, K acts as regulator since its constituents include of various important enzymes of drought tolerance and water use efficiency. Application of KSR on soil-plant system under greenhouse/field conditions can be a valuable tool for increased crop productivity [10]. All crops required K especially high carbohydrate content such as banana, potatoes, Alfalfa, sweat potato and sugarcane etc. Studies showed that crops need more K than actual requirement needed for the optimum growth. Once K deficiency occurs in plants, it can have a dramatic effect on the plant stability to survive and function during stress periods such as high temperature and drought. One of the common signs of K deficiency is the chlorosis along leaf tip margin of the dorsal surface and in severe cases of K deficiency; the fired margins of the leaf may fall out [11].

Why bio-fertilizers?

Farmers use synthetic fertilizers without careful judgement and un-judicious manner has led to the pollution and contamination of the soil, due to this destroyed beneficial microorganisms and friendly insects, making the crop more prone to diseases and reduced soil fertility. The demand is much higher than the availability. It is estimated that by 2020, to achieve the targeted production of ~ 321 million tonnes of food grain, the requirement of nutrients will be ~ 28.8 million tonnes, while their availability will be only ~ 21.6 million tonnes being a deficit of about ~ 7.2 million tonnes [12]. In order to promote organic farming of the agriculturally important and high value crops in an eco-friendly and sustainable manner, bio-fertilizers are important in restricting the soil degradation and environmental pollution. They are renewable, pollution free, environment friendly and are of low cost [13]. In order to feed the ever-growing populations of the worldwide agricultural based country has to increase the agricultural productivity. [14] FAO According to United Nations Food and Agriculture Organization estimations, the demand for the agricultural commodities will be increased which is ~ 60% higher in 2030 than present time and more than ~ 85% of this additional demand will be from developing countries [15]. Since K is a nutrient of high cost and demand fertilizer, India ranks 4th position in terms of consumption of K fertilizers. However, India totally depends on import of K fertilizers. India is the world largest reserve of low-grade potassium mineral i.e. waste micas (muscovite and biotite) and feldspar [16]. Indian soil itself has high potassium content; there are three forms of K found in the soil *viz.*, soil minerals, non-exchangeable and available form. In most soils, 90 to 98% of the total K in the rooting zone is relatively unavailable, fixed in minerals such as micas or feldspar [17], compared to exchangeable K that ranges from 0.1 to 3%. The microbial K pool is estimated 0.25 to 0.50% of the total K content. These KSB have the potential to mineralize this unavailable form of potassium through production of various acids.

These microorganisms occur in the rhizosphere and they can construct good and healthy rhizosphere by having a constant and sustainable production of nutrients to be supplied into the plant roots by which they can improve the physical properties of the soil and enhance water-holding capacity. KSB were capable of solubilizing rock K, synthetic K mineral powder such as mica, illite and orthoclase through production and excretion of some organic acids and enzymes [18]. It is well established that microbial life only occupies a minor volume of soil being localized in hot spots such as the rhizosphere soil [19]. In agricultural ecosystem, these efficient microorganisms have played a vital role nutrient recycling. These microorganisms occur in soils naturally, but their populations are often very low. So that if we want to increase the crop yield, the desired microbes from rhizosphere are isolated and artificially cultured in adequate count in a suitable carriers or as they are in suitable formation of microbial consortium by artificial culturing. Plant rhizospheric zone is rich in nutrients when compared with the non rhizosphric, due to the accumulation of a variety of organic compounds released from roots by exudation, secretion, and deposition [20]. Because these organic compounds can be used as carbon and energy sources by microorganisms, microbial growth and activity is particularly intense in the rhizosphere.

Beneficial rhizobacteria that stimulate plant growth are usually referred to as plant growth promoting rhizobacteria or PGPR [21], a group that includes different bacterial species and strains belonging to genera such as *Acetobacter*, *Azospirillum*, *Azotobacter*, *Bacillus, Burkholderia, Herbaspirillum,* and *Pseudomonas* etc., [22,23]. PGPR promoted growth directly, e.g. by fixation of atmospheric nitrogen, solubilization of minerals such as phosphorus, production of siderophores that solubilize and sequester iron, or production of plant growth regulators i.e. hormones [24]. Some bacteria support plant growth indirectly, by improving growth-restricting conditions either via production of antagonistic substances or by inducing resistance against plant pathogens. Generally, inoculants are commercially available as solid carrier forms [25]. A frequent observation is that in solid carrier based inoculants, the number of viable cells decreases from 10^9 to 10^7 colony-forming units (cfu) per g after 90 days of storage [22]. These indigenous isolates have a better potential to multiply under abiotic stresses. Importance of indigenous strains and ecological specificity while selecting the microbial inoculants for a specific environment is realized.

Does liquid bio-fertilizer formulation effective?

The liquid bio-fertilizers have a distinct advantage in terms of cost saving over chemical fertilizers in addition to yield advantage. Chemical fertilizations otherwise may have negative effects on soil as well as human health, change the chemistry of soils which may no longer support plant growth. The maintaining soil fertility as well as producing economical yields requires the appropriate use of all inputs including plant nutrients of which one of the most important is potash (K_2O).

A current danger is reducing potash inputs to save money, but this can be very short sighted. The current issues related to potash use on arable crops, especially recent very worrying evidence for a decline in the use of potash fertilizers [25]. This declining use will have an adverse effect on soil fertility and on the production of economically viable crop yields of acceptable quality. The exchangeable K, which is determined by routine soil analysis, K that is most readily available for uptake by roots. It is the K in the soil solution and in the easily available pool. The less readily available K is that has been retained within soil minerals from previous applications of fertilizers and manures or has been released from native soil minerals by weathering. [10] Glasshouse experiments have shown that the K in this pool is slowly available to crops and is a vital source of potassium. The mineral matrix K is that K which is present in native soil minerals such as feldspars and micas; some soils contain huge amount of these minerals some very low in quantity; the clay content of the soil is not a reliable guide as to the type of mineral [Table-1].

Potassium in the soil minerals is very slowly released by weathering and not sufficient to supply the needs of crop cultivars, which is a large yield potential [27].

Table-1 *Effect of indigenous Potassium Solubilizing Bacteria on growth of maize in Vivo condition,* [26]

Tr. No.	Treatments	Shoot	Root	Dry Cob	Total dry
		Weight (g plant^{-1})			
T_1	K and P control 1, full dose of RDN*	94.70	13.15	47.70	155.55
T_2	Isolate KSB 11+ full dose of RDN*	95.70	13.54	54.50	163.74
T_3	Isolate KSB 16+ full dose of RDN*	95.78	13.23	62.50	171.51
T_4	Isolate KSB 27+ full dose of RDN*	95.92	12.69	65.73	174.34
T_5	*P. striata*+ full dose of RDN*	95.30	13.46	55.32	164.08
T_6	PSB 98 (2) + full dose of RDN*	95.35	13.72	69.80	178.87
T_7	S. *marcescens* + full dose of RDN*	95.16	13.89	68.93	177.98
T_8	Isolate KSB 11+ P. *striata*+ full dose of RDN*	98.47	14.16	77.10	189.73
T_9	Isolate KSB 11+ PSB 98 (2) + full dose of RDN*	99.59	14.55	93.93	190.85
T_{10}	Isolate KSB 11+ S. *marcescens* + full dose of RDN*	97.44	14.07	70.20	181.71
T_{11}	Isolate KSB 16+ P. *striata*+ full dose of RDN*	97.72	14.35	52.37	164.44
T_{12}	Isolate KSB 16+ PSB 98 (2) + full dose of RDN*	99.49	14.27	84.43	196.16
T_{13}	Isolate KSB 16+ S. *marcescens* + full dose of RDN*	98.16	13.94	74.87	186.97
T_{14}	Isolate KSB 27+ P. *striata*+ full dose of RDN*	98.32	13.93	73.57	185.82
T_{15}	Isolate KSB 27+ PSB 98 (2) + full dose of RDN*	99.37	14.42	97.23	211.02
T_{16}	Isolate KSB 27+ S. marcescens + full dose of RDN*	97.61	14.32	75.20	187.13
T_{17}	K and P control 2, (100% RDF)	95.49	13.42	57.76	166.67
T_{18}	Isolate KSB 11+ (100% RDF)	96.39	13.24	80.07	189.70
T_{19}	Isolate KSB 16(100% RDF)	96.32	12.61	50.53	159.46
T_{20}	Isolate KSB 27(100% RDF)	96.44	13.64	66.13	176.21
T_{21}	P. *striata* +(100% RDF)	96.90	13.39	56.43	165.72
T_{22}	PSB 98 (2) +(100% RDF)	95.77	13.72	98.97	208.46
T_{23}	S. *marcescens* + (100% RDF)	96.41	13.76	75.50	185.67
T_{24}	Isolate KSB 11+ P. *striata* +(100% RDF)	98.64	14.22	78.93	191.79
T_{25}	Isolate KSB 11+ PSB 98 (2) +(100% RDF)	99.26	14.79	89.50	203.55
T_{26}	Isolate KSB 11+ S. *marcescens* + (100% RDF)	97.74	14.14	82.90	194.78
T_{27}	Isolate KSB 16+ P. *striata* +(100% RDF)	98.06	14.28	78.80	191.14
T_{28}	Isolate KSB 16+ PSB 98 (2) +(100% RDF)	99.35	14.63	91.07	205.05
T_{29}	Isolate KSB 16+ S. *marcescens* + (100% RDF)	98.50	14.29	84.40	197.19
T_{30}	Isolate KSB 27+ P. *striata* +(100% RDF)	97.67	14.32	77.03	189.02
T_{31}	Isolate KSB 27+ PSB 98 (2) +(100% RDF)	99.27	14.43	91.53	205.23
T_{32}	Isolate KSB 27+ S. *marcescens* + (100% RDF)	98.70	13.97	83.30	195.97
	S.Em±	0.39	0.260	0.008	0.58
	CD@1%	1.24	0.852	0.03	1.76

Table-2 *Potassium solubilizing microorganisms (KSMs) produce various organic acids in different strains, which help in solubilization of insoluble potassium to soluble potassium*

S. No.	Crops		Reference
1	*Penicillium frequentans, Clasdosporium*	Oxalic, Citric, Gluconic Acids	[28]
2	*Paenibacillus mucilaginosus*	Tartaric, Citric, Oxalic	[29, 27]
3	*Aspergillus niger, Penicillium* sp.	Citric, Glycolic, Sucinnic	[30]
4	*B. megaterium, Pseudomonas* sp., *B. subtilis*	Lactic, Malic	[31]
5	*B. megaterium, E. freundii Citric, Gluconic*	Oxalic, Lactic	[31]
6	*Arthrobacter* sp., *Bacillus* sp., *B. firmus*	Lactic, Citric	[32]
7	*Aspergillus fumigatus, Aspergillus candidus*	Oxalic, Tartaric, Citric, Oxalic	[33]
8	*Pseudomonas aeruginosa*	Acetate, Citrate, Oxalate	[34] [35]
9	*B. mucilaginosus*	Oxalate, Citrate	[36]

The essential feature of this concept of the behaviour of soil K is its reversible transfer between the exchangeable and less readily available pools. Thus, when K is added in fertilizers and manures it goes first into the soil solution, from where it is taken up by plant roots. Some of the K is then adsorbed onto the exchange sites, where it is readily available for release back into the soil solution. From these exchange sites K can move to be within the “silicate layers” that constitute the soil minerals. However, when K is in demand by the growing crop this K can be released back into the soil solution for uptake by plant roots [Table-2]. Amount and timing of transfer of K between these pools and the factors that control the transfer are of very important, especially if farmers stop applying potash. Little K is lost in drainage from many soils and what is lost does no harm to the environment.

Factors affecting the effectiveness of bio-fertilizers

Temperature

Temperature is one of the important factors for affecting the shelf life of potassic liquid bio-fertilizer. It can affect their activity pre or post bio-fertilizer application. Optimum temperature and its limits vary with strain to strain of microorganisms. The colonization proceeds at field temperatures in the cropping season, but slows at lower temperature. The strains used in liquid formulation normally grows at 37 ± 1°C and able to tolerate temperature up to 45 ± 1°C for two years or more. Whereas solid base shelf life is hardly up to 3 months as a raise in temperature beyond 35°C and start rapid, decline the population of microorganisms in soil [37, 38].

Acclimatization

Effect of environment on bio-fertilizers has a negative effect on different strains, but most of the research was done on the carrier based bio-fertilizers for nitrogen and phosphorus and very little research was done in case of potassic bio-fertilizers liquid or solid. In nitrogen and phosphorus bio-fertilizers, it is observed that the efficiency of liquid is almost same in all environments, but the efficiency may reduce 20-25% in different climatic conditions in case of solid base [39]. Normally in liquid formulation of an organism remain active for a long time after application, ideally throughout the period of the crop (2 years to the maximum), or in soil throughout the crop cycle. Temperature, humidity, leaf surface, root exudates and competitor's microorganisms etc., are the critical inactivate the potassium mineralizing/ solubilizing microbes. They may be lost physically from the target location by the action of wind, rain or leaching depending on the fact why and where the product is used.

Effect of moisture

Moisture and humidity affect the storage, stability and activity of microbes up to its field application. Some organisms may need moisture for their activity, but in case of carrier based inoculums the organism gets stressed due to numbers of reasons when carriers become dry during transport and storage. Microbial strains needs wet plant and/or soil surface in order to its establishment and showing its activity. These conditions can be fulfilled only by liquid formulation as they contain humectants. The level of the direct effect of humidity on spore forming bacteria in liquid forms is relatively very low.

Sunlight intensity

Sunlight intensity is directly related with temperature, where microbes are sensitive to temperature. The most harmful rays Ultraviolet B (280-320 nm) and Ultraviolet A (320-400 nm) reaching the earth's surface have directly affect the microbes. However, microbes are very sensitive to various wavelengths, which have been outside this range. To count the harmful effects of high temperature sunscreens are added to a formulation. Sunscreens act by reflecting and scattering physically or by absorbing radiation selectively, converting short wavelengths to harmless longer ones. However, no such types of sunscreens are available in solid base to resist the effect of sunlight.

Effect of pH

The pH of a product plays a vital role in liquid inoculum preparation. It must be stabilized within certain ranges with diluted NaOH and HCL. The organisms are inactivated at the extreme high and low pH, therefore, a buffer is maintained by adding some additives, which render the better shelf life in liquid bio-fertilizers [25]. The maintenance of optimal pH improves shelf life of potash mobilizing bacteria.

Stabilization of liquid inoculums

The longest period in the life of a product elapses during storage, before use in the field, which may from several weeks to years. Microorganisms are required to remain viable during storage, with minimum loss of viability/ activity and without breakdown of the formulation properties. The liquid formulations are added with suitable additives for improving stability, which promote growth throughout the plant lifecycle by maintaining proper storage conditions prior to application by appropriate processing after production. Stability of the product is improved by resolving various physical and contamination problems like adhesion to the target site, activation time and the purity of the mother culture used for the subsequent preparation of the product respectively.

Organic carbon content in soil

Organic carbon adds in soil by the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. The soil organic matter (SOM) is the organic fraction of soil exclusive of non-decomposed plant and animal residues. Decomposition is a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules into simpler molecules of organic and inorganic importance [40]. SOM contains approximately 58% C; therefore, a factor of 1.72 can be used to convert OC to SOM. The soil organic carbon is the main source of energy for soil microorganisms. So that organic carbon content is very important for the establishment of applied potassic liquid formulation.

Handling and Application of liquid Inoculums

Liquid inoculums ensure the facility of easy handling and application. This is exemplified by the addition of thickeners or suspenders to suspensions, which aids in maintaining even distribution of the organism over the plant. Liquid potassic formulations prevents the clumping of the organism and ensure its ready to re-suspension after prolonged storage, whereas uniformity is not maintained in solid carrier based bio-fertilizer. It is evident that the population count come down to 10^5-cfu ml^{-1} (colony forming unit) in the duration of six months at room temperature in the case of solid carrier based bio-fertilizer while it survives in liquid up to 2 years and maintains population up to 10^8 cfu ml^{-1} [41].

Metrology for application of effective K bio-fertilizers

Potassium solubilizing bacterial (KSB) inoculants used as a seed treatments, it is cheap and easiest means of inoculation shown in [Fig- 2].

It also used as a seedling treatment. 200 g inoculants are mixed with 500 ml of water to make slurry. The seeds required are mixed in the slurry so as to have a uniform coating of the inoculants over the seeds and then shade drying for 30 minutes. The shade-dried seeds should be sown within 24 hours. One packet of inoculants (200 g) is sufficient to treat 10 kg of seeds [13]. The application of potassic bio-fertilizer also used as a seedling root dip this method is used for transplanted crops and it is also used with farm yard manure directly in main field just before transplanting/sowing of seeds.

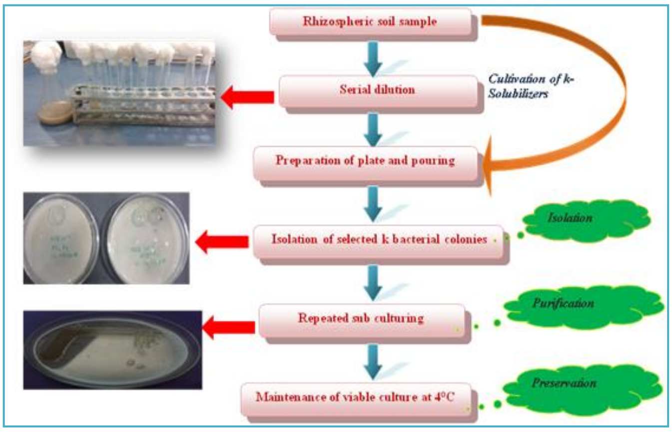

Fig. 2: Flow chart for the effective isolation of KSB from rhizospheric soil

Effect of KSB on solubilization of potassium and crop growth

Rapidly increasing human population, industrialization and urbanization has led to agricultural land shrinkage resulting in food crisis. Microorganisms are ubiquitous and participate in an inimitable role in maintaining the dynamism and integrity of the sustainable biosphere. Microorganisms mediated transformation, degradation and recycling of organic matter ensures the sustained existence of life in an eco-friendly manner [42]. Even though there is a considerable refinement in the field of bio-fertilizers for the past 3-4 decades the bio-fertilizer industry has been facing some technological constraints, some being resolvable the rest need strong research & development activities [Fig-3].

Constraints

Inoculation of seeds and seedling treatments of plants with the KSMs generally showed significant enhancement of germination percentage, seedling vigour, plant growth, and yield and K uptake by plants under glasshouse and field conditions [8]. Enhancement of plant K nutrition might be due to the stimulation of root growth or the elongation of root hairs by specific microorganisms [43, 44]. Potassium solubilizing bacteria *Bacillus* species which proved solubilization as well as crop growth [26], they found variability amongst isolates indicates that it is prudent and necessary to keep the isolation of beneficial bacteria a continuous programme. The additional beneficial traits exhibited by the strains indicate the possibility of isolating a strain with multiple beneficial effects [45]. [26] K-solubilizing strains were isolated from rhizosphere of tea and used as K bio-fertilizers in tea that have solubilizing capacity of murate of potash (MOP)was increased as comparison to mineral K sources.

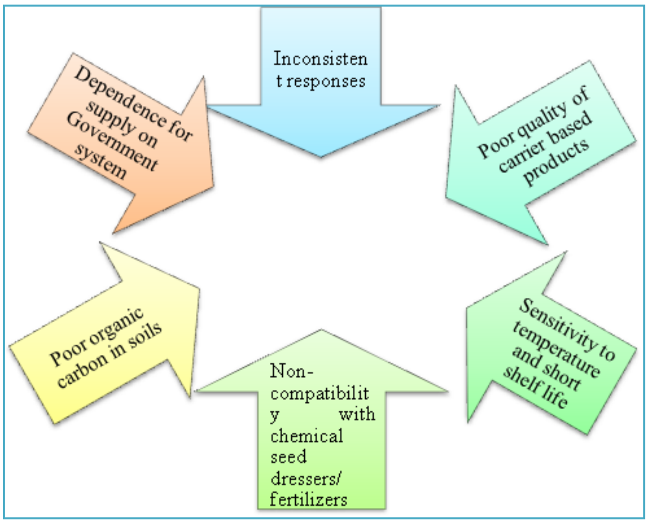

Fig. 3: Factors and representations of K bio-fertilizers are poorly acceptable among farmers

Crisis of efficient strains

Unavailability of potential regional strains is one of the major reasons. The specificity and competitive ability of the strain is the key point on which the efficacies of the organism relay with respect to the hosting soil and plant variety. The ability to fix Nitrogen and survival capacity are the limiting factors of the Liquid as well as the carrier based bio-fertilizers (Annual Report 2010-2011 Deptt. of Agri. and Cooperation Ministry of Agriculture Govt. of India).

Possible genotypic changes

During the production of the bio-fertilizers the organism may get interacted with other organisms which may leads to change in basic character of the organisms. Apart from this during fermentation, the strains may undergo mutations, which may alter the efficacy and viability leading to the economical loss.

Lack of awareness

In spite of many ongoing projects on the development of K-bio-fertilizers, proper attention towards the technology is still needed in order to manifest the results at field level. Communication gap and miscommunication of the farmers by some commercial producers has also been considerable constraint. Lack of storage and marketing facilities, consistent awareness in the farmers by conducting community programs is still welcome. As the production and distribution of bio-fertilizers is seasonal, the commercial production units may suffer from lack of demand. Moreover, the establishment of microorganisms resisting the antagonistic activity of the native microbes is always challenging. Soil nature, temperature, humidity, pH, local insect population, etc., are some other acclimatization problems [46]. The earlier products of bio-fertilizers were carrier (solid) based where lignite is usually added as a carrier material and that is also hazardous to the production workers. Also, the shelf life of carrier based bio-fertilizers has only 6 months and very difficult in transportation. The liquid bio-fertilizers on the other hand have a shelf life of minimum one year, with no health hazards to production workers and are easy to transport. Additionally, liquid bio-fertilizers can be used in drip irrigation and as a component of organic farming.

Future strategies for the development of efficient K- bio-fertilizers

- Research, selection and application of suitable K bio-inoculants with respect to soil nature, agro climatic condition, crop variety under proper agriculture practices needed.
- Genotypic study of the potassium solubilizing bacterial strains and molecular characterization of the plant parts is necessary to understand the plant mechanisms for potassium absorption and its need to plant.
- Study of soil for compatible studies with respect to K-microbial interventions.
- Exploring the novel soil K-solubilizing bacteria and maintaining the gene bank for future exploitation.
- Identifying, studying the population genetics and preserving the useful K-solubilizing microbes by advanced bio molecular techniques and bioinformatics tools.
- Suitable combinations of K- microbial formulations (liquid microbial consortium) with optimized field results are preferable to the sustainable production.
- Soil analysis, crop rotation, organic manure usage, maintenance of proper moisture content, regular sterilization practices are emphasized, which are necessary to maximize the K-biofertilizer efficacy.
- Global standards in the research & development should be maintained during the production and storage of the K-bio-fertilizers formulations.
- Development of new strains with enhanced capabilities by genetic engineering techniques and rDNA technology is needed to maintain an environment by eco-friendly way for evergreen agriculture.
- Constructive awareness and technical support by microbiologists and agricultural professionals must be provided to the Agrarians.
- Nevertheless, with an awareness of the limitations of existing methods, so that the use of KSB as potential bio-fertilizers in different soil conditions becomes a reality.
- Furthermore, scientists need to address certain issues, like how to improve the efficacy of bio-fertilizers , what should be an ideal and universal delivery system, how to stabilize these microbes in soil systems, and how nutritional and root exudation aspects could be controlled in order to get maximum benefits from KSB application.

Concluding remarks

Nowadays relaying on agriculture throughout the evolution and would be depending on it forever. The impact of globalization, industrialization, transition in the technology is creating a negative shade on agriculture in the developing countries like India declined the percentage of the farming community drastically due increasing population and the rapid urbanization resulting in raising demand for food commodities. The alarming rate increasing global population, demanding the safe, nutritive and qualitative as well as sufficient food for the surviving the human being. Soil heath has become the greatest assertion for the scientific community in this ever growing polluted globe. The ppotassium solubilizers from rhizospheric soil to develop an efficient indigenous microbial strain must be required for enhancing plant growth and yield of crops and maintaining soil fertility. This type of microbial strain is cost effective and environmentally friendly for enhancing the sustainable agriculture. The use of microbial inoculants as bio fertilizers is an important tool for sustainable agricultural and providing alternative of chemical fertilizer. However K-biofertilizer is still not popular in India but the threat of global food crises in India and other countries, another technology in the agriculture like liquid K-bio-fertilizers are obligatory. Liquid biofertilizer of course have the capacity to replace the traditional chemical fertilizers, which plays a major role in restoring the soil health, but a lot of measures in terms of technology, government support, subsidies, and constructive awareness by well trained technicians among the agrarians are emphasized.

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Conflict of interest
The authors did not declare any conflict of interest.

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